Sustained diffusion of renewable energy

Valentina Dinica

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SUSTAINED DIFFUSION OF RENEWABLE ENERGY

POLITICALLY DEFINED INVESTMENT CONTEXTS
FOR THE DIFFUSION OF RENEWABLE ELECTRICITY TECHNOLOGIES
IN SPAIN, THE NETHERLANDS AND THE UNITED KINGDOM

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born on 17 August 1971
in Bucharest, Romania

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“Some would like to understand what they believe in;
others would like to believe what they understand.”
Stanislaw Jerzy Lec

For my parents

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Foreword and acknowledgements

For me everything began with filters. I was a student in the last year at the Faculty of Textile Engineering doing research in the mathematical modelling and texture design of filters for the reduction of atmospheric emissions from industrial production plants and power plants. Doing literature review (supplementary!) on the problem of air pollution, I was deeply moved to learn about the environmental consequences of industrial activities, and fossil fuels burning in particular. So impressed I was, that I decided to shift to a different career. After four years of postgraduate studies in public administration and environmental policy, I was given the opportunity to explore at will the choices and chances for a better environment.

In September 1998, I started the work for my doctoral thesis in policy approaches for the diffusion of renewable energy technologies. Idealistically driven, I landed in an ideal place for such a job: the Center for Clean Technology and Environmental Policy, at the University of Twente in the Netherlands. What makes this place ideal for writing a dissertation is people. Although I always wanted to do research, writing a doctoral dissertation takes more than will. It takes sustained professional and psychological support. Lots of support. And I think there is nobody who could have offered me more support in both fields than my daily supervisor, Maarten Arentsen. The energy and inspiration to write this book has extensively come from him. Maarten always took care - when my ‘dose of will’ was exhausted - to immediately refill it with encouragements and reassurance. I have not experienced so far that somebody can have so much confidence in me. My greatest thanks to you, Maarten, for patiently giving me the freedom to explore the field at will, the guidance to investigate preferred directions, and the support to preserve and persist on the chosen path. I have always highly valued your sharp and fresh insights, and stared amazed at your total dedication to work and helping others. I very much enjoyed the cooperation with you, as progress in research has combined nicely with a self-discovery process you initiated, towards helping me mature as a social science researcher.

Likewise, I wish to express my gratitude to my promotor Hans Bressers for his contribution to this ideal working climate. During these years, I was time and time again heartened by our discussions on social science research methodology, and your suggestions in coping with the frequent problems of analytical complexity, for which I thank you so much Hans. Your patience and unrelenting enthusiasm for my work helped me substantially to strengthen my motivation and renew efforts to carry on.

Further, I have greatly benefited from doing my PhD at CSTM, as I was given the opportunity to attend numerous international professional events - summer schools, workshops, seminars and congresses - and conduct extensive empirical research in Spain, United Kingdom and the Netherlands. This highly improved my international visibility as energy policy researcher and enabled me to meet numerous people whose expertise appreciably contributed to developing my thinking.

In the process of working for a doctoral thesis, the environment is very important. I would like to thank all former and present colleagues for the pleasant and friendly atmosphere I always found at CSTM. I will never forget the impressive help they gave me when I moved to Enschede and then again inside Enschede. Without hesitation many of them helped me arrange my flat, moving heavy pieces of furniture and painting walls. And, of course, I also received help for the eternal problem of flat-tire and bike malfunctioning. My colleagues have always been kind enough to help me with such technical problems. I am very grateful for all the help I received. Many thanks to Ada Krooshoop for her constant friendly support and for her assistance in editing this book.

I also wish to thank Kinny and Maarten for their beautiful friendship and for standing by my side through all the ups and downs in the last years.

My thesis could not have been written without the cooperation of many experts from the academia, the industry and governmental agencies in the countries where I conducted empirical research. I wish to thank all those who have kindly taken the time to answer my questions in interviews and guide me in field research. I would like to give special thanks to Steve Thomas for his support in organising empirical research in the United Kingdom, and for hosting me at the Science and Policy Research Unit, University of Sussex. I am also thankful to Catherine Mitchell for the extensive discussions and literature she provided me during my visit to the Warwick Business School. Precious support was received from Nicola Steen when she was still working for the Association of Independent Electricity Producers. My empirical research in Spain has greatly benefited from the insights and the cooperation of Cristobal Lopez (Iberdrola Ingineria y Consultoria), Manuel Bustos and Jòse Mària Gonzalez Velez (Association for Renewable Energy Producers), Enrique Ocharan de la Camara (Ministry of Economy), Carlos Alberto Fernández López (Institute for Energy Saving and Diversification), Jose Antonio Franco del Pozo (Endesa Cogeneraccion y Renovables) and Ana Claver (Center for Energy, Technology and Environmental Research). In the Netherlands, I have received substantial support from Geert Jan van Mulekom (KEMA Power Generation and Sustainable) and Ben Jeroense (Project Bureau Duurzame Energie).

I will always be grateful to my parents for all the efforts they have done so that I could study for as long as I wished, wherever I wanted. Moving away from town, and later away from the country, seems trivial to many nowadays, in the high mobility age. Yet parents know better this is not that simple. Life is very busy. In seven years abroad I still did not get used to see my family just once in a year and neither did they. But I could always sense their constant care and support in spite of the distance. In October 1999 my dear nice Andra was born. Although I only saw her four times so far, she is always by my side, smiling in the picture on my desk, which gives me so much energy throughout each and every day. And so does the rest of my family.

Valentina Dinica
Enschede, April 2003

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Introduction and problem statement

1.1 The background of research and the research topic

The use of renewable energy resources for electricity generation has many advantages as compared to fossil fuels and nuclear energy. Renewable resources are no/low costs indigenous resources and contribute to the diversification of the energy resource basis. This increases the security of supply, especially having in view the political risks and expected depleatability of fossil fuels. Besides, renewable energy resources reduce environmental and human health impacts and - highly important - are the only types of energy resources currently available that respond to the challenge of sustainable development (see Dincer 2000; Edinger and Kaul 2000).

On the basis of the idea of intergenerational equity, on which the concept of sustainable development rests, three categories of generation technologies can be differentiated: environmentally-friendly technologies; fossil-based ‘bridging technologies’; and technologies for sustainable electricity production. In the last category technologies using the following types of resources can be placed: hydropower, biomass, biogas, wind energy, solar energy, hydrogen, geothermal energy (aquifers and hot dry rock), and ocean power (wave and tidal energy)[1].

Both industrialised and developing countries are interested to increase the contribution of renewable energy resources in their electricity supply systems. But they have different *priorities in the reasons* to adopt renewables, and different approaches by which the diffusion of renewables can respond to their priorities. In developing countries, rural electrification needs, the urge to reduce human health impacts from the direct burning in households of low quality coal and biomass, and the strive local socio-economic development are the core reasons why governments are interested in renewables. The decentralised use of renewable resources in stand-alone electricity systems appears to be the most attractive way by which renewables could diffuse in developing countries, serving all these goals.

In industrialised countries, the main drivers behind the interest in renewables are different. These countries are especially interested in security of supply, given the dependence of many of them on imported fossil fuels or on domestic but steadily depleatable (and often low quality) fossil fuels. But they are also under social pressure to shut down nuclear power plants. Besides, since early 1990s, renewables’ use has become a priority on certain countries’ political agenda, especially Western European countries, as a means to address the challenges of climate change abatement and sustainable development. Since industrialised countries are often widely electrified the diffusion of renewable technologies by means of grid connected power plants is a feasible approach likely to be more often used especially in the case of intermittent resources as wind and solar energy.

Beside differences in priorities and the most suitable diffusion approach, the adoption of renewable electricity technologies encounters different configurations of obstacles. For example in industrialised countries, social and local administrative opposition are often serious obstacles in renewables’ diffusion. In developing countries, investments can be often obstructed by political instability or absence of local skilled labour, or competition for land

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[1] In the working paper “Technologies for sustainable electricity supply” (Dinica 2000 pp.1-50) we elaborated on the sustainable development concept, operationalising it for the case of electricity supply. We looked at the extent of impact of currently used electricity generation technologies on human health, environmental quality and resource availability in the long term. Based on this analysis we differentiated between the three categories of technologies and the resources that may be considered as sustainable for electricity generation.

resources[2]. But most importantly, industrialised and developing countries differ in their abilities and means to stimulate the adoption of renewable electricity technologies. Industrialised countries are better equipped to address the economic obstacle - caused by expensiveness of renewable technologies, and the financing obstacle - caused by the difficulty to find investors willing to finance power plants based on such technologies (see Section 2.2). Governmental financial support from both consumers of electricity and public budgets is feasible as long as there is a political decision to support renewables. Besides, these countries count with the presence of economic actors with sufficient internal financial resources and various types of specialised financing agents could bring private finance into renewable power plants. But developing countries are seldom, or only to a limited extent, able to financially support renewable electricity plants from public budgets or consumers' bills, while the private finance potential is very limited. International financial support from various programs is often needed to stimulate investments in renewable energy. Therefore, the integration of renewable power plants into current electricity systems requires different analyses for industrialised and developing countries. *This study is concerned with the opportunities for adoption of renewable electricity technologies in industrialised countries*.

As just mentioned, the obstacles and their magnitude differ among industrial and developing countries. But they also differ often among industrialised countries, while many are technology specific. For example, in some countries poor institutional coordination or unclear competencies among public authorities of different types, or at different administrative levels can cause serious obstacles to diffusion. In other countries, a very high social valuation of the environment for leisure activities could restrict the siting of renewables power plants with higher land intensity (e.g. based on forestry crops) or visual impact (wind turbines) and the extent to which they are able to diffuse in the electricity systems. But obstacles can also be technology specific such as noise and electromagnetic interference from wind technology, impacts of small hydropower plants with storage systems (see Chapter 4) on river ecosystems, or atmospheric pollution for certain types of biomass resources used in certain types of electricity generation technologies. But the common challenges for the adoption of renewable electricity technologies in all industrialised countries are the economic and financing obstacles. The extent to which these obstacles have different magnitudes in various industrialised countries is an opened question that we will address among others in this study. But they are undoubtedly common. Consequently, *in this study we are interested in how industrialised countries could help renewable electricity technologies overcome the economic and financing obstacles to adoption*.

In industrialised countries, the concern for renewables started the 1970s. The uncertainty on the political availability of fossil fuel resources, put in motion many governments to create support frames for the emergence of alternative technologies based on renewable resources. Increasing concern for the physical availability of fossil fuels added to the need of supporting renewables. In addition, social pressure to deal with the environmental and health consequences of fossil fuels burning and nuclear resources' use ensured during the 1980's a certain degree of continuity in the policy attention that renewable technologies received in many industrialised countries. During the 1990s, climate change and sustainable development concerns started to exert increasing pressure on political agendas. Governments were challenged to account for the long-term consequences of their industrial and economic policies and growth targets. A shift towards a more substantial use of renewable energy resources has

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[2] For example, due to the problem of agricultural overproduction, in many Western European countries farmers get financial rewards if they voluntarily decide to set aside land, or change food crops with biomass for energy crops. In developing countries, food production is the main priority.

been seen in this context as an optimal solution to handle the conflicting demands for electricity consumption growth, on the one hand, and environmental quality, climate safety and sustainable development, on the other hand.

During the 1970s, governmental support was mainly targeted at research and demonstration of various designs of renewable electricity technologies. Some countries maintained this as the only form of public support also throughout the following decade. However several governments, especially in Western European countries, started during the 1980s programs to stimulate the adoption of renewable electricity technologies in power plants for commercial and/or self-generation purposes. But as the number of countries introducing support systems for the stimulation of investments increased, so did the diversity in the support approaches used. As early as the introduction of adoption support systems, the debate started on which support schemes could help a faster and more substantial adoption of renewable electricity technologies and which are the consequences for societal costs and improvements in the technical and economic performances of technologies. The debate was similarly strong in the political scene and in the arena of economists and policy analysts. With the liberalisation of electricity industries in many industrialised countries, the types of support schemes addressing economic and financing barriers increased in diversity.

While during the monopolistic organisation of electricity industries, certain support schemes dominated, such as legally guaranteed contracts and prices for the purchase of renewable electricity, and production subsidies or investment subsidies, after liberalisation new schemes were introduced. These include fiscal incentives, voluntary agreements with electricity companies, tradable green certificates and green pricing schemes (see Section 2.3.1). This led to the intensification of the debates regarding the merits of different approaches or particular support schemes.

A series of studies[3] were carried out, comparing support schemes addressing the economic and financing obstacles, and results of already implemented programs for market adoption in different countries. Such studies were made especially in Western Europe and the United States, where most attempts to introduce renewables were made[4]. Our general criticism to the research carried out so far is that they do not explain how the observed results of market adoption were achieved, and what do those results mean for long-term continuity of diffusion. Our more specific criticism to the studies on adoption potential of support systems regards five main aspects.

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[3] Since research on the issue of renewable energy resources use started, in early 1970s, this new field has been growing slowly with inputs from scientists from a wide diversity of disciplines and research traditions. However, in 2000, one can hardly speak about coagulated research streams and distinguishable theoretical approaches. This is in spite of the fact (and to the regret for the fact) that research has seldom been interdisciplinary (that is knowledge gained from different disciplines were not integrated but at the best just affixed to one another without theoretical support and explanation mechanisms). In terms of the practical forms of research studies, these have been very diverse – from long-term dedicated research projects in academic environments, often in the form of doctoral dissertations such as ours, to governmental or internationally coordinated studies for the purpose of policy-making advice, projects of consultancy agencies for potential investors and financing agents or national associations of renewable energy producers, as well as a multitude of papers for scientific or industry journals and for conference participation. In this section when we refer to 'studies' we mean all forms of theoretical or empirical research that refer to the issue of the stimulation of renewable energy resources use.

[4] Few examples of such studies are Ackermann et al. 2001; Lenz 2000; Ellis and Peake 1996; Haas (ed), 2000; Lew 1997; IEA 1997; Maartens et al. 2001; Espey 2001; Brunt and Spooner 1998; Mitchell 1994; Moore and Ihle 1999; Watt and Outhred 2001; Langniss 1996; Langniss et al. 1998; Hemmelskamp 1998; ECN [1] 2000; Rader and Wiser 1999; NRRI November 1994.

Firstly, the way support systems are described and analysed is not (sufficiently) helpful in understanding the consequences for diffusion. Classifications and analyses of support schemes' characteristics are often made from the perspective of policy makers (see Table 2.2 Chapter 2). This way some studies differentiate between support systems in terms of the dominant scheme used - for example subsidy support systems, or fiscal incentive systems, or tradable green certificate systems (often referred to as 'quota systems'), or 'feed-in tariff systems'. Since the liberalisation of electricity industries, most studies focus on the comparison of the last two mentioned support systems. But many studies make just inventories of support schemes used per country and proceed swiftly with inferences regarding their effectiveness by looking at the capacity installed after short-medium periods of time of system operation.

Other studies make a step further, but still incomplete, in the analysing support systems. They differentiate between consumption-based and production-based support systems, with or without the simultaneous differentiation between price-driven and quantity-driven support (e.g. in ECN 2001). The first mentioned type of system generally supports investments in renewable power plants indirectly, by stimulating demand for renewable electricity - either voluntarily or by compulsory purchase. The second mentioned system assumes the support of renewable technologies directly, by attracting the interest of potential investors through different types of schemes that help them reduce production costs or recover their extra costs compared to market prices. The label 'price-driven support system' is used when incentives to invest in renewable technologies come in one or another form of price support. The unknown element is how much capacity of renewable power plants is likely to be installed. The label of 'quantity-driven support system' is used when there is a voluntary agreement or legal obligation that certain economic actors or an entire industry segment (usually inside the electricity industry) buy(s) certain amounts of renewable electricity. In this case the element that is known (or at least expected) in advance is the capacity of renewable power plants likely to be installed. But the unknown element is the price - for individual generators and/or as average at industry level that renewable electricity can be paid.

Having in view that classifications differ frequently, the findings of such studies are difficult to compare. But, more importantly, these classifications and characterisations of support systems are not sufficiently suggestive with regard to what types of economic actors would be likely to be interested to invest, what kind of investment strategies would they adopt in different circumstances, to what extent would private financial resources be available and from what sources, and what would be the consequences of investment and financing decisions for the extent of market adoption.

Secondly, the way financial aspects of support systems are described is not sufficiently suggestive with regard to the attractiveness of potential adopters to invest. Comparisons among countries, and within the same country but along time, are made by looking at the price per kilowatt-hour, or the percentages of fiscal rebates and/or investment subsidies that the support system enables. Another option is to express the extent of price support as a percentage of average consumer prices in the respective country. But as long as the issue of how does financial support compare to production costs in each country is not dealt with, the potential to assess the attractiveness to invest under such a system is slim. Having in view these first two shortcomings in current studies we consider it necessary to *formulate in this study a new approach for describing, analysing and comparing support systems, that is more suitable for understanding the consequences of their characteristics for adoption*.

Thirdly, the studies on adoption effectiveness of support systems are overwhelmingly short term oriented. Research so far has been interested in which support systems can achieve a larger extent of adoption - in terms of installed capacity increase, or electricity production or market share increase. But no attention was paid on whether adoption can be sustained in the long term, and under which conditions. The only long term oriented studies are of a different nature and regard scenarios on possible contribution of renewables in electricity supply systems. But the assumptions on which they are built and the factors taken into consideration in constructing scenarios go much beyond the aspect of support systems addressing economic and financial obstacles. *In this study, we are concerned not only with the adoption of renewable technologies in short-medium term* - that can be referred to as market introduction period. *But we are also interested in* the prospects for continuity of diffusion in long term - that we refer to as the *sustainability of market diffusion processes*.

Fourthly, the effectiveness is measured often in terms of the extent of adoption of renewable technologies and cost reductions. In some cases, improvements in technical performances are also considered. As regards the first effectiveness indicator, three measures are generally used: kilowatt-hours production (kWh), market share increase (%), or megawatts installed capacity increase (MW). We argue that the last is the most appropriate for renewable technologies, because for intermittent resources the amount of electricity production in kWh is strongly influenced by quality and availability of resources, which varies annually and from country to country[5]. As for the market share increase, this indicator is strongly affected by changes in the total electricity consumption.

As concerns cost reductions, the political way of looking at it, and hence also the way of many policy and scientific studies so far, is in terms of reduction in production costs per kWh or overall investments costs for the installation of one megawatt capacity (costs per kW installed). But, in our view, both indicators are misleading because they are ‘contaminated’ by the influence of many factors of very diverse nature that do have to do with the progress booked by renewable technologies in terms of manufacturing costs. The fact that production costs per kWh are influenced by many factors, not related to the cost performances of renewable technology themselves, raises the question on the extent to which economic and financing obstacles can be overcome or just lowered. Also, the question raises on the extent to which there could be differences among countries (and for what reasons) in the possibility to overcome or lower these obstacles. *This study will address the issue of cost-performances, looking at the factors influencing production costs per kWh of renewable technologies, and the extent to which they are liable for influence by governmental intervention or industry / market developments accompanying diffusion*.

When technological improvements are analysed, they are mainly expressed by some standard indicators that are seldom motivated. For example, for wind technology the most often used indicators are the increase in installed capacity per turbine and rotor diameter (e.g. Johnson and Jacobsson 2001; Gipe 1993). But the issues of why are these indicators important to look at, how do changes in technical performances relate to the rate of adoption - both the adoption already achieved and expectations for the future, and how do they relate to the impacts on long-term diffusion potential, are left un-explored.

For the renewable technologies chosen, *this study will look at technological performances and select indicators for technical characteristics from the perspective of their role in reducing/removing obstacles (of any type) for adoption with solutions in the technical sphere, and their role in increasing the technically exploitable potential for long-term diffusion expansion*. We are interested to look in this study at the technical improvements that are desirable for long-term diffusion and under which contexts are some technical characteristics

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[5] For example assuming a wind power plant of a certain size in terms of installed capacity, and using the same type of technology, this can yield different levels of electricity production in kWh from one year to another, and from one country to another were there are differences in available wind speeds and annual availability of necessary wind speeds.

more important than others, having in view the strong influence of resource quality and availability on the technical performances of certain type of renewable technologies.

Fifthly, there is currently little concern with the mechanisms that relate the types of support systems used with the adoption results observed and with the prospects of diffusion continuity. As regards the economic studies on policy support effectiveness the explanatory mechanisms used are the classical demand-price analyses. These models do not take into account that beside profit-making, investors might also have various types of strategic reasons to invest, how would they affect individual investment decisions, and how would these be reflected in terms of industry level developments. Both in policy and economic studies, the issue of patterns by which technology diffuses and how it relates to the characteristics of the support system put in place, as well as what it means for short-medium term adoption and long term diffusion, are seldom or only partially explored.

For example, few studies look at the types of financing schemes used in different countries[6]. Some explore a very wide variety of factors that might have influenced their use and what changes would be necessary where, in order to overcome the financing obstacles (Langniss et al. 1998). Others focus on specific types of financing schemes and/or specific types of potential owners of renewable power plants (more often small companies, communities or individuals) and look at their obstacles and options to overcome them (Mitchell and Mackerron 1993). However, what is missing is raising above the country-specific obstacles and opportunities and trying to understand: how the types of financing schemes used, and the types of economic actors developing renewable power plants (could) relate to the characteristics of support systems addressing the economic and financing obstacles. *This study is concerned with underpinning the diffusion patterns and mechanisms that relate characteristics of support systems to the adoption results in short-medium term of system operation and consequences for long-term diffusion prospects*.

In addition to the set of studies on the adoption results of support systems, there are also other types of studies focusing on renewables. For example, a category that can be referred to as ‘first wave’ research on renewables is formed by studies looking at the obstacles and success factors for renewables adoption. This research approach was still fashionable in the 1990s[7], although they have several disadvantages. Firstly, a series of ad-hoc factors of very different nature and degree of steering potential are aggregated, looking at the extent of market adoption with poor or no systematic explanation on causality. The mechanisms by which the factors tackled may lead to the observed results are often left untangled. Moreover, such studies often imply that what they consider ‘success’ is a long-lived outcome, and diffusion continuation is taken for granted. Secondly, many of the factors aggregated in the analysis are country specific. The mixture of success factors can rarely be reproduced in other countries, implying that such studies also have a limited potential for contribution to policy-making advice.

There are also other types of studies on renewable resources uses. Some are concerned with modelling and scenarios about the potential share of (specific) renewables in the future or individual types of renewable technologies[8]. Since mid 1995 numerous studies were concerned with how liberalisation could affect the adoption of renewable electricity technologies[9]. However, in 2000/2001 the issue was clarified, at least for European Union countries, that

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[6] Mitchell 1994; ETSU [1] 1996; Langniss 1996, Langniss et al. 1998; van Zuylen et al. 1993.

[7] E.g. Moskovitz 1992; Hohmeyer et al. 1998; Ecotec Research and European Environment Agency 2001; ECN [3] 2000; Reiche 2002, Krause et al. 1992.

[8] E.g. Lehmann et al. 1998; Grubb 1995; Jahraus et. al. 1991; Horazak and Brushwood 1999; ESD 1993.

[9] Elliot 1990; Groscurth et al. 2000; Miller and Serchuk 1996; Zucchet 2000; Wolhgemuth 1999 and 2002; Bess 1999; Morthorst 1998; Froggatt 2000; Slingerland 1999.

renewable electricity production would be kept apart from the general liberalised electricity markets for some time to come. Most countries chose to continue with the use of special support schemes that isolate renewables from the market because the economic and in some cases also the financing barriers persisted years after the start of governmental programs for their adoption. Abandoning the special economic protection for renewables would have meant leaving the earlier embarked policy line unfinished, for which substantial public money was spent.

Goals such security of supply, climate change abatement, and sustainable development have an increasing importance on political agendas of many industrialised countries. They all require the use of renewable energy resources. This has led many Western European governments, as well as the European Union, to consider the separation of renewable technologies from the general electricity industry by means of special support systems as justified. As a result, the research topic of how liberalisation could affect the adoption of renewables has been moving slowly to the background. The question of which support systems can be more effective in bringing and keeping renewables in electricity production systems receives, at the time of writing, renewed and increased attention.

Consequently, having in view the shortcomings and remaining gaps of studies carried out so far, this study aims to contribute to the scientific understanding and empirical knowledge regarding the impact of public support to stimulate renewable resources use in electricity production. In particular it focuses on the analysis of the impact of policy support for the removal/lowering of economic and financing obstacles in short-medium term, as well as on how does this affect the prospects for long-term diffusion continuation of renewable electricity technologies. The study is not only concerned with the question of the degree to which, and the mechanisms whereby, different types of policy support initiate investments, but also how policy support schemes influence the sustainability of diffusion processes. *Therefore, this study focuses both on early adoption and long-term diffusion of renewable electricity technologies.* In the following section, we formulate the problem statement and research questions that this study will address.

1.2 The problem statement and research questions

The *central research question* in this study is:

> *What are the consequences of the design of policy support systems - aiming to address the economic and financing obstacles faced by renewable electricity technologies - for the patterns and extent of short-medium term adoption, and for the prospects for sustainability of diffusion processes in the long term?*

The central research question is addressed by means of seven *specific research questions*:

1. How can support systems concerned with the economic and financing obstacles of renewable electricity technologies be systematically described and compared from the perspective of investors?
2. What are the preconditions for sustainable diffusion processes of renewable electricity technologies?
3. To what extent can support systems influence the cost-performances of renewable electricity technologies?
4. What aspects of technological performances could improve the prospects for long-term sustainability of diffusion processes?

5. How do investors behave - potential owners and financing agents - under different types of support systems?
6. What are the consequences of investors' behaviour under different types of support systems for the patterns of renewable electricity technologies'diffusion?
7. What are the consequences of the patterns of adoption of renewable electricity technologies for the extent of their adoption in short-medium term, and for the prospects of sustainability of diffusion processes in the long term?

1.2.1 Scientific contribution

The mechanisms whereby support systems focused on the economic and financing barriers influence renewables' diffusion have not been subject of systematic scientific research thus far. We intent to extend the scope of current analyses by developing a theory that specifies the relationship between core characteristics of support systems from investors' perspectives, their investment behaviour under different types of support systems and the sustainability of the market diffusion processes of renewable electricity technologies.

This theory is developed in the first part of the book and aims to integrate insights (and inspiration) from different disciplines and research fields: financing theories, policy studies, evolutionary and institutional economics, diffusion theories, engineering, and natural science aspects on (selected) renewable resources. We take aim at integrating theoretical considerations on the economics and technical performances of innovative technologies with insights from empirical studies regarding the particularities of renewable power plants on technical and economic aspects. Ignoring these particularities and following very general modes of thinking on innovative technology adoption, or incumbent modes of thinking on the adoption of conventional electricity technologies proved to be a pitfall of many research studies so far.

We strive towards a strong interdisciplinary approach, envisaging to underpin the mechansims linking conditions and developments in different spheres (policy, financing, economic, technical, industrial, institutional, and social) in an integrated theoretical construction. These mechanisms would be linked to one another in a construct that spans from the charactersitics of support system challenging the economic and financing barriers, at one end, to the adoption and prospects for long term diffusion, at the other end. Highly relevant findings of renewable resource studies, technology studies, economic analyses of renewable electricity production, investigations into the dymanics of emerging industrial bases for renewable technologies, social integration and adminstrative approval approaches related to renewables are processed for this purpose, while keeping focus and interpreting them from the perspective of the dependent and independent variables.

So far, technology studies are looking at aspects such as the latest developments in the technical characteristics of various designs of a specific renewable technology. Economists, financial consultants, developers and financing agents (banks, insurance companies) elaborate studies looking very sharply at the details of cost performances and production costs for different types of renewable technologies. Sociologists and industry representatives focus on the opportunities for jobs' creation and new business creation in incumbent industrial sectors, serving in the life cycle of renewable power plants. Our study aims at integrating core aspects from the multitude of disciplines concerned so far with renewables' diffusion. But, while integrating knowledge, it aims to disentangle their role in mediating the relationship between support systems' characteristics, on the one hand, and the extent of adoption and prospects for long term diffusion of renewable technologies, on the other.

1.2.2 Societal relevance

The use of renewable energy resources is desirable because of many strong reasons. Studies quantifying and comparing the environmental impacts of different types of fossil fuel based technologies, renewables-based technologies, and nuclear-resource technologies clearly showed (IDAE 2000) that all types of renewable resources have lower impacts on all elements of the environment (land, water, ecosystems, atmosphere). Besides, given the depleatability of fossil fuels and the risk associated with the use of nuclear resources, sustainable development requires a substantial shift towards the use of renewable energy resources. In addition, many governments of industrialised countries started to consider the threat of climate change as increasingly credible.

The global political situation poses increasing risks on the availability and price of fossil fuels, on the import of which many countries depend. In addition, price increases are expected to occur because, as the currently used low and medium-depth fossil fuel reserves are being consumed, the costs of reaching and bringing to surface deeper reserves will have high impacts on market prices for fuels. In most industrialised countries that implemented energy efficiency policies up to 2000, electricity consumption has actually increased and the trend is likely to continue in the future. This urges a shift away from the fossil-nuclear track. Hence, renewables are important for national independence in electricity generation and meeting future consumption needs. This makes many countries very eager and to have renewable power plants located inside their territory and to develop their own national industry of renewable technologies.

Since the 1970s/1980s, several industrialised countries, including inside the European Union, invested substantial public money into the development of national manufacturing industries - each for various types of technologies, in accordance to their resource availability. Progress was achieved both in the reduction of manufacturing costs and in technical performances. But, by 2000, only few technologies could compete with conventional technologies without price support, in specific niche circumstances. The persistence of economic and financing obstacles requires the introduction or continuity of implementation of support systems. Unless there is sufficient market demand to offer a basis for the continuity of technical and cost performance improvements there is the risk that manufacturing companies - where also private investments were made, will shut down.

Consequently, there are many reasons making governments highly interested in stimulating renewable use. But countries differ in their preferences for support schemes to be used[10]. Sometimes this emerges from differences in the level of ambition for the greening of electricity supply, or the rate of market growth governments deem desirable, given the societal costs of diffusion. In the European Union (EU), these differences emerged strongly in the debates preceding the adoption of the 77/2001 Directive on the Treatment of Renewable Electricity. The European Union authorities initially intended to propose a harmonised treatment of renewable electricity generation in all member countries.

Given the plans of a previous Directive (92/96/EC) to liberalise and integrate electricity industries of EU countries, the harmonisation of support systems was deemed necessary in order to integrate also the trade of renewable electricity in the general electricity market, and to avoid distorting international trade though differences of financial support. But after years of dialogue, member states could not agree on a common framework for renewable electricity support. As the 77/2001 Directive mentions, it was “too early to decide on a Community-wide

[10] Besides there is a strong competition between countries in Europe to build their own industries of renewable technologies’ manufacturing and service.

framework regarding support schemes, in view of the limited experience with the national schemes”. The European Council decided to assess the success and cost effectiveness of national support schemes towards the end of 2005 and eventually propose a common framework afterwards[11].

In this context, the assessment of the potential for renewables adoption represented by different support systems has re-emerged as an important question at the top of the agendas of policy-makers. This study addresses precisely this question, proposing an analytical framework able to underpin the diffusion potential both ex-ante, ex-post as well as in international comparison. But, in the same time, the study is going one step further, asking whether any effective support system, able to bring some extent of installed capacity in the industry, is in the same time able to create an industrial-socio-economic context that could ensure the continuity of market diffusion processes on a long time-span.

Large amounts of public money were spent so far by EU member states for the market introduction of renewables and the two important questions still remain: under which types of support systems money was more effectively spent; and what extra gains have been booked in the countries were diffusion was more costly? This study addresses the question of what kind of support can be effective under which circumstances. But it also pays attention to what extent and under which circumstances can societal costs be paid back, also in monetary terms, as a result of public support. This kind of knowledge is important to assist decision-makers take suitable choices on the approach to renewables’ support.

1.2.3 The empirical approach

The theory developed in this study will be empirically tested by analysing support systems in three countries - the Netherlands, Spain and UK. The technologies on which we focus are wind, biomass electricity and small hydropower technology. The choice for the three countries is related to diversity in the types of support systems, which will be further explained in Chapter 5. The choice for the three technologies relates to the need to look at more technology types in other to improve the empirical insight into the role that technology characteristic factors can play in investment decisions. Besides, this can help observe whether these can alter the diffusion results of the same type of support system.

The format of the theory is such that for each combination of circumstances (independent variables) an expectation can be derived for the outcomes (dependent variables). By first assessing empirically for each case first the value of the independent variables, then deriving the theoretically expected values of the dependent variables, and ultimately assessing these outcomes in empirical reality, the theory can be tested on a case by case basis. Though every (sub)case provides only a partial test, that is tests only the expectations for a singular combination of circumstances, nevertheless by this repeated partial testing also - all in all - the general logic behind the theory is put to the test (cf. Yin 1994). A case study for empirical research is defined by a situation where a support system addressing the economic and financing barriers of a certain type of renewable technology is stable over a short-medium term period. We consider such a period to be of 5 to 10 years, which should be sufficient to allow investors to get accustomed to the support systems and to allow measurable adoption results to be observed.

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[11] An European Union wide support system for renewable electricity would not be implemented before 2012 in order to create sufficient policy stability in national contexts to encourage investments.

1.3 The organisation of the book

The book consists of four parts. In Part I we elaborate the analytical framework, in Part II and III we test it empirically, and in Part IV we conclude by evaluating the analytical framework and the significance of empirical findings of the study.

The argument in the theoretical part - Part I - is developed as follows. In Chapter 2 we present the building blocks of the theory. In its framework, we answer theoretically research questions 1, 2 and 3 formulated in Section 1.2. Chapter 3 presents the theory regarding the mechanisms that link the characteristics of support systems to the short-term adoption and prospects for the long-term sustainability of market diffusion processes. In this chapter we answer theoretically research questions 5, 6 and 7, and formulate the hypotheses of the analytical framework. Further, in Chapter 4 we look at state-of-the-art of the currently available technological designs for the three types of renewable electricity technologies chosen for empirical research. Based on this, we analyse the existing and desirable technical characteristics and performances that in our view have the potential to expand the feasible scale of diffusion. This constitutes the concern of research question 4. But this chapter serves in the same time for the operationalisation of two of the diffusion indicators included in the formulation of hypotheses, in Chapter 3. Chapter 5 concludes Part I, by describing the research design and methodology of data collection. It also makes a summary of operationalisation of all variables of the analytical framework, and it gives a detailed description of the steps taken in empirical analyses.

Part II of the book tests the theoretical expectations of the analytical framework for the market introduction and diffusion of three renewable technologies in Spain. This part starts with the description and analysis of the support systems for the three technologies in Chapter 6. Because of changes in the characteristics of support systems for each of the three renewable technologies in the period studied, 1980-2000, we differentiate between six case studies. At the end of Chapter 6 we specify the hypothesis that is to be tested for each case study. Chapters 7, 8 and 9 are entirely dedicated to the testing of these hypotheses for the three technologies' market introduction and diffusion in Spain as follows. In Chapter 7 two hypotheses are tested for wind technology: one for the period 1980-1994, and one for the period 1995-2000. In Chapter 8 two hypotheses are tested for biomass electricity technologies: one for the period 1980-1995, and one for the period 1996-2000. In Chapter 9, two hypotheses are tested for small hydropower for the same period as in the case of wind technology. Part II of the book ends with Chapter 10, which draws some conclusions regarding the diffusion of the three renewable electricity technologies in Spain.

Part III of the book is also empirically focused, and tests the theoretical expectations for wind technology diffusion in two countries: The Netherlands and the United Kingdom. In the case of The Netherlands, the high number of support schemes used and the complexity of their interaction require extensive description and analysis, in order to configure the characteristics of the support system applicable for investors in wind technology. This is done in Chapter 11, which concludes with the specification of hypothesis to be tested, and of the period for which it will be tested, 1990-1997. The testing of this hypothesis for the case study of wind technology diffusion in the Netherlands, in the period 1990-1997, is done in Chapter 12. Finally, Chapter 13 takes both steps of hypothesis specification and testing for the case study of wind technology diffusion in the United Kingdom, for the period 1990-2002. Part IV consists of Chapter 14 where we summarise the theoretical considerations and empirical findings, and conclude with regard to the validity of the theory and main policy lessons.

When the reader prefers to read in layers in order to get a quick first impression of the contents of the book, it is possible to continue reading with the summarising sections of

Chapters 2 and 3. After that, the full Chapter 5 gives an overview of operationalisation, from where the reader may go directly to Chapter 10. There we make a summary of the main empirical findings of our research in Spain. The concluding sections of Chapters 11, 12 and 13 offer a bird-eye view of the specification and extent of empirical confirmation of hypotheses for the case studies - wind in the Netherlands and wind in the United Kingdom. The first layer reading may then end with Chapter 14 - Summary and conclusions.

1.4 Summary

In this chapter, we introduced the research topic, our approach to it and the main research questions. In this study, we focus on how industrialised countries could support the diffusion of renewable electricity technologies. From the possible obstacles to diffusion, we look theoretically only at the economic obstacle - caused by the expensiveness of renewable technologies, and at the financing obstacle - caused by the difficulty to find investors willing to finance such power plants based on such technologies.

Since the introduction of the first governmental policy schemes for market adoption, in the 1980s, the scientific and political debates remained unabated as to which types of support systems could help a faster and more substantial adoption of renewable electricity technologies, to what extent they can bring improvements in the technical-economic performances of technologies, and which are the consequences for societal costs.

In Section 1.1, a short review of a large amount of research studies on renewables' market introduction and diffusion yielded criticism on the following aspects: the way support systems and financial aspects are described and analysed; the short-term orientation of studies; the way the most frequently used indicators of policy effectiveness are described and analysed (extent of market adoption, cost performance improvements and technological performance improvements); and the concern for (or explanatory power of) the mechanisms that relate the types of support systems with the adoption results observed. Based on this critical analysis of current research, we formulated in Section 1.2 the central research question and the seven specific research questions with the help of which we plan to improve the understanding of renewable technologies diffusion. *Theoretically, we look at the consequences of the design of support systems - aiming to overcome the economic and financing obstacles - for the short-medium term adoption and long term diffusion.* In Section 1.3, we explained how theoretical and empirical research is organised in this book.

2

The borders and building blocks of the analytical framework

2.1 Introduction

In this chapter we present the building blocks of the theory and address the first three specific research questions. In Section 2.2 we explain the economic and financing obstacles of renewable electricity technologies and their context. Section 2.3 is concerned with answering the first research question: How can support systems concerned with the economic and financing obstacles of renewable electricity technologies be systematically described and compared from the perspective of investors? Further, Section 2.4 makes a short overview of the dominant research perspectives in innovation diffusion literature and specifies the perspective on technology diffusion adopted in this study. Section 2.5 makes an outline of the analytical framework of the study, explaining the main building blocks, the rationality of their selection and their relationships.

Section 2.6 specifies the types of renewable technologies on the adoption of which the analytical framework is focused, from the standpoint of stage of technical development, as well as our conception of technology and innovations with regard to renewable electricity generation. In Section 2.7 we address the second research question: What are the preconditions for sustainable diffusion processes of renewable electricity technologies? There we define the concept of sustainable diffusion and we look at the circumstances that may enable the continuity of diffusion processes in the long term. The sustainability of diffusion processes depends, among others, on the cost performances of renewable technologies, compared to competing technologies. This issue is addressed in Section 2.8, which answers the third research question: To what extent can support systems influence the cost-performances of renewable electricity technologies? Section 2.9 summarises the content of this chapter.

2.2 The economic and financing obstacles of renewable electricity technologies

In spite of the continuous improvements in technical and cost performances since the 1970s, renewable electricity technologies (RETs) assume production costs per kilowatt hour that are currently still higher than the costs for fossil-based, nuclear and large hydropower based electricity. Because they are capital intensive, interested investors experience difficulties in receiving financing. There are three main groups of reasons on which the economic and financing obstacles rest.

Firstly, *the failure to internalise the external costs of electricity generation* from conventional technologies is largely responsible for the persistence of the cost difference with renewable technologies. The costs of the environmental and human health impacts of fossil-based and nuclear technologies are not reflected in the electricity production costs[1]. There are serious methodological difficulties in establishing full range and scale of consequences of conventional resources use. The highest difficulty for the estimation of fossil fuels' external costs is derived from the uncertainties on their role in climate change and the consequences of climate change. In the case of nuclear resources the difficulty is to quantify the risks and long term impacts of the nuclear wastes storage and the nuclear power plants' decommissioning, since little experience exists as yet. Besides environmental benefits, renewable resources bring also a series of social benefits. These come in the form of employment - often in rural areas where economic activities are often restricted, diversity of fuel supply and more stability in energy prices.

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[1] For more information on the externalities of fossil fuels see Hohmeyer 1993; Swezey and Wan 1995.

Among those who agree that the environmental costs of conventional energy resources and technologies should be internalised, the idea predominates that this can be done in the form of a carbon tax or other type of similar tax (see Section 2.3.1.4, indirect incentives). However an international carbon tax seems still far from being politically feasible. The interested industries - fuel extraction and processing and conventional power generation - strongly oppose this idea and have the political leverage to impose their opinion through the huge employment force they represent. Besides, electricity-intensive industrial sectors lobby with social and financial back-up against any electricity taxes, as these are feared to affect national industries' competitive position in the international economic arena.

Secondly, *fossil-based, nuclear and large hydropower technologies have been heavily subsidised for decades*. In spite of the privatisation and/or liberalisation of electricity industries in many industrialised countries, fuel subsidies from public budgets or from consumers' bills are still maintained. The strong lobbying position of the fuel industry and the conventional power industry, cumulate with the fear of politicians that the subsequent increase in production costs would drive new conventional power plants out of the market. This would lead to sudden massive unemployment in the fuel extraction/processing industry and in the electricity generation industry, with high political costs for those deciding on subsidy cut.

Thirdly, *renewable electricity technologies assume higher total investment costs per kW installed than their competitor conventional technologies*. Renewables require higher technology factory costs. For conventional power plants, investment costs are typically in the range of 500-1300 €/kW, while for RET projects many technologies are in the range of 750-1500 €/kW installed, with often higher costs for small hydropower and solar electricity projects. In addition, RET also have higher transactions costs and higher project development costs. But - highly important - "the additional infrastructure costs required for large conventional power projects such as transmission and distribution lines, and pipeline infrastructure for natural gas, is often not factored into the overall costs" (Wright 2002).

The annual variable costs are very low for RET plants, compared to fossil and nuclear technologies. However, renewable technologies are disadvantaged in financing because they need one large loan at the beginning, to pay for the high investment costs. Conventional power investors have lower initial-loan requirements and can leave the request for loans for long-term fuel purchase and other variable costs for later in the projects' economic life.

When the higher investment costs of renewable technologies are required by loan financiers to be reimbursed over short periods of time (which is typical in the phase of market introduction) this leads to the increase in the projects annual requirements for prices per kWh to be received from the electricity company or consumer of renewable electricity. Overcoming the financing obstacle assumes in this case the increase of the economic obstacle. This forms a vicious circle between the economic obstacle and the financing obstacle.

Another cause of the financing obstacle is the fact, as empirical evidence suggests, in the period of market introduction only small companies or new entrants in the electricity industry are generally interested in RETs - in the absence of support instruments. They are often environmentally-motivated economic actors, or having some self-generation interests or companies exploiting some niche markets where the use of renewable energy resources is more attractive than other business opportunities interests or other types of energy resources. These types of project developers often do not have the institutional track record required by financial agents to provide loans (Mendis 1997: 7). Traditional financing agents prefer to negotiate with large corporations with experience in technology, energy or infrastructure projects. Alternatively, they would rather lend to long-established business partners expanding in the field of energy production, or companies that can prove some business experience and reliability with references from other financing agents and economic actors. Unless their preferred business partners enter the RET market, the financing obstacle is doomed to persist.

But the entry of large corporations and energy utilities requires attractive investment opportunities, and this requires the use of support instruments to make RET projects profitable according to the business requirements of these economic actors. Overcoming the economic obstacles by means of price support would then help overcoming the financing obstacle through the entrance of large corporations in the RET business. This would allow the renewable technologies to build the track record required by financing agents, enabling presumably the financing of RET projects for small developers and new entrants as well.

With the liberalisation of electricity industries during the 1990s in many industrialised countries, the electricity price has lowered and is expected to continue to decrease in short term. This raises the magnitude of the economic obstacle for renewable electricity. However, governments in many countries are still interested in supporting the market introduction of renewable technologies, in view of the many benefits it clearly brings in electricity production. There is already a rich experience with a multitude of support instruments for this purpose, which we present in Section 2.3.1.

2.3 The characteristics of support systems

This section starts with an overview of the support instruments used so far, and currently contemplated in industrialised countries, in order to address the economic and financing barriers of facing the diffusion of renewable electricity technologies. Following this, we look at the characteristics based on which typologies of support systems are made in the literature. After that, we propose a new way of describing and analysing support systems, and explain the choice of proposed characteristics.

2.3.1 Types of support instruments

Governments in industrialised countries used during the 1980s and the 1990s a large variety of support instruments[2] to stimulate the market adoption of RETs. Since 2000, the diversity of instruments continues to increase, mainly as a result of the implementation of regulations for electricity industries' liberalisation and the national policies for climate change mitigation. Based on the review of a wide body of literature (see reference list) we differentiate among nine groups of support instruments, as shown in Figure 2.1. We describe below each group, providing also examples of countries where these instruments were used. This section illustrates the point that a wide diversity of support instruments have been implemented, which poses a serious challenge to policy analysts regarding the analytical approach to be taken when assessing the compared effectiveness of support systems used in different countries.

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[2] Support systems can consist of one or more types of support instruments, the last being more often the case.

Figure 2.1 *Groups of support instruments helping to address the financing and economic barriers of renewable electricity technologies*

* Subsidies
(investment / production costs)

* Soft-loans

* Instruments enabling
bank financing

* Fiscal instruments
(direct / indirect incentives)

* Voluntary agreements for investments in
renewable electricity plants

* Governmental requirement to invest in
renewable electricity plants

* Governmentally guaranteed purchase of
renewable electricity

* Programs for voluntary purchase of
renewable electricity

* Tradable CO_2 emissions permits

2.3.1.1 Subsidies

Subsidies are one of the oldest support instruments used for RETs adoption. They have predominantly taken the form of investment subsidies. These are cash payments to the developer or owner of the renewable energy project, which directly reduce investment costs. The payments can be made before or soon after the power plant is put into operation, in which case they are referred to as up-front subsidies. But they can also be divided into tranches and paid during a schedule agreed upon with the owner, which often depends on the performance of the RET project. There are three main criteria of investment subsidy allocation: first-come first-served, competition-based allocation, or selection by authorities on the basis of certain criteria. Investment subsidies can represent a fixed percentage of investment costs for all developers. But they can be regulated as a ceiling of total investment costs, while certain authorities are enabled to decide on the extent of cost support depending on developer and/or various power plant criteria[3]. Investment subsidies are especially important in the first stages of market introduction, because RETs assume very high initial costs per unit of installed capacity. In industrialised countries, up to 1996 they varied in the range of 10-67% (IEA 1997[1]: 20), with decreasing percentages in late 1990s.

When investment costs lower, production subsidies are seen as a more effective support instrument than investment subsidies. The argument is that production subsidies stimulate the owner to operate the plant as efficiently as possible, since the price support is given per unit of electricity (kilowatthour) generated by the plant. The time-horizon and level of production subsidy allocation can be agreed at the beginning of project development, or can be left for negotiation during the period of project operation.

2.3.1.2 Soft-loans

Another type of support instrument that governments have used can be referred to as soft loans. This assumes the payment by the government of a percentage or the entire interest rate that project developers have to pay when loans are used to finance RET projects. This has similar effects to subsidies, but often assume a smaller extent of financial support[4]. The loan could come from a financing institution or agency of the government, or from a commercial bank or

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[3] As a general pattern, subsidies have been higher for smaller-size projects and small developers.

[4] Interest rates are generally in the range of 6% - 12% of the loan amount, while the loans amount can be between 40% (in early stages of market introduction) to 80% of investment costs of the RET plant.

other type of financing agent with who the government concluded an agreement to finance developers of RET projects. This instrument is very helpful to use in the first stages of market introduction to overcome the financing barrier. Due to perception of high technology and/or resource risks, financing agents either plainly refuse to give loans for investments in RET power plants, or attach high risk premiums that lead to high interest rates on loans. In other circumstances financing agents could have strict criteria on the types of developers, for who they agree to approve loans, leaving other types of economic actors unable to invest, which obstructs diffusion. But soft loans remain often necessary also in the later stages of diffusion in the case of smaller size RET projects, which incur higher transaction costs than large size projects[5] (see Chapter 3).

2.3.1.3 Support instruments enabling bank financing

The obstacle of availability and costs of financing can also be addressed by means of other types of support instruments: project loan guarantees, project aggregation or bundling (Rader and Wiser 1999: 12), and third party finance. *Governmental guarantees on project loans* are frequently necessary during the market introduction phase, when loan providers do not recognise RET projects as market valuable assets nor as investments with reliable output (electricity generation). Through this support instrument, the government declares to the financing agent that in case the renewable energy project does not perform as predicted, in terms of generated cash flows, or in case it incurs a technical failure, the government would pay the remaining share of the loan to the financier. In some cases this could result not only in improved financing availability but also in the reduction of risk premiums and consequently of interest rates and production costs of renewable electricity. When projects perform well, no financial expenses are incurred by the state. When sufficient track-record of economic viability has been built, this instrument is normally replaced by back-up from insurance companies and manufacturers of technology[6].

Project aggregation or bundling refers to a way of addressing the problems of financing availability and financing costs by aggregating more RET projects in order to secure a single large loan. This approach is generally used when sizes of projects are too small compared to the standards of the financing agent. After the loan is received the money is split among the developers whose projects were aggregated. Beside access to finance, this instrument also results in lower interest rates, because the transaction costs per project are reduced. The aggregation of RET projects can be done by any type of economic actor. But when a government agency takes the role of aggregator agent, this has higher chances to result in more attractive financing terms including lower interest rates[7].

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[5] Soft loans have been provided in several European countries also voluntarily, by ethical banks that agree with below market level interest rates for investments in environmentally friendly technologies. Examples of countries that used the soft-loan scheme, either governmentally backed or voluntarily, are the Netherlands, Japan, Belgium, France, Austria, Australia, Germany, and Portugal (IEA 1997 [1] Vol. II Annex B).

[6] Insurance companies are often hesitant to enter the business of innovative technologies, just like financing agents. When they do so, they require very high risk premiums in early stages of adoption, which increases production costs per kWh. Guarantees on project loans from manufacturing companies are more likely to be adopted when the company is a large corporation with sufficient financial resources and market valuable assets or is a subsidiary of such a corporation which is clearly and fully backing-up the manufacturer financially.

[7] An example where this instrument was successfully used is the Autonomous Community of Catalonia in Spain, where the regional energy agency concluded agreements with regional banks for large and low interest rate loans that were consequently split to finance the installation of solar based energy systems by households and small companies (Salat 2001).

Third party financing, is a way of financing whereby a governmental agency (or any financially strong economic actor) develops, finances, installs and operates a renewable energy project. This is done based on an agreement with an economic actor who does not have access to financial resources to invest in the project on his own. The renewable electricity generated can be sold to the local/regional electricity company (utility) or directly to a consumer. The payments from the electricity buyer are used to recover investment and operation costs plus some profits to the third party financier. When the financial claims have been fulfilled, the RET project becomes the property of the economic actor on behalf of whom the renewable plant was commissioned. This support instrument enables diffusion by means of small developers, such as small and medium size production companies, communities, or co-operatives who often encounter financing difficulties. It can play a catalysing role in the early stage of market introduction, but it remains also an important tool in later stages when small developers and small projects still face financing obstacles.

2.3.1.4. Fiscal instruments

Fiscal instruments can stimulate investments in renewable power plants directly or indirectly. *Direct fiscal incentives* can take the form of tax reimbursement, exemption or rebate, improving the cost performances of renewable energy plants. The effect of such fiscal instruments is similar to that of subsidies but, depending on the type of tax envisaged, it cannot always be enjoyed by all types of economic actors. The number of schemes that could be conceived in this group is basically the same to the number of taxes a RET project and/or its investors can be exposed to. Several examples of direct fiscal incentives that have been used in the United States and the European Union[8] are: investment tax credits or reductions, production tax credits or reductions, accelerated depreciation, profit tax reduction, income tax reduction or exemption, lower rate on the Value Added Tax, property taxes reduction or exemption, or reduction in social security tax contributions.

Investment tax credits and production tax credits have been mainly used on the United States. The first are more popular at state level and assume the allowance of the investor “to reduce its tax obligation by some portion of the amount invested in a (wind) project. The tax credit can be designed to be used only in the first year of production, or it can be spread on a number of years” (Rader and Wiser 1999: 25). But investment tax reduction schemes can also be applied at the level of renewable technology manufacturing, whereby the taxes for the purchase of such equipment are lowered, making the technology less expensive. In 1995, six states in the United States used support instruments whereby manufacturers of wind equipment were exempted of sales taxes, which lowered investment costs in wind projects (Rader and Wiser 1999: 30). Portugal also allowed for lower Value Added Tax on the purchase of renewable energy equipment. In Greece, tax reductions as high as 100% were allowed for the purchase of certain renewable technologies, while Italy and Denmark also enabled tax exemptions for investments RET power plants (Goldstein et al. 1999: 6).

The production tax credit was introduced in the United States at federal level in 1992 to support wind energy, through the Energy Policy Act. This instrument allows investors to reduce their annual tax obligations - for all businesses owned, not only the wind power plants - by an amount that depends on the wind electricity production of the plants owned, measured in

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[8] In the European Union, fiscal incentives have been used in the Netherlands, Sweden, Finland, Denmark, Germany, Portugal, France, Austria, Italy, Ireland and Luxembourg. Besides, Norway also used investment tax exemption and 50% production tax exemption for wind power plants (ECN April 2002: 37). Outside Europe, Japan, Australia, Canada, and New Zealand have also used tax exemptions (IEA 1997[1] Vol. II Annex B).

kWh/year. The production tax credit was set at 1,5 $c/kWh and played a crucial role in wind technology diffusion in the United States (Kahn 1996).

The support instrument of accelerated depreciation was used in the United States, the Netherlands and Greece. As Rader and Wiser (1999: 36) clearly describe it: "Accelerated depreciation is a non-cash expense that is meant to approximate the loss of asset value with time, and is defined as the portion of an investment that can be deducted from taxable income in any given year. Tax depreciation therefore reduces yearly income taxes. It results in tax benefits early in a project's life, and is preferred by investors because an after-tax dollar is worth more today than in future years. Therefore, although total taxes paid are generally the same over the life of the plant regardless of the depreciation schedule, the time value of money makes accelerated depreciation a net benefit".

Income tax instruments assume the reduction or exemption of such taxes when investments are made in renewable electricity plants. This can be applied both for investments by private companies and individuals who invest from their personal saving. Such a scheme was used in the Netherlands since 1995, under the name of Green Funds (see Chapter 11). Further, the reduction of renewable electricity sales taxes - or the Value Added Tax - could bring substantial reductions in renewable electricity production costs. An attempt to introduce such a tax in the Netherlands was however refused by the European Union competition authorities. Another instrument - property tax reductions - can also play a substantial role in lowering the investment and production costs for RET projects since renewable technologies are very capital intensive. The more expensive a technology is in terms of equipment costs per kW installed, the more important can the role of such a tax scheme be to improve costs performances. Hence, this scheme is especially important in the early stages of market introduction.

As regards the *indirect fiscal instruments*, they are constituted by environmental taxes aiming to alter the incentive framework of generators and/or consumers of electricity to use renewable resources, or to save energy resources' consumption or to reduce electricity consumption. Three types of environmental taxes can be generally differentiated: emission taxes, product taxes and consumer taxes. For the reduction of energy-related emissions contributing to climate change, taxes can be set both at the supply-side and the demand-side of the electricity sector. Emission taxes can be set either in the form of carbon (or CO_2) taxes, or in the more general form of greenhouse gas taxes. Product taxes may be laid on fossil fuels, for example, when they need to be differentiated according to the carbon content of the fuel[9]. But product taxes may also be charged on polluting generation technologies to discourage their use. Consumer taxes are generally charged on household and sometimes small industrial consumers. But often large-scale industrial consumers are left outside such obligation due to international competitiveness reasons. Renewable electricity is then either exempted from consumer taxes or the tax is charged, but given back to renewable generators in the form of production subsidies[10].

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[9] An example of such instrument is the carbon-based environmental tax on energy resources introduced in 1990 in Finland. The level of tax depended on the CO_2 content and energy content of the fuels used. The scheme exempted renewable energy resources of this tax, stimulating both generators and large consumers to shift towards tax-free resources. In Denmark, renewable electricity generators also get the CO_2 tax reimbursed (Cerveny and Resch 1998: 5-6).

[10] In the United Kingdom, a climate change levy on electricity consumption was implemented since April 2001. It is imposed only on industrial, commercial and public consumers. Renewable electricity was declared levy-free, with the exception of hydropower plants above 10 MW. This way, although its main aim is to encourage energy efficiency in order to meet the climate target, the levy also acts as an incentive to buy renewable electricity by suppliers and large green consumers. Self-generated electricity based on renewables also qualifies for levy exemption. Another example is the allowance of exemption from a special electricity tax (the Ecotax - aiming to stimulate energy saving) for the consumers using renewable electricity,

2.3.1.5 Voluntary agreements for investments in renewable electricity plants

Voluntary agreements for renewable energy investments have been used so far, in Western Europe, only in Denmark and the Netherlands[11]. But since late 1990s, more governments attempt to engage electricity companies in such agreements, given the reduced leverage authorities have on companies' economic activities since the liberalization of electricity industries.

In principle voluntary agreements can take three basic forms: a) negotiated agreements, where the targets are discussed and agreed between electricity companies (utilities) or large industrial consumers firms and public authorities; b) self-declarations of generators/large consumers, where targets are set by them unilaterally; c) programs designed by and envisaging targets set by public authorities, and to which firms may subscribe on a voluntary basis (Carraro and Leveque 1999). All three types of arrangements could be very diverse, for the implementation of which many of the support instruments mentioned so far can be involved. But it is also possible that the expenses are exclusively born by the companies making the agreement.

2.3.1.6 Governmental requirement to invest renewable electricity plants

This support instrument has also been infrequent and is not very likely to be used in countries with liberalised electricity industries. It assumes government obligation on electricity generation companies to install certain levels of megawatts (MW) power plants that use renewable resources, or to generate a certain percentage of electricity from renewable resources. The obligation cannot be met by purchasing renewable electricity from other companies. Only several states in the United States have so far used this approach (Wiser 1999). An indirect requirement to consider investments in renewable plants was introduced in 1994 in Denmark, whereby utilities were obliged to conduct an Integrated Resource Planing assessment that included the use of renewable resources and energy conservation technologies before any new major investments were made in electricity plants (Meyer in ECN March 1999: 50).

2.3.1.7 Governmentally guaranteed purchase of renewable electricity

This is a very large and potentially complex group of instruments. Simply stated it assumes that the government guarantees investors in RET projects that its agencies or, more often, electricity companies will buy renewable electricity. The diversity in this group comes with the details regarding: how much electricity would be bought, for how long, at what price, as well as - when, how and by whose intervention could the price, the electricity volumes, and purchase guarantee change. We differentiate among four major approaches in this group:

introduced in the Netherlands beginning with 1998 (see Chapter 11 for details). Besides, renewable generators were receiving also a production subsidy from the funds collected for fossil and nuclear energy based electricity. A similar scheme has been used since 1998 also in Finland, where consumers have to pay the tax for electricity even when this comes from the use of renewable resources. But the funds are then used to subsidise renewable electricity generators using renewable resources (IEA 1997[1] Vol. II).

[11] The first voluntary agreement for RET investments was concluded 1985 in Denmark between the government and energy utilities. It envisaged the commitment of utilities to install 100 MW of wind power plants by 1992. Later, in 1993, another agreement was signed that concerned investments in biomass electricity plants, with a target adjustment in 1997. In the Netherlands, 1991, a voluntary agreement for CO_2 emissions reduction was concluded between the Dutch government and that Association of Distribution Companies. This was accompanied by the target to *generate or trade* 3% of the distributed electricity from renewable resources by 2000. The financial resources for this target were coming from a combination of environmental tax on small consumers' electricity bills, investment subsidies from central budget and various fiscal instruments.

a) price-focused support instruments, whereby regulations are mainly concerned with the price for which electricity is purchased, and do not place ceilings on the amount of electricity purchase at industry level; but the time period for which the price guarantee holds for individual project owners can be limited or unlimited;
b) volume-focused support instruments, whereby the main regulatory concern is on the amount of RET output to be purchased; this can be expressed as kWh, or as MW capacity, or - more often - as percentage of obliged electricity companies' business volume; but it can also be regulated just broadly as percentage of the electricity industry's business volume; the purchase prices during projects' life time emerge from the balance between the obligation volume and the available supply of renewable generators, being hence not known when plants are commissioned; the time period for which the purchase contracts hold depends also on this balance, in combination with the design of the support instrument;
c) mixed-guarantee support instruments, whereby regulations regard both details on price and on volumes of renewable electricity to be purchased; regulations on volume are generally expressed as percentage electricity or MW capacity ceiling - per electricity company or at industry level; and finally
d) weak-guarantee support instruments, whereby regulations refer to price aspects but only broadly, leaving them rather unpredictable for potential investors while the volume of renewable electricity purchase at industry level is considered unlimited.

Table 2.1 *Types of support instruments for governmentally-guaranteed purchase*

Regulatory focus	price-focused	volume-focused	mixed-guarantee	weak-guarantee
Price (per kWh)	X (regulated)	unpredictable	X (regulated)	unpredictable
Volume at industry/company level (kWh, MW, %)	not specified	X (limited)	X (limited)	not specified
General denomination in the literature	feed-in tariffs	quota models	feed-in tariffs quota models	feed-in tariffs

The four major approaches in this group of support instruments are represented in Table 2.1. Research studies and market analysis reports distinguish between 'feed-in tariffs' or the 'buy-back model', on the one hand, and '(tradable) quota models' on the other hand. But a careful look at the design of the support instruments generally categorised as belonging to one of these two categories reveals that basically 'feed-in tariff models' are in some cases price-focused, in other cases they are mixed-guarantee models, while in still other situations they are based on the weak-guarantee regulatory approach. Further, the '(tradable) quota models' are in some cases volume-focused support instruments while in others they are actually mixed-guarantee support instruments.

An example of *price-focused governmental guarantee* can be found in Germany in the period 1990-1998. During these years, German public electricity utilities were obliged to buy renewable electricity (from specified resources) in unlimited amounts, from all RET generators situated in their monopoly area. Renewable generators were entitled to receive a price between 80-90% of average consumer prices of the buyer utility. As these costs were passed over to consumers and developments in some regions were more substantial than in other regions, the law was adjusted in 1998. A purchase ceiling was introduced whereby utilities are obliged to buy renewable electricity only as long as the amount offered for sale does not surpass 5% of company's volume of electricity trade (in kWh). Hence, since 1998 the main German support instrument has taken the form of a *mixed-guarantee regulatory approach*. In all studies and market reports written, the German approach, both before and since 1998, is referred to as 'feed-in tariff system'. A similar system exists in Austria, with a 3% ceiling on electricity companies' business volume, and in France since 2001 with a 1500 MW ceiling on guaranteed purchase at industry level (ECN April 2002).

Other examples of mixed-guarantee support instruments are those implemented in the United Kingdom 1990-1998, Ireland, and France 1996-2000. The literature refers to these models as 'competitive bidding' (e.g. IEA 1997[1]) or 'quota models' (Menanteau et al. 2002; Lauber 2002). However, we argue that, while having a competitive bidding element, they have nothing in common with what is more generally understood as quota models (see below). These three countries allocated fixed price and fixed length guaranteed purchase contracts for renewable generators, like in Germany. But, instead of unlimited purchase, they established for how much MW capacity governments wanted to guarantee the purchase[12]. In addition, instead of paying a regulated price, they required interested generators to compete and they approved the decided MW capacity by accepting the project proposals with the lowest bidded contractual prices. Even if the contractual price was not directly regulated it can be considered as predictable, since it was basically known once successful contracts were allocated and it remained stable during the entire period of guaranteed contract lengths. Hence, the instrument has a competitive element, but it resembles much more strongly the 'feed-in models'.

But mixed-guarantee support instruments can also be designed very differently, in ways that resemble what the literature refers to also as 'quota models'. Examples here are the new support instruments for governmentally guaranteed purchase of renewable electricity in the United Kingdom (since operational since 2002), Belgium, and Denmark. The Renewable Obligation in the United Kingdom is imposed on suppliers[13]. It aims to lead to 10% renewable electricity consumption by 2010 and it is envisaged to be in place until March 2027. The obligation can be implemented by means of generating renewable electricity, or buying physical streams of renewable electricity, or buying tradable green certificates[14]. Green certificates have a regulated price ceiling of 4,8 €c/kWh, which means that the price for renewable electricity purchase is not totally unpredictable[15]. A similar regulatory approach was designed in Belgium where the quota purchase obligation is placed also on supply companies, with a penalty price for non-compliance that increases from year to year. In Denmark, the

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[12] See in Chapter 13 how this approach was implemented in the United Kingdom. France adopted in 1995 a Program for the Promotion of Wind Power - the EOOL Plan - with a target to achieve 250-500 MW wind power by 2005. But this program was interrupted because new regulations were put in place in 2001. The contract guarantee was for 10 years but with different prices for the first five years and for the last 10 years (ECN April 2002). In the UK and Ireland renewable generators received guaranteed contracts for 8 years and later for 15 years.

[13] Suppliers are electricity companies that are at the end of the value chain of electricity supply. Their main business is to sell electricity directly to consumers.

[14] Tradable green certificates represent a support model whereby generators using renewable resources receive the price for renewable electricity from two sources. The first is the price from the sale of electricity in the power pool market or by means of bilateral contract. The second is the price received for the documents he obtains from qualified authorities as proof that the electricity was generated from renewable resources. These documents are called Green Certificates and can be traded on a separate market or simultaneously with the physical streams of electricity. Buyers of green certificates can be motivated not only by a governmental obligation laid on him to buy such certificates, or renewable electricity, but also by green ideology or various other strategic reasons.

[15] The quota obligation is not split among technological bands, creating competition among renewable technologies in different stages in technical-economic development. This places uncertainties on prices. In order to enable the participation of the currently more expensive technologies in the obligation system, the government proposed in 2001 a subsidy scheme. This joins a series of financial support packages earlier commissioned (see Dinica 2002 [1]).

policy is to impose a quota purchase obligation on consumers but the details on design were still being negotiated in 2002 (ECN April 2002)

One example of *volume-focused regulatory approach* can be found in Italy. There, since January 2001 an obligation was imposed on generation companies to produce 2% of their business volume of electricity based on renewable resources by 2002, or to buy green certificates from other renewable generators equating their quota obligation. New RET projects can participate in this quota obligation only during the first eight years, which can be considered as the maximum guaranteed contract period when obligees choose to buy renewable electricity or green certificates. The price for renewable electricity and green certificates is unpredictable, since there is no price floor or ceiling envisaged in case obligees prefer to buy renewable electricity or green certificates.

Finally, a *weak-guarantee regulatory approach* could be identified in the period 1980-1994 in Spain for wind and biomass electricity technologies. The purchase of renewable electricity from such plants was unlimited at industry level but there was no clear provision in the law with regard to the price of purchase. The law only mentioned that generators would receive a certain guaranteed price that was to be decided upon by the competent minister. But no indication was given on how this price would be calculated nor for how long would it apply. In conclusion, the group of governmentally guaranteed purchase support instruments is a very complex group. It has a large potential of policy design diversity, which in our view can be divided into four categories: price-focused, volume-focused, mixed-guarantee, and weak-guarantee regulatory approaches.

2.3.1.8 Programs for voluntary purchase of renewable electricity

This group of support instruments is based on the principle that electricity companies or consumers agree to pay above-market prices for renewable electricity. Voluntary buyers can have different reasons to pay higher prices, such as placing value on RETs contribution to pollution reduction, green image considerations, an appreciation of innovative clean technologies, business strategic interest, or the improvement of local socio-economic development context. The time-period and level of above market prices that they agree to buy can be agreed before-hand, with regular re-negotiations, or can be left entirely at the decision of buyers when they wish to withdraw or change their financial contribution. Three categories of programs can be differentiated in this group:

a) purchase of renewable electricity by energy utilities/electricity companies based on a voluntary agreement with the government or different public authorities[16];
b) purchase of renewable electricity by electricity companies/utilities based on voluntary agreement with individual owners of RET plants or representative associations[17];
c) voluntary purchase by consumers - households, commercial, or industrial users.

As regards the last category, they are generally referred to in the literature as ‘green pricing programs’. The first such program was introduced in 1995 in the Netherlands by an electricity company (see Chapter 11), and by 2002 it spread in many industrialised countries such as the

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[16] For example, in Austria, a voluntary agreement was concluded between certain municipalities and the local energy utilities, which provides for premium prices for renewable electricity for generators located within a certain area around the municipalities part to the agreement (IEA 1997[1] Vol. I). In the Netherlands, the 1991 voluntary agreement for CO_2 emissions reduction between the Dutch government and that Association of Distribution Companies envisaged the commitment to meet the 3% target of renewable generation neither by generation or by purchase of both.

[17] In the period between late 1970 - 1992, an agreement was operational between the Association of Danish Electric Utilities, the Danish Wind Power Association and Danish wind electricity generators, regarding the purchase of wind electricity for an above-market price (Meyer in ECN March 1999: 50).

Germany, Switzerland, Finland, and Sweden, the United Kingdom, the United States and Australia. Empirical research showed that two types of green pricing programs were developed[18]. Firstly, there are green investment funds, which assume a donation by consumers into a special fund. The electricity company pledges to also contribute financially to that fund and not to make profits in the future RET plant or to make 'normal' commercial business profits. Sometimes there is also a commitment that within a certain number of years the company would build a significant capacity of RET based on those investment funds.

Secondly, there are programs designed as voluntary production subsidies for existing plants, or RET projects planned to be put into operation by independent power generators or electricity companies. The accreditation body ensures that the amount subscribed for by green consumers matched the amount bought by the company managing the green price program. Green prices can be paid either as prices per kWh or as fixed monthly amounts. However, overall the programs of voluntary purchase by consumers have led to very small investments in new RET projects, except for the Netherlands where special fiscal incentives have been put in place since 1996 to make them more effective[19].

2.3.1.9 Tradable CO_2 emissions permits

Since the adoption in 1997 of the Kyoto Protocol for climate change mitigation and targets for greenhouse gas emission reduction, the possibility of a new support instrument for RET emerged[20]. The Kyoto Protocol offered the Annex I countries - that includes industrialised countries and countries with economies in transition with emission reduction targets - three mechanisms for international cooperation that may be used to complement the domestic efforts for target achievement: joint implementation, clean development mechanism, and international emission trading. These are generally referred to in the literature as 'the flexible mechanisms', of which only the last has the potential to support RET diffusion in industrial countries[21].

Tradable emission permits are relatively new policy instruments that aim to achieve emission reduction targets at minimum costs to society. By 2002, only the United Kingdom had an operational domestic system of CO_2 emissions trade. International trade was conducted

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[18] Most programs have been developed by electricity companies that are in direct business contact with consumers - supply and distribution companies. But specialised green electricity supply companies also emerged, for example in the United Kingdom and the Netherlands. In order to induce and increase consumer confidence that the electricity they buy is indeed based on renewable resources, independent institutions - often environmental organisations - took over the role of accreditation bodies. But some programs are still solely managed by electricity companies.

[19] Since May 2001 they are accompanied by governmentally supported accreditation and monitoring mechanisms for the voluntary trade of green certificates aiming to improve the effectiveness of green pricing schemes (see Dinica and Arentsen 2001).

[20] Carbon dioxide (CO_2) is the largest contributor to global warming, having a share of 60% in the additional climate forcing caused by greenhouse gases since the beginning of the industrialization period. It is estimated that the combustion of fossil fuels accounts for 80% of the CO_2 emissions originating in human activities in industrialised countries. Energy policies for renewables stimulation have direct effect on the reduction of CO_2 emissions, as they reduce the rate of fossil fuels combustion.

[21] The joint implementation mechanism assumes cooperation at project level between parties in Annex I countries. It aims at the enhanced harnessing of the most cost-effective measures for emission reduction at the level of these countries. But so far it seems that the main focus is on investment by industrialised countries into countries with economies in transition because there a large low cost potential for emission reduction still exists and will be available for a long time. The clean development mechanism resembles the joint implementation mechanism but regards the cooperation of Annex I countries with developing countries. It was conceived to support the efforts of developing countries to direct their development towards more sustainable patterns, while contributing in the same time to the achievement of the 1992 United Nations Framework Climate Change Convention goals. Participation in this mechanism is voluntary and emission reductions may be certified and accounted for in the reductions achieved by the Annex I party (Dinica 2002[2]).

only between some companies in the United States and Canada on a voluntary basis. The European Union has been planning since 1990s its own internal CO_2 trading regime by the year 2005 (IEA 2001: 49). The intention was to prepare future obligees in Member States - most likely energy companies and industrial production companies with high energy consumption[22] - for the start of international emission trading planned for 2008 (Viguier 2001).

The mechanism can work as follows. After a certain reduction target is set at the level of an industry or at national level, the quota of allowable emissions is derived for each company that is obliged to cut emissions. Permits are issued by a governmental authority, each representing the right to emit a certain volume of CO_2 emissions. The emission quota of a company can be this way translated in a number of permits. Companies incurring lower costs for emission reduction have the incentive to engage in larger reductions than those required and sell the extra emission permits to companies that have higher expenses[23]. When quotas are set at company level, emissions may be traded in the domestic market under three schemes. One assumes trade among subsidiaries of the same company and is also referred to as ‘quota bubbling’. A second one presupposes trading among companies, denominated as ‘quota offsetting’. The third one is related to the time horizon of targets and allows firms to account emission reductions or the purchased permits for future reduction requirements. This scheme is known as the ‘banking’ of emission credits.

Generators of renewable electricity receive a special CO_2 reduction certificate for each unit of electricity generation[24] (e.g. 1000 kWh). Authorised bodies calculate for each renewable resource/technology the amount of CO_2 emissions avoided as per kWh compared to the (average) emissions of fossil fuel based electricity generation. This amount is written in the CO_2 reduction certificates that the RET generator received from the accreditation body. The buyer of CO_2 emission permits is allowed to increase emissions by the level represented by all permits bought. By selling the CO_2 reduction credits, the cash flow of RET projects can improve significantly. This support instrument is likely to be helpful only to those RETs for which production costs are in the lower range of CO_2 permits market prices. In the early stages of trade, other cheaper options for CO_2 reduction will compete for market shares in the CO_2 permit market, making the potential for RETs diffusion under this instrument uncertain. The potential is however likely to increase in long term.

2.3.2 Configurations of support systems and approaches in describing them

Since early 1980s when the first support instruments for RET market adoption emerged in industrialised countries, two phenomena could be observed at both national and international level: 1) the increase in diversity of support instruments used; and 2) the change in time of the types or the design details of support instruments.

During the 1980s, investment subsidies played a major role in many countries’ support systems. During the 1990s, the most frequently used support instrument was that of governmentally guaranteed purchase. Regulatory approaches were diverse, taking the forms of ‘price-focused’, ‘mixed guarantee’ or ‘weak guarantee’ approaches (see Table 2.1). But while the governmentally guaranteed purchase was the backbone of support systems, other types of instruments have also been used in the same time. Soft-loans and direct fiscal incentives have

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[22] These target groups are the most likely because large emission sources are located there, and the allocation of quotas, and compliance verification can be more easily performed.

[23] But in order for a market of permits to emerge, it is necessary that the number of companies is high and that there are significant cost differentials to justify trade.

[24] The CO_2 reduction certificate will be received separate from the green electricity certificate. The two certificates will be most likely traded in separate markets.

been the instruments most often accompanying the governmental guarantee on purchase. In late 1990s some countries started to also use schemes based on voluntary agreements for renewable electricity purchase (including consumer green pricing) and indirect fiscal incentives. Besides, more countries were considering to shift towards a 'volume-based' or 'mixed-guarantee' regulatory approach of the governmental purchase guarantee instrument, in order to contain the costs of diffusion and to introduce incentives for competition among RET generators and equipment manufacturers.

Appendix 2.1 shows the types of support instruments used simultaneously in late 1990s, and being prepared for implementation (highlighted in italics), in 21 industrialised countries (based on IEA 1997 [1] and ECN April 2002). This illustrates how diverse the configurations of support systems addressing the economic-financing barriers can be. Configuration diversity poses a significant challenge for the policy analysts, regarding the approach to be taken when describing support systems used in different countries and/or in different periods of time. While often support systems have in their configuration an instrument that can be viewed as the backbone of the support system, often more types of support instruments are used, the interaction of which alters the incentive framework to invest in RET as compared to the incentive embedded in the 'core' instrument alone.

So far, researchers and market/policy analysts describing or evaluating support systems for RET implemented in various countries have used very different ways of describing and categorising them. Examples of encountered typologies are shown in Table 2.2.

In the studies we reviewed, typologies are often ad-hoc depending on, or inspired from, the instruments used in the countries of concern for the study. Two patterns of deriving typologies can be observed:

- a first approach in which support instruments are considered from the perspective of the way they stimulate investments - directly or indirectly (examples 1 to 4); and
- a second approach whereby support systems are differentiated depending on the instruments viewed as their backbone - or the core instrument.

A closer look at the types of support instruments placed in the distinguished categories in the first typology approach reveals that often there is just a language preference. Market-push instruments are not different from production-stimulating, or from investment-focused instruments, while market-pull instruments are roughly the same to those described as consumption-stimulating and generation-focused instruments. But in some cases, the same support instrument is classified differently in various studies[25], which makes comparison of research findings difficult. As regards the second typology approach, the difficulty of conducting comparative research on support effectiveness emerges from the fact that this simplification comes at the cost of understanding the interaction with the other the (non-core) support instruments. This makes the causality relationships between a certain type of support system and the extent of market adoption doubtful, casting also doubts on conclusions regarding the relative potential for investment stimulation of the categories differentiated.

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[25] For example, some view tax incentives as market-pull support schemes (Loiter and Norberg-Bohm 1999: 94), or consumption-stimulating schemes (e.g. ECN 2001: 25). But others classify them as market-push schemes because they provide direct price support to cover the cost gap of renewable electricity generation, as compared to conventional technologies - fossil-based, nuclear and large hydropower (e.g. Rader and Wiser 1999: 8).

Table 2.2 *Typologies of support systems encountered in the literature*

Typologies used in the literature	Examples of studies
1. market-push and demand-pull instruments	Rader and Wiser 1999: 8; Loiter and Norberg-Bohm 1999: 94
2. production-stimulating and consumption-stimulating instruments	ECN 2001: 25
3. fiscal incentives and financial incentives	IEA 1987: 44-48; Painuly 2001: 86
4. direct support and indirect support instruments	Lew 1997
5. regulatory approaches (price-driven and capacity-driven), voluntary approaches, and mixed strategies	Haas et al. 2000: 10 IPPC Technical Paper I, 1999
6. fixed price regulations and market stimulation incentives	Grubb 1995: I-192-I.193 Krohn 2000
7. price-based models (or feed-in-tariffs) versus quota/quantity-models of support[26]	Hvelplund 2001; Menanteau et al. 2002; Lauber 2002; Meyer 2002; Huber et al. 2002; Lange et al. April 2002; WPM December 1999: 39
8. investment subsidies, fixed price systems and fixed quantity systems	Krohn 2000; Espey 2001[2]
9. fixed prices, production incentives (subsidies), competitive tenders and (more recently also) tradable green certificates	Moore and Ihle 1999: 5; Harisson and Milborrow, WPM April 2002: 45; ECN March 2001: 86
10. commercialisation incentives (loans, tax credits and subsidies), production incentives (fixed prices), and competitive market bidding	Goldstein et al. 1999; Ecotec Research and European Environment Agency 2001
11. fixed prices, competitive tenders, quotas with tradable green certificates, green pricing / taxes	Ackermann et al, 2001; Langniss 1997
12. guaranteed markets, output/capacity quotas, economic or fiscal incentives, and green pricing	IEA Vol. II, 1997 Annex B OECD 1997; ECN October 1999

But both approaches of typologies have two crucial shortfalls. Firstly, they *do not incorporate the aspect of the extent of financial support* offered by the support instruments or the configurations of support systems classified as such. For example, all studies we are aware of claim that feed-in tariffs lead to large market adoption only because three countries that used this approach for wind technology - Denmark, Germany and Spain -recorded large levels of installed capacity indeed. But the same type of support instrument was used for wind technology in other countries too, and for other types of technologies, without impressive results. The main reason for failure in those cases was the insufficient extent of price support (e.g wind in the Netherlands up to 1997; wind and biomass electricity technologies in Spain up to 1994; see empirical case studies). The extent of price support is at least equally important for investors as the type of instrument it comes from.

Details on the extent of financial support are present only in the already too numerous country surveys on renewables policy and market results, commissioned by governmental agencies and European Union institutions. They look at the prices per kWh guarantees or price-ranges possible under the support instruments described, and at the percentages of investment

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[26] This typology is the most frequently discussed since the liberalisation of electricity industries, and the emergence of the ambition of the European Union to harmonise support systems used by Member States. In 2002, six EU countries had a type of price-based support systems in place - as the core instrument in their package - while six countries were preparing the implementation of a volume/quota based regulatory approach (ECN April 2002).

subsidies and tax reduction applicable to groups of project owners or types of RET plants. But since the quality, availability and distribution of renewable resources differ among countries, these indicators are not satisfactory to assess and compare the extent of financial support in different countries. As long as the issue of how does financial support compare to production costs in each country is not dealt with, the potential to assess the attractiveness to invest under different support systems is small.

Despite the fact that empirical surveys acknowledge that there are enormous differences among countries regarding governmental price support (e.g. Cerveny 1998: 21), this issue has not been incorporated so far systematically in scientific comparative evaluation studies. We did not observe so far a concern for the extent to which and circumstances under which projects become and could remain profitable. The risks for consumers' bill increase are carefully weighted in many studies, but the concern for risks on the profitability of RET projects they are aiming to support is quaintly missing. The concern of polity for the economic allocation of resources seems to have trapped the scientific community as well, since late 1990s, in an endless debate on the consequences of using fixed-price versus quota-models of support[27]. Support systems need to be also described in terms of the extent of financial support offered, precisely because they aim to help investors overcome the economic barrier[28].

Secondly, the current approaches to describe support systems are not sufficiently suggestive with regard to the degree of attractiveness of the support instruments/systems to invest for different types of economic and financing actors, from the perspective of risk acceptability. Signals from the scientific community have started to be emerged in late 1990s that a different standpoint of policy analysis is needed. For example, a joint research project into the Financing of Renewable Energy Systems, funded in part by the European Commission, looked at the financing opportunities and barriers in several countries for various types of RET, and at investors' behaviour under various country specific contexts (Langniss et al. 1998[29]). One of researchers' conclusions was that "Europe needs to weigh up the cost of the *economic risk* associated with different types of support mechanism for renewables before deciding whether fixed prices or minimum quotas are the best option in a competitive market. Both political risk and market risk have a strong influence on the cost of finance. Providing subsidies on the one hand but introducing market uncertainty on the other is a self defeating approach.". Further, they warned that "The factors underlying tariff prices - such as the regulatory philosophy, taxation, and the constitutional and political traditions of a country can all pose risks. (…). Market regulators and policy makers should consider some of these factors more closely" [30].

The studies we encountered addressing the issue of investment decisions of electricity utilities/companies, independent power producers and financing agents mention the crucial role of policy risks, market risks and political risks when investment decisions are made[31]. A study

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[27] The only places where the issues of RETs projects' profitability and the prospects for achievement of renewable energy targets under the available extent of financial support come to the floor are the journals focusing on renewable energy issues and conferences where representatives of technology manufacturing industries and investors try to bring this issue more closely to the policy debates (examples of journals: Wind Power Monthly, Renewable Energy, Renewable Energy World, New Energy, Las Energias Renovables).

[28] Not all support systems are explicitly concerned also with the financing barrier.

[29] The research report analysed 64 case studies of renewable energy projects developed in eight European Union Member States.

[30] Wind Power Monthly November 1998: 44, "Policies that go beyond national interest".

[31] Hines 1997; Joskow 1995; Kahn 1991; Derkinderen and Crum 1981; Burr 1999; Murray 1998; Sidak and Spulber 1998; Kumar and Wong 1994; Tye and Hawthorne 1997; Siddique 1995; Awerbuch 1993; Gish

of the international firm of market analysts Datamonitor has gone one step further, inquiring independent power producers regarding the most important factors taken into account when considering to invest in power plants. The study found that the following eight variables are the main decision criteria: national regulations and energy policy; electricity price; possibility/price of power purchase agreement; whether the power plant has to participate in the market power pool; investment risk profile; fuel costs/availability; planning approval process; and the number of licences awarded in the past to independent producers and expectations for the future[32]. Five of the factors mentioned as key decision criteria are related to the price attractiveness and stability of electricity sale. In the case of renewables, these criteria are directly related to the design of the support system for renewable electricity. Besides, the study looked at the ranking of the eight factors in different regions across the globe, revealing that in Europe energy policies and regulations constitute the most weighty factor.

Since late 1990s, the topic of the impact of policy design and specific types of support instruments on financing costs[33] and parameters due to such risks has started to get the attention of researchers both in Europe and in the United States[34]. Some studies discuss also some implications on the types of project developers and financing agents that would be attracted to invest or not under different risk levels. But the typologies used so far for support systems description do not articulate the risks on renewable energy projects' cash-flows associated with the design of support systems.

Consequently, there is a need to approach support systems' analysis in a way that bridges the aspects of support systems' design with the assessment criteria of the target group - investors: financing agents and project developers. Because of the two shortages mentioned, the currently used approaches in describing support systems and analysing their effectiveness have not led to satisfactory explanations from theoretical point of view.

2.3.3 A different approach to describe and analyse support systems

The investment behaviour of project developers and the attitude of financing agents towards RET investments are to a large extent shaped by the risks on projects' cash flows. But they are also influenced by the profitability of renewable energy projects. As most renewable technologies are more expensive than conventional electricity generation systems they have to compete with, support instruments are needed to enable investments. These should be able to at least cover the cost-gaps, and to allow developers yield some profits on their investments.

In this study, we propose to describe and analyse the support systems addressing the economic and financing barriers of RET market adoption in terms of two characteristics:

- *aggregated risks on the economic feasibility and profitability of* renewable electricity *projects* emerging from the support instruments used and their interaction, and
- *range of project profitability* that emerges from all support instruments that investors are eligible to use for the production of renewable electricity.

This approach to describe support systems has also the advantage of parsimony, having in view the large diversity and frequently also high complexity of support systems encountered in

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1999; Awerbuch et al. 1996; Woo et al. 2001; Bodmer 1995; Churchill 1996; Foltz et al. 1994; Kolbe et al. 1994; Perl and Luftig 1991.

[32] Datamonitor - survey reviewed in Wind power Monthly (October 1999: 10, "Price and policy factors analysed"). The order of factors mentioning was done by us.

[33] Financing costs, as meant here, include both the interest rates to banks and the returns on equity investments to project owners (Chapter 3 discusses financing parameters in more detail).

[34] Wiser and Pickle 1997; Kahn 1996; Wiser and Kahn 1996; Langniss et al. 1998; Jones and Eto 1997.

practice, and the countless configurations that could theoretically conceived through the combination of support instruments from the nine groups differentiated in Section 2.3.1.

The choice to characterise support systems in terms of level of risks induced for the economic feasibility and profitability of RET projects is motivated by the importance of being able to understand what types of economic actors a support system is likely to attract and whether traditional financing agents in the country would be willing to unlock their financial potential to enable the sustained market adoption of RET. Different types of economic actors have different requirements with regard to the risks on project cash flows they are willing to accept. Some are more flexible than others as regards risk acceptance, but in higher risk investment contexts they require higher profits. Traditional financing agents - such as commercial banks, pension funds, saving funds and so on - have also specific risk level requirements. But generally they tend to be more risk adverse than the economic actors who engage in the role of project developers.

Support instruments and their interaction could, unintentionally, pose risks on the cash flows of projects, which could drive certain types of economic and financing actors from the business of renewable electricity production. But risks on the cash flows of projects are also influenced by many other variables. Guidelines and empirical literature on power plants investments[35] advise developers of electricity generation projects to carefully scrutinise the following types of risks before taking the decision to invest: resource quality, availability and cost risks, technology risks, construction risks, planning approval risks, environmental impact risks, (i.e. impacts or pollution beyond that permitted by competent authorities), interest rate risks, currency exchange risks, operation risks[36], institutional and other regulatory risks[37].

As regards financing agents they look at a range of risks that encompasses that of project developers. But this range expands in the area of credit worthiness of project developers, that is to say the extent to which their financial reserves and market valuable assets are sufficient to offer the reimbursement of loans when project cash flows decrease below the limit of economic viability[38]. Beside project risks and company characteristics, financing agents also look at industry characteristics such as industry structure, economics, maturity and stability (Finnerty 1996). Industry characteristics influence also the decision of project developers of whether to enter the market at a certain moment and its detailed investment plans.

Although the existence and reliability of a contract for electricity purchase and price risks are at the core of the investment and lending decisions, these other risks and considerations mentioned also influence the decision to invest and the particularities of project development plans. However, we argue that demand risks, contract risks, and price risks are an important bridge available for understanding the relationship between support system design and investors' decisions to finance renewable electricity generation projects.

As regards the second characteristic - the range of projects' profitability - its selection is motivated on the one hand by the need to have a measure of the extent of financial support offered by support systems, with the help of which comparisons can be made both across countries and, possibly also simultaneously, across types of renewable technologies. Using

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[35] Hines 1997: 189-209; Wright 2002; Welp and Schimana 2002; Jeckoutek and Lamech 1995; Bond and Carter 1995; Rose et al. 1997; Dunkerley 1995; Pollio 1998; Ingersoll et al. 1998; Henney and Keers 1998.

[36] Operation risks can take the forms of: "breakdown of computer control systems, possible fires, explosions, and problems stemming from the weather and geographic conditions, such as earthquake, droughts extended rainy periods" (Hines 1997: 192)

[37] In this category Langniss et al. (1998) mention among others: generally applicable tax regulations, environmental, economic and energy policies, aspects of administrative culture.

[38] "A project that is economically viable is one that will generate sufficient cash flows to cover its cost of capital. A project that is creditworthy is one that, even in reasonably adverse circumstances, will generate sufficient cash flows to cover both operating expenses and debt service" (Ingersoll et al. 1998).

prices per kWh or percentage subsidies and fiscal reduction as indicators, as done so far in survey studies, is not helpful because the production costs of a certain type of renewable technology vary widely among countries. But also production cost-ranges are very different among types of renewable technologies.

On the other hand, the characteristic of project profitability offers a second bridge between the design of support system and investors decision to finance renewable projects. This indicator is simultaneously suggestive for the attractiveness of support systems for both project developers and financing agents. Project profitability is an economic indicator for power plants that incorporates in its calculation both the interest rate required by the financing agent (when loans are used) and the profits of project owners/developers, which are referred to in the financing literature as returns on equity[39].

We label as 'project profitability' what in the financing and economic literature is often referred to as the 'internal rate of return' of projects[40]. As Hadley et al. (1993: A-13) describe it: "The cash flow to the debt and equity holders combined is the basis for calculating the internal rate of return. This defines the cash flow of the project as a whole, without regard to the financial arrangements in its financing".

In this study we use the term 'cash flow' with the meaning revenues for electricity generated, calculated as the contract price/market price per kWh multiplied by the amount of kWh electricity produced. Cash flows have to allow for the payment of debt to the financing agent, the recovery of equity investments by project developer/owner, the payment of operation and maintenance costs, fuel costs (when necessary), taxes and other regular fees such as land rents, insurance; but they also have to allow for the payment of interest rates on debt to financing agents and for equity returns to project owners. The last two variables represent project returns and constitute the basis for calculating project's profitability in the form of a rate. Very roughly the relationship between project' cash out-flows and project returns can be represented as below[41].

cash flows =
(debt reimbursement payments + equity recovery payment) +
(operating/maintenance costs + fuel costs + taxes + other regular fees/expenses) +
project returns

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[39] "Equity" is a term used in financing literature to refer to the cash payments made by project developers, while 'loan' or 'debt' are the terms referred for the payments made by financing agents - commercial banks, saving banks/funds, pension funds, insurance companies. But this does not exclude that financing agents can also provide equity to finance projects. As Wiser and Kahn (1996) define it, "equity represents a residual claim on all surpluses [revenues] generated by the firm or project. Equity returns come in the form of both direct cash flows and tax shields". Equity covers the project costs in its very early stages, when the chances of project success are yet unknown, and the loan has not been issued yet. Because these down payments are made in conditions of high risk, and because the returns on equity are paid after the financial obligations towards the loan-issuing financing agent have been honoured, the returns associated with equity are usually higher than the interest rates required on loans.

[40] Besides the internal rate of return on projects, both theoretical and empirical studies discuss about the internal rate of return for equity investors. In order to avoid confusion we prefer to use the terms 'project profitability' and 'equity returns'. In financing text books the internal rate of return is defined as the yield of a project which is the discounted rate required to make the present value of the returns equal to the initial investment costs. 'Equity returns' are measured as the ration: (profit on an investment after taxation/total equity invested x 100) (Samuels et al. 1999: 63; 41).

[41] See Hadley et al. (1993) for a more detailed discussion on profitability with specification for renewable power investments in the USA by different types of economic actors, with different tax obligations.

Project returns represent the sum of the total amount to be paid in the form of interest rate to loan financiers and the total amount to be paid in the form of equity returns to the equity investors of the project.

Project returns = total amount paid as interest rate + total amount paid as returns on equity

Project profitability is not an amount but a rate. In the financial structure of the project, loan will contribute with a share of Y% on which the loan financier requires a certain interest rate, and equity will contribute with a share of Z% of total project costs on which investors will require a certain equity return. When no bank loans are used to finance the project (Z = 100%), then the project profitability is the same with the return on equity, since the project owner is the only financing agent. Simply stated:

Project profitability = [Y% of total project costs] x [interest rate in %] +
[Z% of total project costs] x [equity returns in %], in (%)

The financial structure of projects, the interest rate level and the equity returns requirement are strongly influenced by the risks at which the RET project is exposed, including the risks associated with the support system.

The financial support offered by the applicable support instruments can influence a project's profitability by enabling increased cash flows (left side of the first equation), or by reducing taxes and the other regular fees and expenses (right side of the first equation). But it can also do so by reducing the amount that needs to be paid as debt reimbursement and equity recovery when investment subsidies are available. Extra cash flow can be brought about through governmental or voluntary above-market electricity purchase contracts and/or production subsidies, income from tradable green certificates, and/or income from tradable CO_2 emission permits (see Section 2.3.1).

Certain support instruments will however not change the overall profitability of the project, but will increase the returns on equity for project owners, attracting this way more types and more numerous economic actors in the activity of renewable electricity generation. For example, soft loans reduce the interest rates project owners have to pay and enable higher returns on equity. The instruments of project aggregation and governmental guarantees on project loans described in Section 2.3.1.3 could have a similar effect.

Besides, there is the group of indirect fiscal incentives (Section 2.3.1.4), which in some situations do not produce changes in projects' profitability nor in the equity returns of project owners. They are represented in the risk-profitability characterisation of the support system only by means of the risks on the stability of fiscal incentives' use. In some situations, however, it is possible that the fiscal incentives to consumers or electricity companies to buy renewable electricity instead of conventional power would lead to increased purchase prices, if incentives are powerful enough. Enhanced cash flows would lead in this case to increased levels of projects' profitability.

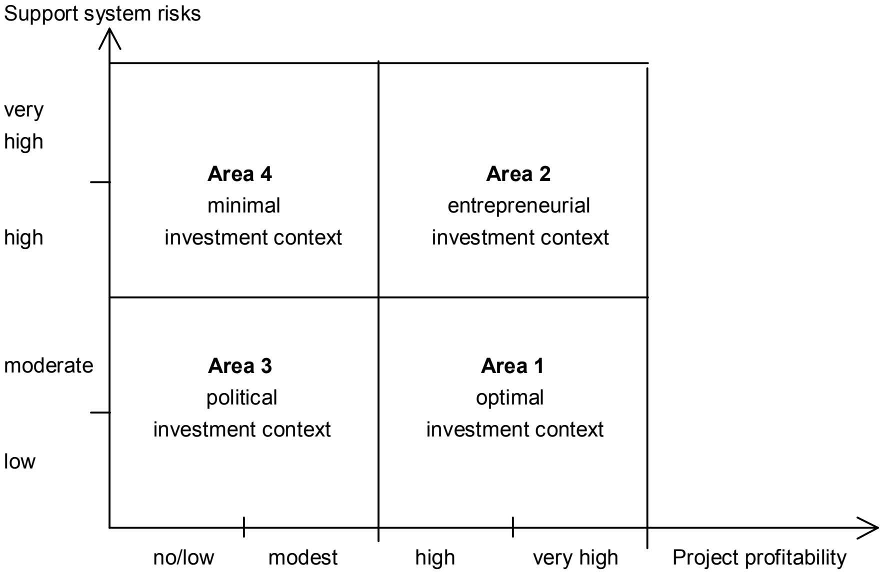
But support instruments also have impacts on projects' profitability through the vehicle of risks on cash flow their design induces. Even when cash flows appear to be high, if their stability for the period of debt reimbursement of project's economic life does not appear satisfactory for financing agents, interest rates will increase as a result of increased risk premiums. If the profitability of projects cannot increase this comes at the expense of lower equity returns (see the second formula). Besides, when cash flow risks are perceived as high the amount of debt that financing agents are willing to provide in the financing the RET projects could lower, for example from 80% of total required financing volume in conditions of low risks to 50% or even 40% in conditions of high risks[42]. This could drive away certain types of economic actors who would not have the financial resources to compensate for the reduced financial contribution of banks. But it can also lead to the increase in project owners' requirements for equity returns. Hence when the risks on project cash flow are high, some developers accepting to go ahead with investments will require higher levels of project profitability than required in lower risk investment contexts[43].

Consequently, we consider that the characteristic of range of projects' profitability is essential for understanding the interplay between support systems design (types of support instruments used their design particularities and their interaction in the chosen configuration) and the investment behaviour of economic actors and financing agents with consequences for short-term and long-term diffusion of renewable electricity technologies.

For a more systematic theoretical analysis we propose to represent the two selected characteristics of support systems by means of a graph as in Figure 2.2 where:

- along the vertical line we represent on the level of *aggregated risks on the economic feasibility and profitability of* renewable electricity *projects* emerging from the support instruments used and their interaction, and
- along the horizontal line we represent *range of* p*roject profitability* that emerges from all support instruments that investors are eligible to use for renewable electricity.

Figure 2.2 *A typology of support systems based on risk-profitability characteristics*



We choose to discuss the characteristics of risks and profitability qualitatively, and to differentiate between four levels of risks and for situations regarding profitability:

- support system posing *low*, *moderate*, *high* and *very high* risks of projects' profitability

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[42] More detailed explanations on the financial parameters are offered in Chapter 3.

[43] As mentioned earlier, the risks of cash flows are also influenced by other factors not related to the design of support systems. However, this should not prevent a theoretical inquiry into the relationship between support systems design and investors behaviour. The other interfering factors need to be looked at in empirical research in order to understand the extent to which they affect the relationship of theoretical interest for us.

- support systems resulting in *no profitability* of projects (i.e below the recovery of investment costs) or enabling *low*, *modest*, *high* and *very high* ranges of projects' profitability.

This four level differentiation along the risk and profitability dimensions results in sixteen combinations of risk-profitability situations that a support system could lead to. However, for several reasons we propose to theoretically discuss the consequences of support systems for diffusion in terms of only four risk-profitability investment contexts. Firstly, production costs per kilowatt-hour for most types of renewable electricity technologies spread wide ranges. These ranges are often larger than those of conventional fossil-based or nuclear-based power plants because of the strong influence of resource quality, availability and location[44]. In Section 2.7, we discuss the factors influencing production costs per kWh in more detail. The general idea is that when support systems do not differentiate the extent of financial support according to sites and/or plant sizes or other factors strongly influencing production costs, the range of projects' profitability that developers would be able to secure in one country can be quite large. This has often been the case in many countries when profitability for some technology expanded over two or more of the levels mentioned.

Secondly, the qualitative analysis of risks means that even when a protocol for the systematic analysis of risks is in place, the border between two adjacent risk levels differentiated could be in some cases blurred through the subjective interpretation of the researcher and of the respondents interviewed with regard to their perceptions. Thirdly, the subjective perception on risks and the minimum profitability requirements of some investors could change in short-medium term after the placing of the support system into operation. This would lead them to behave as if the 'objective risk level' (assuming that this could be traced) and the profitability level was placed in an adjacent 'cell'. For example, some developers might require a combination of low risks and high profitability in order to invest in renewable projects. However after some time they decide to enter the market where the support systems enables actually modest profitability and attracts moderate levels of risks on projects cash flows. Consequently we propose to operate both theoretically and empirically with a typology that has better prospects to minimise the analytical perils of striving to be too specific in support systems' description, and distinguish among only four combinations of support systems' characteristics. We propose to label the four risk-profitability investment contexts as follows, for comfort of reference to these situations:

- *optimal investment context,* with low/moderate support system risks and high/very high profitability of projects (Area 1); this is the investment context that would satisfy all types of economic actors and quite likely also many types of financing agents;
- *entrepreneurial investment context,* with high/very high support system risks and high/ very high profitability of projects (Area 2); this is the environment where mostly risk-taking, entrepreneurial, economic actors would venture to invest, who expect the profits to be proportionally high with the risks faced;
- *political investment context,* with low/moderate support system risks but low or modest profitability of projects or below cost-recovery financial support (Area 3); this is a rather

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[44] For example, the same wind generation plant located in different sites within a country will incur different levels of production costs depending on the annual average wind speed at the site and the annual availability (in hours) of the necessary wind speeds for operation at maximum capacity. Also the same small hydropower plant will have different production costs in sites with different geographical and water resource availability conditions. More generally, electricity projects of different sizes incur increasing production costs with the decrease of plant sizes because transaction costs are higher. In the case of some technologies this also occurs because certain technology particularities, such as for biomass electricity technologies.

politically comfortable support approach which, by aiming to minimise public or consumers financial load, creates a context not very appealing to investors;

- *minimal investment context,* with high / very high support system risks and also low or modest profitability of projects or below cost-recovery financial support (Area 4); this is an investment context giving minimum incentives to invest in RET projects.

The next section outlines a protocol for the analysis of support system risks. The characteristic of the profitability will be operationalised in Chapter 3.

2.3.4 The analysis of support system from the risk perspective

We propose to analyse support systems' risks by distinguishing between the economic component and the policy component of support systems.

The economic component of support systems refers to the forms of support that directly concern the trade arrangements for renewable electricity. Trade could rely on governmentally guaranteed purchase for renewable electricity (see Section 2.3.1.7). In this case, regulations are usually rooted in the legal framework for the organisation and functioning of electricity sector - the electricity law and/or accompanying governmental or ministerial regulations. The regulatory framework specifies one or more of the following elements: how much renewable electricity will be purchased from each generator, and/or at company level and/or industry level, for how long, at what prices, and how are the prices calculated and changed. But trade arrangements can also rely on the voluntary purchase by electricity companies or consumers (Section 2.3.1.8). The just-mentioned particularities of trade are then settled at industry level through the agreement of all actors involved or bilaterally, between seller and buyer. In some cases, however, project owners have to rely on market exchange, selling renewable electricity in the power pool or to the (local) electricity company at the market price.

The availability of a contract for electricity purchase, the length and reliability of that contract, as well as the predictability and reliability of the price for purchase are crucial for the decision of economic and financing actors to invest in RET projects. We propose to refer to trade arrangements as the *economic governance structure* for renewable electricity and to describe them in terms of three elements: type of demand, contractual relations, and price design (see Table 2.3). The analysis of the forms of these elements leads to the assessment of demand risks, contract risks and price risks associated with trade arrangements. Together they form the *economic risks* of the support system.

The policy component of support systems refers to the forms of intervention that:

- improve the economics of renewable electricity projects, in comparison to the price design created in the economic governance structure (that is making projects economically viable or improving their profitability),
- contribute directly to the reduction of financing barriers, and/or
- improve the market position of renewable electricity technologies, in terms of investors and/or consumer choice between renewable and conventional energy technologies.

We will refer to these as *policy support mechanisms* and to the risks on projects' cash flows emerging from them as *policy risks*. In Table 2.3, we mentioned the types of policy support mechanisms for each of the three targets mentioned above. These were explained in Section 2.3.1. The policy support mechanisms offering indirect financial/price support and targeted at the improvement of renewables' market position are directly addressing the economic barrier, and indirectly tackling the reduction of the financing barrier.

Table 2.3 *The analysis of risks in the economic component of support systems*

Economic governance structure (economic risks)		
Elements	Characteristics	Forms
Type of demand for purchase of renewable electricity		1. Unlimited purchase from individual RET plants with → unlimited demand at industry / company level → ceiling (%) at industry / company level
		2. Limited purchase from individual RET plants with a) Limited contract length b) Limited volumes of renewable electricity → unlimited demand at industry / company level → ceiling (%) at industry / company level
		3. Quota purchase obligation. Trade flexibility - with tradable green certificates - without tradable green certificates
		4. Voluntary purchase of renewable electricity tradable or green certificates
Contractual relations	Contract lengths	Long-term, short-term, spot exchange contracts
	Price methodology	Intrinsic, extrinsic, fixed price
		(or) The same as in the price design
Price design	Price components	Prescribed, suggested, not indicated
	Price methodology	Intrinsic, extrinsic, mixed
	Price levels	Tariffs, floors, ceilings
	Decisions system	Directive, consultation, market price
Policy support mechanisms (policy risks)		
Target		Types
Direct financial / price support		Investment subsidies Production subsidies Direct fiscal incentives Tradable CO_2 emission permits
Financing accessibility		Soft loans Governmental guarantee on project loan Project aggregation programs Third party financing
Improved market position		Indirect fiscal incentives

In Chapter 5 we will discuss the operationalisation of support systems' risk assessment and of the project profitability characteristic. The next subsection explains the elements of the economic governance structure, their characteristics and forms, as presented in Table 2.3. In our view, these are the core aspects that need to be considered when assessing economic risks for renewable projects. In the last Section, 2.3.4.1, we make some considerations on the general perception of risks associated with the types of policy support mechanisms listed in Table 2.3. These two subsections conclude the presentation of the proposed approach for the analysis of support systems addressing renewables' economic and financing barriers, which lies at the centre of Section 2.3.

2.3.4.1 The design of economic governance structures and economic risks

We chose to describe trade arrangements by means of three elements: type of demand, contractual parameters and price design. Of these, the type of demand plays a major role in investment decisions, setting the baseline risk level above which the risks emerging from contracts, price design and any applicable policy support mechanism are assessed.

Types of demand and demand risks

We differentiate among four commonly used types of demand for renewable electricity purchase, looking from the perspective of potential investors in RET projects[45]. They are mentioned in Table 2.3.

The first type of demand that can be distinguished is that of *unlimited purchase obligation*. Through such a support instrument, regulations set an obligation on electricity companies[46] to buy renewable electricity from any generator located in its region of licensed operation offering it for sale. The purchase obligation holds for unlimited amounts of renewable electricity produced by eligible RET plants. The contract length is either not specified (being implicitly considered as unlimited) or it is mentioned as guaranteed for the economic life-time of the RET plant. But this type of demand can be designed as unlimited purchase at industry or company level, or by placing a ceiling (percentage of total business volume) on the purchase obligation either at industry or company level, in order to contain the costs of the support instrument.

The second type of demand takes the form of *limited purchase from individual renewable generation plants*. This can be implemented as a minimum contract length purchase obligation, or as an obligation to buy only a limited volume of electricity from each generation plant - for example the electricity produced in the first 20.000 hours of plant operation. Such an obligation can also be designed as unlimited or limited purchase obligation at industry and/or company level, as under the first mentioned type of demand. Investments under this type of demand are attractive only for the types of developers, technologies and sites where the costs and required profitability can be recovered during the period of governmentally guaranteed contract, respectively from the cash flows for electricity volumes with guaranteed purchase. For technologies using intermittent resources, the demand risks are higher in the case of limited period guaranteed contract. Besides, demand risks increase when contracts are shorter because, since some intermittent resources are also poorly predictable such as wind and small hydropower resources, there is the risk that not sufficient electricity would be produced during the period of guaranteed contract. Consequently, there is the risk that cash flows received on the basis of these contracts cannot cover the investment costs, all variable costs and ensure some minimum levels of profitability in the period available.

In both the case of unlimited and limited governmentally guaranteed purchase type of demand, regulations can also refer to the particularities of contractual relations and to the aspects of price design. When the forms of these two elements of the economic governance structure are regulated in laws approved in the parliament, investors perceive contract and price risks to be lower than when these aspects are left for decision by the government. Further, the risks are perceived even higher when the details on contracts and price design are settled at ministerial level or by subordinated agencies. The lower the administrative level is, where

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[45] When investors cannot rely on any of these four types of demand, the trade of renewable electricity takes place based on the same terms and conditions as electricity from conventional resources. The support system relies then only on policy support mechanisms for price support and/or the overcoming of financing obstacles, and trade arrangements have to be searched in the electricity market.

[46] The obligation can be in principle placed at a certain level in the value chain of electricity production, but the most often so far have been distribution companies.

decisions on these elements are taken, the higher is the risk perception by investors because the level of political stability is considered to decrease with each administrative level downwards. But besides the aspect of authorities involved in the design of contracts and prices, there are also several characteristics of these elements that are important for shaping the perception on economic risk. We discuss these after presenting the remaining two types of demand for renewable electricity.

The third type of demand is very different from the previous ones and refers to quota purchase obligations. It assumes that certain electricity companies or consumers must provide evidence by a certain deadline that they bought or consumed specified volumes of renewable electricity. This instrument can take a very large variety of forms depending on: the level in the value chain of electricity supply where the obligation is placed, whether obligees have the right to comply with the obligation by investing in RET projects or only by means of purchasing from other companies, and whether the obligation can be fulfilled by means of tradable green certificates or only through the purchase of physical streams of electricity. In addition, it is also important how can quota-related expenses be recovered: unlimited common levy fund on all consumers, limited levy fund on all consumers, or only on the customers of each obligee. Table 2.4 makes an overview on the possibilities of enforcing a quota obligation for the purchase of renewable electricity.

Table 2.4 *Possible approaches to enforce a quota obligation for renewable electricity*

Type of quota obligation	The obligated economic actor	Right to own RET plants	Possibility to use tradable green certificates	Recovery of quota-related expenses
Obligation to buy from third parties	Vertically integrated utilities	No	Yes / No	Unlimited levy fund Limited levy fund Own customers
	Generation companies			
	Transmission company			
	Distribution companies			
	Supply companies			Unlimited levy fund Limited levy fund
Obligation to buy or generate	Vertically integrated utilities	Yes	Yes / No	Unlimited levy fund Limited levy fund Own customers
	Transmission company			
	Distribution companies			
	Supply companies		Yes	Unlimited levy-fund Limited levy-fund
	Consumers		Yes	Unlimited levy-fund

The economic risks for non-obligee investors under a quota type of demand depend on the extent to which, certain aspects are addressed in the obligation design. The key design aspects of the forms they can take are mentioned in Table 2.5. Under quota types of demand, regulations do not cover the aspects of contractual relations because obligees need to have the opportunity to look for the lowest cost option of complying with the quota obligation. As regards price design, the aim is in principle to minimise governmental intervention. However, because investors need to have a reference for the assessment of the economic viability and profitability of the plants they intend to build, under some regulatory approaches certain aspects of quota obligation are designed in such a way as to offer acceptable levels of price risks. Hence, under the quota type of demand investors can make assessments regarding only demand and price risks. We suggest that this can be done on the basis of the design variables mentioned in Table 2.5, looking at the interaction of the forms of certain variables, as shown in Table 2.6.

Table 2.5 *Regulatory design variables for quota obligations and possible forms*

Variables in quota obligations design	Possible forms of variables
The obligee	Generators / Grid companies / Suppliers / Consumers
Cost discharge	Unlimited levy fund on all consumers / Limited levy fund on all consumers / Own customers
Right of obligee to own RET plants	Yes / No
Possibility to use green certificates	Yes / No
Price ceiling renewable electricity	Yes / No
Price floor renewable electricity	Yes / No
Penalty for non-compliance obligation	Financial / Licence suspension
Destination funds from financial penalty	To compliant obligees / To RET generators
Life-time of green certificates	1 year / Few years / Unlimited
Frequency of compliance proof	Annual / Every few years / Long
Banking of green certificates	Yes / No
Borrowing of green certificates	Yes / No
Split of obligation in technology bands	Yes / No
Time horizon of quota obligation	Long / Shorter than investment cost recovery

Table 2.6 *Quota design variables for the assessment of demand risks and price risks*

Assessment of demand risks	Assessment of price risks
who are the obligees, and if they have the right to own renewable plants	the cost discharge mechanism; and the presence of price floors and ceilings
which cost-discharge mechanism applies and what is the penalty for non-compliance	(in case of tradable green certificates:) the life-time of certificates and the frequency of compliance proof
(in case of tradable green certificates:) whether banking and borrowing of tradable green certificates is allowed and to what extent	the destination of funds from non-compliance penalties and the time horizon of the obligation
the time horizon of the obligation	the split of the obligation in technological bands

The purchase of renewable electricity and/or green certificates can take place based on spot-market contracts, short terms contracts or long term contracts (see explanations below). The incentives of obligees to engage in any of these types of contracts emerge from the design of the quota obligation.

The fourth type of demand for renewable electricity that can be differentiated is that whereby certain types of electricity companies or consumers agree to buy renewable electricity voluntarily at above-market prices or to buy green certificates. The aspects of contract lengths, electricity volume, and prices depend on buyers' willingness to contribute to renewables support. The issues of demand risks and contract risks merge in this case, and the important thing is the reliability and stability of voluntary demand. When this demand emerges as a result of the application of certain policy support mechanisms, for example indirect fiscal instruments, demand risks can be assessed by looking at the risks embedded in the application of the respective policy mechanism(s). The willingness to pay for the environmental benefits of renewable resources (for both consumers and electricity companies) can fluctuate with the economic cycle and many other factors beyond the prediction of RET investors, which makes this type of demand highly risky unless long term contracts are available.

Types of contracts and contract risks

In Table 2.3, we mentioned contracts as the second important element in the design of economic governance structure for renewable electricity. The literature on power plants investments indicates the importance of securing a long-term and fixed-price electricity purchase contract before the plant is constructed[47]. The shorter the contract and the more vague or unpredictable the contractual price is, the higher contract risks are. But when the perceived demand is high, or assessed as sufficient to justify investment, power plants are also built in conditions of having only a short-term contract, or not having a contract available yet - that is having to relay on the spot exchange in power pools[48]. Such power plants are referred to as 'merchant plants'. The core characteristics of contractual relations that we propose to consider in analysing contract risks in renewable electricity support systems are: contract lengths and contractual pricing methodology.

In terms of length, three types of contracts are generally differentiated in empirical literature for the electricity industry: spot exchange, short-term contracts, and long-term contracts. Short-term contracts are generally considered as shorter than five years, while long terms contract are seen as those that cover a period of at least 10 years. The contracts with a length of five to ten years are viewed both as short contracts and long contracts, depending on the type of investors and market circumstances. Contract risks related to length are accordingly related to investors and market variables.

Short-term contracts and *long-terms contracts* can be the result of a governmentally guaranteed demand for limited or unlimited volume purchase of renewable electricity from each RET plant. But they can also be contracts concluded under a quota obligation, or based on voluntary demand with above market prices. In these last two cases, short-term contracts can sometimes be considered more attractive to the power plant investor, when short-term profit opportunities are assessed as higher than under alternative long-term contracts, while long-term demand is also perceived as reliable. Not only renewable electricity but also green certificates can be traded based on all three types of contracts differentiated. When contracts are guaranteed in a law requiring parliamentary approval they are assessed as posing lower risks of contract breach or non-renewal than when they are regulated by lower rank administrative institutions.

Short-term contracts and long-term contracts can be concluded as having both a financial component and a physical trade component, that is the delivery of renewable electricity. But they can also have only a financial component. Financial market contracts are a special form of contracts used also in the electricity industry. They are financial instruments associated with spot market trade for the physical delivery of electricity and are actually concluded in order to avoid the high volatility that spot market prices can have. Examples of financial market contracts are referred to as hedging contracts (or contracts for difference), and futures contracts (or forward contracts) in the financing literature, because they do not reflect the exact market conditions at the moment of exchange, given by the balance of supply and demand. Hence, financial market contracts play the important role of reducing the economic risks associated with spot exchanges, and contracts that last only for very short-term periods.

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[47] See references in footnote 31.

[48] Spot market trade in the electricity industry assumes that a large number of sellers and buyers are bidding their own curve of demand or supply of electricity. Participants in the spot market provide the market manager with lists of offers for sale or demand for purchase. In these lists they state the price per unit of electricity for each volume of electricity they are ready to buy or sale, and for each time unit when they are willing to trade electricity (Hogan 1993). The spot market manager aggregates all demand and supply curves bided and derives the spot market or the market-clearing price. Spot markets in the electricity industry can be organised between the level of generation and the rest of the levels in the value chain, and are generally referred to as power pools. The level of generation is considered to include all electricity companies involved in generation activities, even if they are active at other levels in the value chain as well. Spot transactions have a double character: they are both physical and financial transactions. This means that certain volumes of electricity are physically traded between partners and that the price of exchange forms an integral part of the spot market trade.

As regards the second characteristic, contractual prices can be settled as fixed prices, or as methodologies for price revision during the contract period. In the last case three approaches of adjustment methodologies can be used: intrinsic, extrinsic or mixed (based on Bernow et al. 1990). In all cases contractual prices are generally linked to inflation index. Intrinsic price-indexing methodologies reflect (predominantly or entirely) the changes in the economic and/or technical conditions of the seller of electricity, that is the RET generator. They can incorporate for example changes in the fuel costs of the generator[49] or in the technical and economic performances of technologies, or in the licensing conditions, or in the avoided emissions such as CO_2, NO_x, SO_2. 'Intrinsic variables' are more easily under the control or decision leverage of RET generators, which means they can take action to minimise the negative impact on contractual prices. Alternatively, intrinsic price methodologies place them at least in the position to predict changes in price components and derive expectations regarding consequences for contractual prices - and further for the economic viability and profitability of projects.

Extrinsic price-indexing methodologies contain mainly variables beyond the control and prediction capability of the renewable power generator and can be very diverse. So far, when regulations tracing the price design allowed them, electricity utilities preferred to link contractual price to the fuel costs of the other electricity sellers in its system (regional fuel costs), or to the fuel costs of their own power plants, or to the average fuel costs of the entire electricity system. Besides, the formula can also incorporate changes in the technical aspects of electricity grid transport operation, or changes in the size of consumer base and their demand volumes and patterns. Under the monopoly organisation of electricity utilities, conventional fuel-costs were often linked to the price for renewable electricity. A frequent approach was that of 'avoided costs' methodology, whereby the electricity company was allowed to pay the RET generator only a price equal to the expenses avoided by not buying from the conventional electricity generators it was normally trading with. In a liberalised system, the indexing methodology is often linked with the average market price of electricity in the power pool or at consumption level. Other examples of possible extrinsic variables are: avoided grid losses[50], grid congestion[51] and fuel diversity benefits[52], technical or economic parameters of the

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[49] From renewable resources, only few incur fuels, costs - biomass, landfill gas, sewage gas and other organic resources or crops. Hydropower may also be subject to resource costs.

[50] Avoided grid losses means a premium that RET generators receive when their plants are located close to the distribution center of electricity. Had the electricity company had to buy the same electricity amounts from generators located at larger distances from the distribution center, requiring transport through high voltage, medium voltage transport network, it would have had to pay a higher price for the same volume of electricity. During grid transport, losses in grids occur (around 8%) which have to be paid anyway. When there is agreement (or governmental regulation) that this price component should be included in the methodology, contractual parties could agree on an estimated average fixed price for this benefit. But when this is left for regular revision, the RET generator has difficulties in predicting its level because it does not have insight into the economic operations of the buyer - from what other generation plants it buys electricity and which are the real losses it avoids. With the liberalisation of electricity industries these aspects can be claimed as confidential business information.

[51] In case of disappearance of central coordination of electricity generation plants and central investment planning specific to the monopoly organisation of electricity industries, grid congestion problems are expected to emerge and aggravate.

[52] In principle, 'diversity' is seen as an intrinsic characteristic of renewables. But its presence in the price methodology can be viewed as an extrinsic variable, because the diversity role that they play in the resource base of each buyer will differ and not depend on the renewable generators directly. Some electricity companies may wish to accommodate more renewables than others in their business and, consequently, may price this characteristic differently. And, as the resource base of renewable generators changes in time, the diversity value may also change. But this does not mean that the diversity value cannot

purchasing company. Extrinsic price indexing attracts higher risks than intrinsic methods. Mixed contractual price methodologies assume a combination of intrinsic and extrinsic variables, the weighting of which needs to be very careful in order to assess contract price risks.

Price design and price risks

Price design is third element in the design of economic governance structure mentioned in Table 2.3. By *price design* we define all regulatory provisions affecting the way the exchange price for renewable electricity is formed, and which are directly related to trade arrangements. Price risks are related to the extent to which, and the forms in which, the following aspects are regulated: how the price for renewable electricity should be calculated, what are the price components to be included, whether the purchase price should take specific levels of not, and who decides on all these price aspects and how (for an analysis of contractual prices and price risks see Comnes et al. 1995: 15-28).

Consequently, we propose to describe the price design given in the regulatory framework based on four characteristics, which can take the following forms:

- price methodology: intrinsic, extrinsic, mixed
- price components: prescribed, suggested, not indicated
- price levels: tariffs, ceilings, floors, no limits indicated
- frequency of updating: no updating; annual; several years
- decision system: directive, consultation, market price.

In the case of voluntary type of demand for renewable electricity or green certificates, there is no prescribed price design that needs to be followed. The exchange takes place only based on the contractual price methodology agreed by buyer(s) and seller(s). But in the cases of governmentally guaranteed unlimited, limited or quota purchase, the regulatory price design traces the borders for the setting of contractual prices between the renewable generators and the economic actor obliged to buy renewable electricity. Regulations can prescribe or suggest the price components and methodology, which buyers and sellers have to take into account. For example they can require that contractual prices should include price components such as avoided grid losses, or environmental benefits of renewables, or resource diversity and security premiums, and so on. They can also go further and specify the entire methodology for the calculation of contractual prices, which can be extrinsic, intrinsic or mixed, as discussed above. But regulations may also make no reference with regard to the price components that should be taken into account. Leaving this entirely to the decision of buyers and sellers, which attracts very high price risks.

Further, price levels could be set in regulations by means of tariffs, maximum prices (ceilings), or minimum prices (floors). They can be set with or without revisions during the envisaged duration of the protective economic governance structure for renewables. But when revisions are made the frequency of change needs to be specified, together with the methodology, decision authority and decision mechanisms for change.

As regards the decision mechanism for these characteristics, the directive type of decision assumes that decisions are taken by authorities unilaterally, without any form of previous consultation with generators of renewable electricity. Decisions on price design might involve consultations with other governmental bodies. But as long as renewable generators do not have a place at the negotiation table, this decision mechanism could be perceived as risky. The level of perceived risk depends on the credibility of political commitment for long-term renewables

be priced at constant levels throughout the time. The way this is priced will depend on environmental regulations and on the own commitment of the company for clean energy.

support. This could be searched in the national energy policy plans, and the governance programs of the political parties represented in public authorities with competencies or leverage on energy matters. But often risk perception increases the more price design is shoved away from parliament adopted laws to governmental decrees and to ministerial orders or decisions. Beside the general perception of increased political risks along this vector, regulations adopted at lower administrative level require often shorter procedures for change, which aggravates the perception of instability. The consultation decision mechanism codifies in the case of price design a decision based on a principle/methodology set in the regulatory framework or adopted by a policy/industry network with specified members, when legal rules delegate them to do so. For renewable generators, having access to the decision-making process with regard to price design could be associated with a lower price risk perception. The market price decision mechanism assumes that most or all aspects of price design are set exclusively by negotiations between the buyer and seller of renewable electricity, or, based on the forces of supply and demand, if trade takes place on the spot market.

Governments may adopt very diverse approaches on price design. At one end of the scale are the tight regulations whereby price components and methodology are prescribed by means of directive from certain public authorities. This can also take the form of tariffs that are directly specified, without explanations on how these were derived or would be changed. At the other end of the scale, there can be very loose regulations whereby no lower or upper price limits are indicated for contractual prices. In some cases, price components or methodologies are vaguely formulated or offered just as suggestions, so as buyers and sellers could have a departure basis for bilateral negotiations. But when even these are missing, price design is entirely left to the market, attracting very high price risks.

We consider that price risks can be assessed in the cases of unlimited and limited types of demand (Table 2.3) by looking at the forms of the five selected characteristics for price design. In the case of quota based economic governance structure, when regulations do not refer directly to these characteristics, price risks could be interpreted by looking at the forms of certain design variables that are specific to quota obligation approaches, and to their interaction as suggested in Table 2.6. The final price risks faced by generators for individual RET plants result from the combined analysis of price design and contractual price methodology.

2.3.4.2 Policy support mechanisms and policy risks

In Table 2.3 we classified policy support mechanisms in three groups: direct price support, mechanisms improving the accessibility of financial resources, and policy support that improves the market position of renewable electricity vis-a-vis conventional electricity. The risks associated with policy support mechanisms can be analysed in terms of:

a) the timing of their application: before the entry of the operation of the power plant; or during part or the entire economic lifetime of the plant;
b) its position in the regulatory hierarchy, that is parliamentary law, governmental decision or ministerial order;
c) the context in which policy support mechanisms are used;
d) the preferred policy style of economic actors in the country.

As regards the timing of their application, one can distinguish policy support mechanisms posing low/no risks because they are implemented in the phase of project preparation or construction. For example, four groups of policy support mechanisms can be considered as posing low risks: third party financing, project aggregation programs, governmental guarantee on project loan, and investment subsidies (see Section 2.3.1). Once these forms of support have been implemented, the profitability or viability of projects during the operation phase is not exposed to risks if the support mechanism is withdrawn. However, for investment subsidies a note should be made, namely that if implementation is scheduled to take place in tranches during the period of plant operation, risks could emerge with regard to the timing and availability of the follow-up tranches.

When the implementation of policy support mechanisms takes place during part or the entire economic lifetime of the plant, risk analysis needs to combine the other three criteria mentioned above. This is the case of production subsidies, fiscal incentives - both direct and indirect, and tradable CO_2 emission permits. Most of the debate so far has been regarding the desirability of fiscal incentives versus production subsidies.

In some countries (potential) renewable energy generators might tend to consider fiscal incentives less desirable than production subsidies (e.g. in Spain), because they are often complex and the eligibility of various types of economic actors/legal status of the company is not always clear. Besides, more public authorities are often involved in the implementation of fiscal incentives and, when regulations are not clear enough or leaving too much scope for the interpretation of fiscal authorities or local agencies, this is perceived to put the economics of RET projects at risk. The perception that production subsidies are less risky than fiscal instruments is strengthened when developers have confidence in the political commitment for renewables' support, and when other environmental policy goals were achieved with reliable production subsidies schemes in the past. Besides, when production subsidies help indirectly other national or local goals such as electricity supply in poorly/no electrified regions or the creation of jobs and industrial basis in economically depressed areas, the risk perception can also improve.

In other countries, fiscal incentives may be viewed by developers as less risky. The argument used is that they cannot be attacked by the lobby of conventional power industry as easily as production subsidies, because they are compatible with market principles and do not distort competition. In some countries, where there is a tradition of operating with fiscal instruments to achieve public goals, the use of fiscal instruments can more easily be accepted as low risk support mechanisms than in countries which are just experimenting with it. Consequently, policy risks of support mechanisms can be perceived differently in different national contexts, and empirical research needs to take into account the forms and the interaction of the analysis criteria mentioned in the introduction.

As regards tradable CO_2 emission permits, the risks for this price component can be analysed in the same way as the price risks in the case of quota obligations based on tradable green certificates. But having in view that renewable technologies compete in this case not only with one another but also with other cheaper options for CO_2 emissions reduction and the expected price volatility, the risks are likely to be perceived as higher than the other policy support mechanisms.

In conclusion, we propose to analyse support systems addressing the economic and financing barriers of RETs in terms of two characteristics: risks and ranges of project profitability. Support systems could create different forms of economic governance structures by imposing various forms of governmentally guaranteed demand and/or stimulating voluntary demand for renewable electricity. But they can also enhance support by means of special policy mechanisms that increase the price support directly, for example by means of subsidies and fiscal instruments or remove the financing barriers. When the option is not to make use of governmentally guaranteed purchase approaches, policy support mechanisms can be used to improve the market position of RET projects compared to conventional fuel power plants. Having in view the two components differentiated in Section 2.3.4 we will refer to national configurations of renewable electricity support for market adoption as 'economic-policy support systems', that can be described and analysed in terms of aggregated economic-policy risks, and ranges of project profitability enabled.

The next section makes a short overview of the main theoretical perspectives taken so far in innovations' diffusion literature and highlights the analytical angle taken in this study for the investigation of renewable electricity technologies' diffusion.

2.4 The analytical perspective taken on technology diffusion. Diffusion patterns

Insights into the state of the art of diffusion research point towards two major weaknesses: diffusion research is overwhelmingly focused on exploring diffusion processes and is less preoccupied with understanding how do these processes start (Miller and Garnsey 2000) and which are the diffusion patterns driving them. Anchored in various disciplines, most theories focus on the question 'how do innovations spread from a cluster of first-movers to wide-range adoption?'. But they are hardly concerned with the questions of 'which are the diffusion patterns in the early adoption period' or 'how do diffusion patterns change in time while diffusion processes continue'. Diffusion accounts do not offer insights into how the features of the economic investment contexts influence early-adopters decision to invest and the particularities of their investment plans.

The large-scale spread of new technologies has been analysed in diffusion research so far across numerous disciplines, by means of a multitude of explanatory factors that can be grouped in four major categories: communication and social network factors, technological factors, institutional factors, and economic factors. Brown (1981) elaborated a typology of perspectives taken in diffusion research, which received wide support in the scientific community. Brown distinguishes between economic-history perspectives, market infrastructure perspectives, adoption perspectives and development perspectives of innovations' diffusion analysis. In addition we also identified a fifth perspective that stands out - that is the economic perspective on diffusion-among-firms. The next subsection explains these perspectives shortly. Section 2.4.2 specifies the approach on diffusion mechanisms that we take in this study, and the indicators with the help of which we choose to monitor the diffusion of renewable electricity technologies.

2.4.1 Perspectives on technology diffusion research

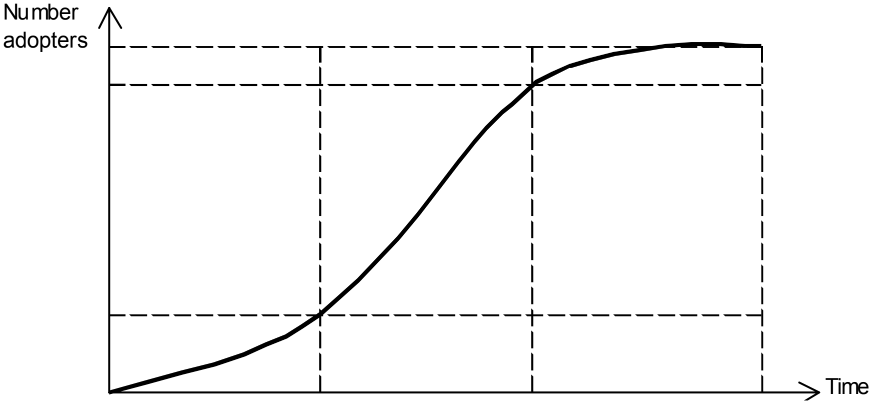
The *economic history perspective* on innovations and diffusion is divided into two lines of research: the 'traditional' and the 'reinterpretation' of economic history. The traditionalists neglect diffusion processes and focus only on the influence of institutional factors and innovations' adoption on economic growth and equilibrium (e.g. Schumpeter 1947). Researchers adopting a 'reinterpretation' approach take a reversed view, looking at how macro-economic conditions influence the diffusion of innovative technologies. But a major shortcoming of this approach is that it operates on the assumption that "once commercial application (of an innovation) is achieved, diffusion readily follows" (Brown 1981: 180). The main interest is on the preconditions of the improvement of cost and efficiency performances of the innovative technologies competing with the incumbent technologies. Another criticism is that only the technical/'inventor entrepreneur' are included in the analysis, while the 'firm entrepreneur' and the 'finance entrepreneur' are completely ignored (Hughes 1976).

A second perspective on innovations' diffusion analysis is referred to as the *market infrastructure perspective*. Researchers taking this perspective consider that the main obstacle for diffusion is the availability of the infrastructure needed for the innovation to reach potential adopters. The mechanism by which diffusion processes take place is the release of infrastructural constraints. An ‘agency of diffusion’ is responsible for the workings of this mechanism. Diffusion agencies can be governmental bodies, private firms or non-profit organisations. Theories in this perspective place emphasis on the institutional context, rather than on the economic actors (or potential adopters), as the key factor in technology diffusion. There are two main areas of interest: a) the processes for the establishment of the diffusion agency(ies) and b) the strategies of the diffusion agency and their consequences for the spatial patterns of diffusion. As regards strategies, four are considered relevant for the spatial diffusion patterns: the development of infrastructure and organisational capabilities; the pricing policy; promotional communication; and market selection and segmentation. The first two are considered to “affect the objective attributes of the innovation, whereas the latter two primarily affect its subjective attributes, that is the beliefs of potential adopters about the objective attributes and/or the potential adopter’s evaluation of them” (Brown 1981: 145).

Hence, this perspective considers to some extent the cultural and cognitive factors affecting adopters’ decision, but the major role in diffusion processes is reserved for the ‘diffusion agency’. It acknowledges however that the results of its strategy can be influenced by intermediary variables such as the characteristics of the innovation promoted, and the level of technical development reached when the diffusion strategy is implemented. But our criticism to this approach is that it considers that when resources are missing - such as financial, human, knowledge - they will be provided by the diffusion agency. The adopter is hence passive in all this process. This approach does not explain how resource barriers are relieved.

Thirdly, the *diffusion-among-firms perspective* has “given a great deal of attention to mathematical models of the diffusion process, particularly to those pertaining to the S-curve of diffusion over time”[53]. The following characteristics are generally considered as influencing diffusion among firms: a) characteristics of the technological innovation (especially profitability, required investment, relative advantage); b) industry characteristics such as competition among firms and the types of previously made technology investments; c) institutional effects such as societal concerns; and d) firm characteristics, such as size, aggressiveness and innovativeness, and level of information about the innovation.

Figure 2.3 *The S-curve of innovations’ adoption in diffusion literature*



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[53] More explanations on this approach can be found in Hurter and Ruberstein (1978) and Linstone and Sahal (1976).

Various diffusion models have been elaborated. Geroski (2000) analysed them and grouped them in four approaches: the endemic model, the probit model, the legitimation and competition model, and the information cascade model. They all try to explain the S-shape diffusion curve from different angles. The endemic model argues that information availability is the key factor that enables and influences the speed of adoption (similar to the adoption perspective - see below). The probit model claims that different firms have different abilities to adopt innovation and are "likely to want to adopt the new technology at different times". The legitimation and competition model explains that the firms' ability and preference for adoption timing explain the increasing part of the S-curve (see Figure 2.3), while competition among firms explains the upper flattening part. Finally, in the information cascade model the main argument is that "the initial choice between different variants of the new technology affect the subsequent diffusion speed of the chosen technology." The last explanation resembles the new economic historians' perspective of looking at diffusion.

Fourthly, the *adoption perspective* on innovations diffusion takes a demand-side oriented analytical approach - that is looking at the adopters' behaviour - and has a dynamic nature. Some also refer to this as the communication perspective (Miller and Garnsey 2000). The founder of this perspective is Hagerstrad (1953; 1967), who conceptualises the "transformation of a population from one with low proportion of adopters to one with a high proportion of adopters by means of information dissemination through media and interpersonal contact" (Brown 1981: 19). This perspective categorises[54] adopters of innovative technologies in two groups: first movers (or entrepreneurs, as viewed by Schumpeter [1947]) and laggards (or imitators). Laggards are seen as risk-adverse economic actors who moreover fail to appreciate the benefits of innovations. The *mechanism* by which diffusion takes place is the improvement of *risk/benefit perceptions* by means of communication and learning among different types of actors (Miller and Garnsey 2000: 449). Only three communication lines were initially considered: media, inter-personal and social network. The resistance of laggards is seen as due to "individual's general propensity to adopt innovation, or his innovativeness. Another important aspect of resistance is the congruence between the innovation and the social, economic and psychological characteristics of the potential adopter" (Brown 1981).

Rogers (1969) looked among others at the role of age, education, achievement, motivation, and entrepreneurship in risk perception reduction and adoption decisions. Others (Rogers and Shoemaker 1971; Foster 1962; 1973) studied the influence of cultural values, indicating that communication style needs to be adjusted to the cultural values for an effective risk perception reduction. Gladwin (1979) looked at the cognitive processes of diffusion agents empirically. In time, new research added more insight into why laggards are resistant. The following factors of influence have been pointed to: "system level explanations" such as social norms of behaviour (Rogers 1983); "reaction of key opinion leaders"; attributes of the innovation itself (Fliegel and Kivlin 1966); as well as economic variables such as the costs of innovations, *the profitability of innovations*, *and individual perceptions on these* (Rogers 1995).

Finally, the *development perspective* is also focused on the demand-side but it has a static nature. It is concerned with two main questions. The first asks: what are the social and economic consequences of innovation diffusion? The second focuses on what is the impact of the level of economic development in countries on innovations' diffusion? Studies under this approach are focused primarily on developing countries. There are two groups of factors viewed as affecting diffusion: a) the availability of infrastructure and resources and b) societal norms and adopters' individual characteristics. Some empirical studies are concerned with

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[54] This perspective is well summarised by Rogers and Shoemaker (1971, "Communication of Innovation: a cross-cultural approach").

issues such as the age, education, and interest in innovations of local people as major determinants of adoption. Other studies discuss the role of infrastructural factors pointing out that "diffusion and entrepreneurship are affected by the availability and distribution of resources or individual access to the means of production and public goods. Examples of resources in this context would include information*; capital, or access to capital through loans*; skill or education; public infrastructure such as transport, electricity, water systems; and public facilities" (Brown 1981: 271). The timing of adoption is seen as being influenced by the following structural factors: a) economic wealth and size of firms, social relations and "location in social, economic and geographic space" (Brown 1981); b) the type and characteristics of the innovation diffusion[55]; c) institutional characteristics; and d) the infrastructure supporting innovations' diffusion or necessary for its use.

Miller and Garnsey (2000) mention other studies (Roy 1994; Agarwal 1983; Havens and Flinn 1975) drawing on the development perspective where the central idea is that "potential adopters in a society have unequal access to the resources for adoption. Of central importance amongst such resources are money, and, or credit". Adopters are hence classified as 'low resource' and 'high resource' economic actors. The prospects for diffusion are seen as related to the divisibility of technology. The more a technology can be divided into small-size units, allowing adoption by lower-resource economic actors, the higher the diffusion rate could be (Gotsch 1972, in Miller and Garnsey 2000). But studies taking the development perspective have the major drawback of being static. There is no diffusion mechanism explaining how the availability of financial resources can be improved. Diffusion depends only on the availability of high resource companies and the divisibility of the technology to be diffused. This implies that some innovations are 'doomed' never to be adopted, for that matter.

2.4.2 The approach on diffusion mechanisms and diffusion patterns taken in the study

Having in view the main variables considered in the five research perspectives on diffusion, the approach to technology diffusion that we choose to take in this study can be characterised as close to the adoption/communication and development perspectives. We are interested in the role played by risks, profitability and motivation in diffusion, which are also of concern in the adoption perspective. But we are also interested in the accessibility of adopters to financial resources, which is of concern under the development perspective.

Renewable electricity technologies require very high investment costs and if loans from traditional financing agents are not available, diffusion could be restricted only to 'high resource' companies. Besides, some types of renewable electricity technologies are 'divisible', such as wind turbines, which could change the patterns of diffusion as compared to technologies with high investment costs and large economies of scale such as those based on biomass resources. But we take a dynamic view compared to the development perspective by considering that the availability of financing resources is not a rigid but a malleable variable, liable to manipulation. Certain types of policy support mechanisms and governmental support by means of various forms of guaranteed purchase of renewable electricity could overcome the barriers of financing accessibility, changing the prospects and patterns of diffusion. In addition, economic actors can find innovative ways of financing, which we aim to investigate by means of the diffusion indicator of 'types of financing schemes'. *The role of project sizes, types of economic actors, and types of financing schemes will be therefore central to our approach on diffusion analysis*.

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[55] A landmark article is "Attributes of Innovations as Factors in Diffusion" 1966 in The American Journal of Sociology, 22 (3) by F.C Fliegel and J.E Kivlin.

As regards risk (perception), profitability and motivation, we are interested in their role in diffusion. But we do not take the view that communication is the core mechanism of diffusion, as the adoption-perspective stream of research does. In our view, the extent and speed of diffusion is a reflection of the availability of financing resources, through the interaction of project developers, financing agents and (eventually) policy makers. Hence, we see *financing resources as the core mechanisms for diffusion*. Besides, we are critical in some regards to the way the three variables are generally discussed. Firstly, the issue of risks is considered only from the point of view of the novelty of technology or product innovativeness. But in practice adopters have to balance technology risks and other types of risks and consequences facing their investment decisions. This includes the risks emerging from the support systems put in place to stimulate their adoption (as defined in Section 2.3.3), when this is applicable. Renewable electricity technologies are capital intensive and have a high degree of asset specificity. They are expensive long-term investments, which require stable markets at least for the period of investment cost recovery. Even assuming that technology perception risks have indeed lowered after some time since adoption started, the presence and level of non-technology risks could keep the ranks of adopters thin.

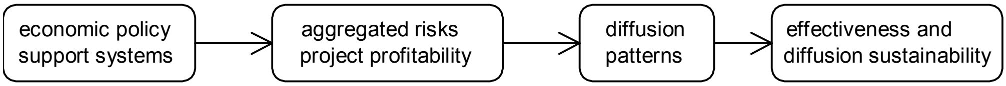
Secondly, the treatment of innovations' profitability is overwhelmingly one-sided in 'communication' diffusion literature, looking only at the subjective side of profitability. Havens and Rogers (1961) argue that "what really determines the rate of adoption of an innovation is the *adopter's perception of profitability and not objective profitability*. There is a vast tradition of social psychology research which indicates the importance of group interaction in determining the selectivity of perception, including perceptions of profitability." While we agree that profitability has a subjective dimension, we argue that economic actors (and also financing agents for that matter) have some border-levels of profitability requirements, which changes in perception and communication cannot push downwards any further. An objective dimension of profitability needs (at least attempted) to be introduced in diffusion analysis. Besides, the profitability factor is seldom understood in the sense we defined it in Section 2.3.3. Quite frequently, profitability is seen as the range of both monetary and non-monetary benefits that the adoption of a new technology offers. We would like to differentiate between monetary profitability and 'drivers to invest', viewing the non-monetary benefits as factors motivating the investment decision.

In conclusion, our analytical angle to technology diffusion draws on the 'adoption perspective' and 'development perspective' taken in current diffusion research literature. But in our view, the main diffusion mechanism is the availability of financing resources. *We propose to monitor diffusion processes by means of the following indicators – that we will refer to as diffusion patterns: types of project developers, types of financing schemes, motivation to invest and project sizes. But in addition to this, we introduce also the indicator of type of technological design*. Renewable electricity technologies have experienced since their conception in the 1970s numerous changes and improvements in technical performances, as learning progressed. These performances have consequences for, and are conditioning in the same time, diffusion processes. But the relationship of technical performances with diffusion processes and individual investors' investment decisions has not been studied so far. In Section 2.6, we discuss the concepts of technological innovativeness and technical improvements with application to renewable electricity technologies. But before that, we present in Section 2.5 the outline of the analytical framework of the study, explaining the main building blocks, the rationality of their selection and their relationships.

2.5 Outline of the analytical framework of the study

In the theory developed in this study, we assume that economic-policy support systems influence the market diffusion patterns of RETs through the characteristics of aggregated economic-policy risks and project profitability. In their turn, diffusion patterns influence the effectiveness of support systems and the extent to which the market diffusion process can be sustained in the long term. Diffusion patterns could be therefore conceptualized as the interface between the characteristics of the economic-policy support systems, the effectiveness of support systems, and the sustainability of market diffusion. We assume that RET diffusion is strongly influenced by considerations of project developers and financing agents regarding the economic-policy risks and the extent of project profitability offered by the support system. But in the same time, cumulated at industry level, diffusion patterns are building blocks of the diffusion process. The analytical framework is represented in Figure 2.4 and concerns the diffusion of individual renewable electricity technologies.

Figure 2.4 *The basic analytical framework of diffusion*



Drawing on the analysis of empirical literature[56] on renewable technologies' market adoption and on technology diffusion theories, we propose a set of five indicators for diffusion patterns. On the one hand, diffusion patterns need to be understood in terms of the types of project developers behind renewable power plants, and the types of financing schemes they use. But, on the other hand, it is necessary to look at diffusion patterns as direct reflections of investment decisions, of which we selected: project size, technological choice, and the drivers to invest. We refer to the technological choice as to the particular design of the renewable energy technology studied and its technical performances with direct relevance to diffusion prospects (see Section 2.6). As regards the drivers to invest we differentiate between three main types of motivations: commercial (solely profit-driven), strategic, and (partly-)self-generation of electricity. The research model assumes that the forms of diffusion patterns have consequences for:

1) the effectiveness of market introduction of renewable technologies in short-medium term; and
2) the prospects to sustain their diffusion in the long-term.

These are the dependent variables of the research model. In Chapter 3, we look at how the risk-profitability investment contexts created by support systems (as differentiated in Figure 2.2) influence the forms of diffusion patterns. After that we discuss the implications of the forms of diffusion patterns for the installed capacity likely to be observed in short-medium term of support system implementation and other diffusion results that together could enable an outlook on diffusion continuation. Conventionally, the diffusion results of different support systems have been expressed in terms of market share increase, or MW installed capacity, or the amount of renewable electricity produced. Some analyses also refer to performance improvements - technical obstacles that have been overcome, innovative designs that have

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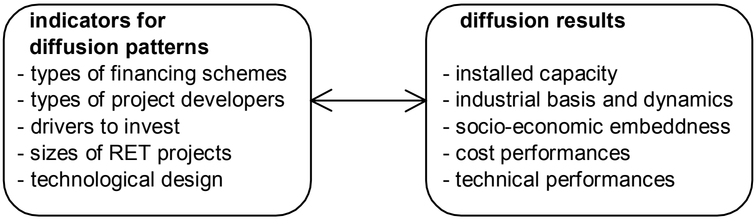
[56] Among others, we used the following studies/articles: Burns 1985; Langniss 1996; Langniss et al. 1998; Farinelli 1994; Wiser and Kahn 1996; Wiser et al. 1997; Wiser 1997; Wilkins 1970; Wagner 1998; Mendis 1997; Lehmann et al. 1998; articles Wind Power Monthly 1994-2000.

been launched, and the extent to which investment costs and production costs have lowered. However, we argue that diffusion continuation prospects can be better understood when the analysis of diffusion results is expanded to the aspects of industrial and socio-economic embeddness supporting developments.

In rough terms, in this study we consider a market diffusion process as sustainable when the techno-economic performances reached, combined with changes in social and business preferences towards the adoption of renewable technologies, do not necessitate anymore the use of economic-policy support systems that isolate RETs from the rest of energy technologies in the market. But, even when these conditions are not fully fulfilled, we view diffusion processes also as sustainable when they have already induced a level of dynamics and embeddness of renewable technologies in the industrial structure and the socio-economic fabric to a point where a total withdrawal of the support system would not be politically desirable. Support systems could be replaced in time given the need to follow the improvements in cost performances of technologies to contain societal costs of diffusion. But when sufficient support pillars have been created through stakeholders in social, economic and industrial sectors along the life cycle of renewable power plants, the political cost of totally abandoning the support system would be higher than continuing the support, provided that the economic and/or financing barriers of renewable technologies have not been overcome yet. This vision on diffusion sustainability rests on a core assumption of the analytical framework, namely that *no other types of obstacles impede diffusion*. For example, the adoption decision of investors is not obstructed by social opposition, environmental, or administrative obstacles. In this study, we look at these other obstacles only empirically, and analyse to what extent and in what circumstances diffusion creates spin-offs leading to observable reductions in their magnitude.

As regards the sustainability of market diffusion processes, there are four indicators of diffusion results that in our view need to be placed at the centre of analysis, in addition to the installed capacity indicator measured as MW installed: cost performances, technical performances, the size of industrial basis and dynamics achieved, and the level of socio-economic embeddness reached. Section 2.7 explains the concept of diffusion sustainability from the perspective of these four indicators, and their relationships. We assume that the prospects for the sustainability market diffusion processes could be underpinned by relating the indicators of diffusion results with the diffusion patterns underlying results. This idea is represented in Figure 2.5, which zooms into the right part of the general research model represented in Figure 2.4. Such an approach would help understand if the diffusion results - even if looking promising and bringing satisfactory results for the time being - are indeed showing a diffusion process that can be sustained in the long-term also.

Figure 2.5 *Indicators for the analysis of the sustainability of market diffusion processes*



The achievement of some progress in the installed capacity increase, cost reductions and improvements in technical and economic performances - the typically analysed diffusion results - are indeed essential signs for the health of an industry and can give an indication of whether developments are on a good track. But they are not sufficient to allow observers understand how long this track is.

It is important not only how much capacity was installed at a certain moment, but also who are the project developers behind investments and which are their reasons to invest. It makes a difference if diffusion is dominated by self-generation projects or by commercial/profit-driven projects. The market potential of RET adoption for self-generation projects could be high under certain circumstances, but it cannot induce the industrial dynamics that investments driven by profit-making interests could unlock. The presence of strategic projects, such as for the introduction of innovative technological designs, or investments based on resource diversity considerations, give an indication of continuity in the interest and attention of economic actors in the respective technology. This gives signals of confidence to the technology manufacturing and service industry and keeps the competitive spirit of other (potential) project developers awaken.

Similarly, the types of financing schemes that have been used to fuel cash into the MW capacity installed at a certain moment are telling their side of the story over the sustainability of diffusion. A market presence of renewable technologies that is supported by the internal financing reserves of developers and by financing schemes that do not recognise RET projects and their cash flows as reliable loan guarantees should rise questions over the continuity of the diffusion process. Internal financing resources are but a limited pocket for the cash-thirsty renewable technologies. A substantial market expansion of renewables requires the involvement of the entire financing community - commercial banks, venture capital investment trusts, saving banks, pension funds, and insurance companies. But for this, a support system is needed that is able to remove sooner or later the barriers of prejudice and scepticism towards renewables, and to respond to the risk and profitability criteria of all types of financing agents that could participate in renewables' diffusion. The acceptance by financing agents of RET power plants as market valuable assets and of renewable electricity as reliable output that can serve as guarantee for the reimbursement of loans is a crucial step towards a sustained long-term RET diffusion. We will refer to this way of financing as 'external financing schemes'.

The financing approach needs, however, to be discussed in close relation to the types of project developers. When a support system attracts mainly investments by small developers, such as private individuals, cooperatives or small private companies, the attitude of the financing community towards RET projects is not likely to change favourably, or at least not at the same speed, as when investments had the financial involvement of large energy companies, industrial groups, regional authorities or governmental agencies. The business culture of domestic financing agents is a core intermediary variable in our research model, which accounts for the dynamics of diffusion patterns in the long-term. But it also accounts to some extent for the types of economic actors that become successful project developers. The dynamics of the different types of project developers in the landscape of RET investments is an important indicator for the fate of the diffusion process.

But even when the involvement of traditional financing agents is secured, if social acceptability and understanding of RET systems is not improved, and if the production of renewable electricity is not able to create some benefits for actors beyond project initiators and financing agents, the long-term diffusion process may be jeopardised. We view the socio-economic embeddness as a process that may occur by means of three channels:

- the creation of jobs: regional/local companies for the manufacturing of components and assembly of generation plants; operation and maintenance jobs; the degree of integration of these activities with the established regional industrial companies; but also the creation of employment at national level can be seen as an indicator of socio-economic

embeddness, suggesting the potential for trade union political lobby in favour of support for renewables;
- long-term and sufficiently substantial direct and indirect economic benefits for the local population, companies and/or public authorities. Such benefits could take the form of direct ownership or partial equity participation in the RET projects located in their vicinity, constant income through land renting, local taxes, or investments in social welfare and economic-industrial development in the region; and
- ownership involvement of individuals and households in RET plants by means of specialised investment funds, creating a wide basis of stakeholders in the social structure.

Increasingly more empirical studies suggest that social opposition for RET power plants' siting lowers when financial benefits accrue also locally, and not only for electricity utilities, large corporations and financing institutions. Diffusion spin-offs might in this way reduce or help overcome social and administrative obstacles. The analysis of the likely types of developers, types of financing schemes, and the potential for installed capacity increase, supports an insight into the extent to which a support system is likely to lead to a socio-economic embeddness capable of exerting political pressure for diffusion continuation, when cost performances do not satisfy market expectations yet.

The study of industrial dynamics and embeddedness reached at a certain moment in time gives insight both into the likely rate of improvements in technical and cost performances and in the potential for political lobby from economic actors operating along the life-cycle of renewable power plants. We consider that the size of the industrial basis and dynamics could be studied by looking at the following indicators:

- the number of companies offering products/services for renewable plants, suggesting both the degree of competitiveness in the industry for the supply of equipment and services to RET project developers (with consequences both for technical and cost performances of RET power plants) and the potential for political lobbying for RETs' sustained diffusion;
- the types of companies involved in industry: this could be either only electricity companies and industrial companies with activities in conventional energy technologies life-cycle, or they can be corporations from a large diversity of industrial sectors, adding to the political leverage of the emergent industry; and
- the degree of specialisation in renewable energy, that is the extent to which companies in the industrial basis have emerged in order to offer products and services solely for RET power plants; when diffusion patterns suggest a large potential of installed capacity increase, industrial companies are more likely to set up companies specialised in RET-related activities than in the case when uncertainty on market size keeps industrial companies horizontally integrated with other types of industrial or commercial activities in order to minimise business risks; we view this indicator as suggestive, on the one hand, for the degree of professionalisation of services and equipment, with positive consequences for the technical and cost performances of RET, and on the other hand for the potential of political lobbying for RETs' sustained diffusion.

The analysis of the size of domestic industrial basis and dynamics a support system is able to induce supports the understanding of the extent to which diffusion processes are likely to be endogenously sustained in the long term. This can be analysed in relation to the indicator of project sizes, types of developers involved in the market, their reasons to invest and the types of financing schemes available. In addition, the observance of project sizes that investors develop helps understand the potential for economies of scale and learning, giving an indication for both the potential of further technical and cost improvements, and the potential of further installed capacity increase under a certain support system.

Further, the choice for technological design of developers with regard to a certain type of RET will be reflected at industry level in the extent to which technical performances satisfy the requirements for integration of the respective technology in the electricity system. Integration refers here both to the grid-connection of renewable power plants and to the stand-alone use of local resources that avoids investments in grid infrastructure expansion in poorly electrified regions. The higher the potential for system integration, the higher the prospects for sustainable diffusion. Hence, we look at technological designs from the perspective of their potential to expand diffusion, overcoming obstacles (of various types) with answers in the technical sphere, and lifting the eventual ceiling on market share increase that could emerge from technical reasons. *The match between the market choice for technological designs and the technical performances required for the respective RET for substantial diffusion in the electricity industry has not been studied so far*. The extent to which investor preferences and diffusion requirements overlap in the technical field is a question that needs to be studied. Chapter 4 integrates the state of the art of a selected set of renewable technologies that will be studied in this study, into our theory of diffusion. The analyses in Chapter 4 serve also as operationalisation of the concept of diffusion-supportive technological designs and technical performances for each type of renewable technology for which diffusion will be empirically analysed in this study.

Consequently, for the analytical framework we select a set of five indicators of diffusion results for the study of sustainability of market diffusion processes in the long term, as represented in Figure 2.5. The sustainability of diffusion represents, together with the effectiveness of the support systems in short-medium term, the dependent variables of the research model. The approach that we take is that theoretical expectations can be formulated regarding the likely forms of diffusion results based on the analysis of the likely diffusion patterns, which in turn are considered to be directly influenced by the risk profitability investment context created by support systems.

In Chapter 3 we explore these relationships, answering theoretically the specific research questions 5, 6 and 7 formulated in Chapter 1. In these theoretical analyses, we make the following *assumptions*:

a) no other types of obstacles impede diffusion (except for the economic and financing ones that support systems address); for example the adoption decision of investors is not obstructed by social opposition, environmental, or administrative obstacles;
b) imported renewable electricity is not eligible for the benefits of the support system;
c) electricity industries are liberalised to the extent that market entry of any type of economic actor willing to engage in electricity generation is possible;
d) investors' decisions to adopt renewable technologies and the details of their investment plans emerge from the design of the support system, with its incentives and disincentives; there is no policy intervention in stimulating or obstructing the market entry of specific types of investors, or specifying the details of their investment decisions, such as regarding sizes of power plants, the choice of technological design and the types of power plants in terms of drivers to invest;
e) renewable electricity from partly-self-generation plants may receive the same benefits from the support system as electricity from commercial projects;
f) there is no governmental limit or requirement on the installed capacity of renewable technology(ies) at industry level of the type of quota purchase obligation (see Table 2.3); while the analyses of diffusion patterns and the prospects of diffusion sustainability remain possible, the effectiveness of support systems takes a different meaning under this type of

economic governance structure, from the MW capacity likely to be installed in short medium terms, to the likelihood that the governmentally imposed quota obligation at industry/company level would be reached during the time horizon envisaged in the support system design; and

g) the support system remains the same over at least a short-medium term period.

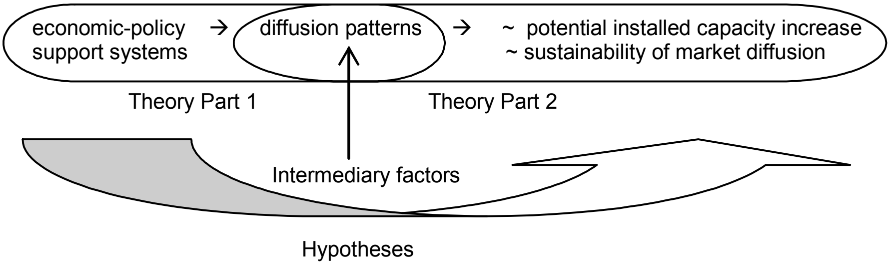
The next subsection presents the organisation of theoretical analysis that underlies the formulation of the hypotheses of the analytical framework.

2.5.1 Organisation of the theoretical analysis

The theoretical analysis consists of two consecutive steps. The first part of the theory regards the impacts of the risk-profitability characteristics of support systems on short-medium term diffusion patterns, analysed for the five selected indicators shown in Figure 2.5. The second part of the theory regards the consequences of diffusion patterns for the capacity increase potential and the sustainability of market diffusion processes. In this second part, we also take into consideration the possible consequences of several intermediary factors on the long-term diffusion patterns, and on the selected indicators for diffusion results. There are three intermediary factors on which we focus:

- the business culture of traditional financing community,
- the level of entrepreneurship of domestic economic actors, and
- the average levels of welfare among domestic, private and corporate economic actors.

Figure 2.6 *The organisation of theoretical analysis*



Both steps are taken in Chapter 3, which are then brought together by formulating hypotheses, as Figure 2.6 suggests. The hypotheses encompass all variables of the model - independent, intermediary and the dependent variables. In the remaining part of this chapter we explain and specify our understanding of the following concepts: technological design, sustainability of market diffusion, technical performances, and cost performances.

2.6 The target of support systems: what types of renewable technologies?

The focus of this study is on the market introduction and diffusion of renewable electricity technologies. This section specifies our definition of technology design, and the renewable technologies to which the analytical framework refers. Next, in the framework of the discussion regarding the concept of sustainable market diffusion processes, Section 2.7 will explain what is the perspective taken in analysing technical performances.

2.6.1 Technological designs of renewable electricity technologies

This sub-section defines the way we look at technology and innovations, since RETs are both complex and new technologies (aside from small hydropower) that are still in the process of performance improvement. Besides, the choice of technological design of investors is one of the diffusion patterns indicators we selected to analyse. In general terms, we differentiate between three levels of defining technologies for the case of electricity generation: technological approaches, principles and designs, as represented in Figure 2.7. We consider that electricity can be generated based on different *technological approaches*, which define the forms of energy underlying electricity generation and the chain of energy transformation processes leading to it. The most conventional technological approach assumes the transformations of the chemical energy embedded in fossil fuel resources in thermal energy, and further in mechanical energy and electric energy. But the same technological approach can be applied for biomass resources, whereby the chemical energy stored in the organic matter is directly used to produce thermal energy. Nuclear technologies use also chemical energy, namely that stored inside the nuclei of atoms (Krause et al. 1992). When the chemical links between atoms' nuclei are broken huge amounts of chemical energy are transformed in thermal energy.

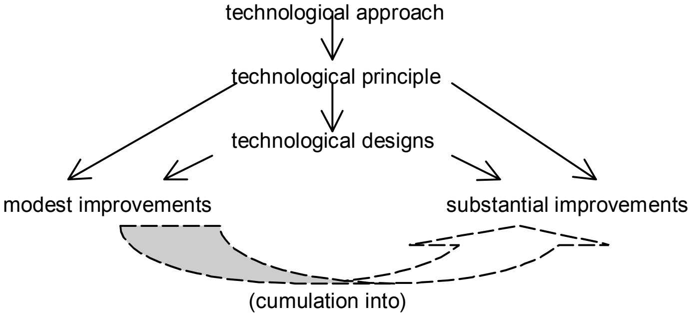
A completely different technological approach assumes the direct transformation of solar energy into chemical energy and afterwards into electrical energy. Likewise, a totally different technological approach assumes the use of kinetic energy of air masses (wind energy) and its transformation in mechanical energy and finally into electrical energy. This differs from the approach of using the potential energy of flowing or stored water (hydropower) to generate electricity.

Each technological approach for electricity generation can rely on more *technological principles* that differ fundamentally on the technical aspects of transforming one form of energy into another. Therefore, a technological principle refers not to what forms of energy undergo conversion but how do these transformation processes take place. For example, the chemical energy stored in fossil fuels is transformed in electrical energy based on other technological principle than that characterising the transformation of the chemical energy inside nuclei into electricity. In the renewables' domain biomass energy can be transformed in electrical energy either through direct burning or by means of biomass transformation into a combustible gas (the gasification process; see Chapter 4) or by means of biomass conversion into an oil that can be used also in combustion for electricity generation at higher efficiency. Likewise, wind energy can be transformed in mechanical energy either based on the vertical axis turbine principle or the horizontal axis turbine principle.

In its turn, a certain technological principle can be developed into more *models or types of design*. In the wind domain, one can find different types of rotor speed designs and blade control designs, which can be combined either with asynchronous or with synchronous generators (see Chapter 4). Technological designs assume technical variations that, while being based on the same technological principle, may result in different technical performances such as efficiency of renewable resource harnessing, or environmental impacts, or use in grid-independent applications (not connected to the grid infrastructure).

As the process of technical improvement continues, new technical characteristics can bring upgradings in the performances of renewable technologies. The literature on *technological innovations* differentiates generally between radical and incremental innovations. Often no definition is given as for the criteria used for categorising various innovations as such (e.g. Loiter and Norberg-Bohm 1999). When definitions are given the perspective on innovativeness varies greatly. Garcia and Calantone (2002) reviewed the use of terms such as radical, really new, incremental and discontinuous innovation in the new product development literature. Differentiating among 15 perspectives[57] of defining innovation in a sample of only 21 studies they observe that "innovativeness is most frequently used as a measure of the degree of newness of an innovation. However, little continuity exists (…) regarding from whose perspective this degree of newness is viewed and what is new". As many as 23 perspectives on newness have been differentiated, ranging as widely as 'new to the world', to 'new technology features' and to 'new uses'.

Figure 2.7 *A performance based perspective on technologies and innovations*[58]



In this study we are not concerned with the degree of novelty the new technological designs or principles incorporate. We are interested in what innovations can bring towards enhanced adoption and long-term continuity of diffusion processes. This translates in an interest regarding the extent to which an innovation, through the technical and/or cost improvements it brings, can contribute to the removal of (some) obstacles facing its adoption, enabling market share increase for the type of energy resource it uses.

Not all improvements are directly relevant or crucial for overcoming the barriers faced by the respective technology. Some innovative characteristics could bring about substantial changes in the performances of a technology, affecting the extent to which the market diffusion of a technology can be successfully sustained in the long term. Others will make only small steps in that direction, while still others can be simple upgradings of previous models without any performance improvements.

We differentiate between innovations with '*substantial' or 'modest' performance improvements* from the perspective of their diffusion expansion potential. But empirical evidence shows that not all available innovations are adopted in the market, and that some innovations have a slower rate of diffusion than others as they pass the journey from laboratory to the market place[59]. Consequently, at any moment in time there might be 'new' innovations and 'old' innovations available simultaneously on the market for potential investors. Our analysis for the indicator of choice of technological design of developers will include both new and existing designs available on the market. This is because our ultimate interest is on the

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[57] Examples of definitions of innovativeness are: the degree of newness of the technology itself, technology superiority compared to incumbent technologies, the newness to market or customers or the adopting firms, the degree of fitness in market or industry where they should compete, etc.

[58] A newly launched technological approach cannot be described in terms of degree of innovativeness with regard to performances because it does not have a predecessor to compare with. As it evolves and it is crystallised into technologies with differentiable technological principles and models, comparison among them becomes possible.

[59] See Figure 2.8 and explanations in Section 2.5.2.

technical performances of the analysed technology at industry level and not whether the chosen designs are new or older.

We define as *technological design with substantial performance improvements* the case when the respective (new or existent) design has performances that eliminate or reduce substantially one or more obstacles with possible answers in the technical sphere, faced by the conventional designs of the technology under study for long-term diffusion expansion. Such obstacles can have a technical nature, or social/administrative acceptance origin, or cost nature. Further, we define as *technological design with modest performance improvements* the case when the respective (new or existent) design has performances which, although reduce or eliminate certain technical drawbacks as compared to the conventional designs, do not contribute to the removal of the obstacles with technical answers nor do they otherwise contribute to substantially improve the prospects for a larger market share increase potential.

The possibility exists however that a series of innovations with modest improvements taking place in time cumulate and create synergies that lead to removal of one or more barriers that impede a substantial and sustained market diffusion. These ideas are represented in Figure 2.7 and they will be operationalized in Chapter 4 for each renewable technology that will be empirically studied. And finally we consider as *conventional* the new technological designs that are performance-neutral from the perspective just mentioned. As regards the existing technological designs they are viewed as 'conventional' when they are the early-developed models that, in spite of their market adoption, present difficulties either for adoption for a wide scale of electricity applications, or for adoption by many types of economic actors or in terms of long-term capacity increase potential.

The framework of diffusion analysis formulated in this study looks at the extent to which support systems favour rather the adoption of technological designs with modest performance improvements from the diffusion expansion perspective, or also the adoption of designs with potential for substantial long-term diffusion impact, by looking which are the market stimuli for the absorption for each type of design.

2.6.2 The life-cycle of renewable technologies and stages considered in the research model

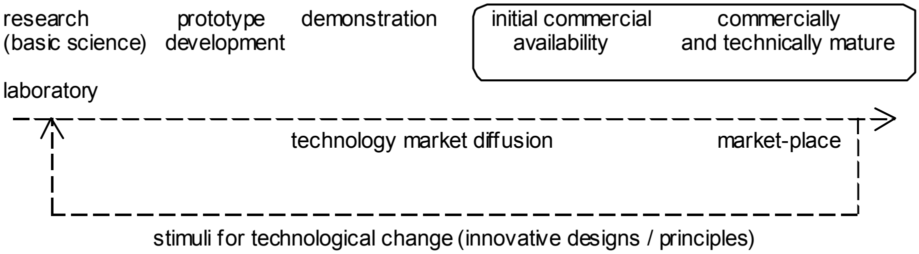
The literature on diffusion and innovations is quite rich in analysing the life-cycle of innovative technologies. Some models of innovative technology diffusion adopt an exclusive linear approach, while others add a dynamic component, which can take different degrees of complexity. In the linear approach, technologies are being transferred from one stage to another until they reach a position of economic competitiveness with the incumbent technologies. Most of these models, though using sometimes different terms, assume a transition that follows the following stages (e.g. Haddad and Jefferiss 1999: 71): research, development, demonstration, initial commercial availability (also referred to as commercial maturity in niche markets), and competitiveness with incumbent technologies (also referred to as commercial and technical maturity).

Mixed models are more diverse, depending on the theoretical set-up in which they are rooted - evolutionary theory, sociology, or historical economics. A mixed approach on technological change is taken for example by Grubler et al. (1999: 249) who differentiate among six "stylized stages of technological development": "invention (fundamental and applied research), innovation (development and demonstration projects), niche market commercialization, pervasive diffusion, saturation and senescence". According to them, saturation occurs when economies of scale and learning are exhausted and improvement potentials are terminated. In this case, senescence is the next last step in a technology's life cycle, "when a better (new) competitor takes market share or redefines performance requirements". But technologies are also viewed as being simultaneously in more stages. The way they view this simultaneosity, however, is through the addition of changes *to components or parts of a technology*, changing either form or performances or both[60].

We would like to propose a way of looking at the processes of technological *diffusion and change* that considers that:

- technologies go through clearly differentiable stages in their journey from the form of idea to that of market presence - the liner model-component; and that
- technologies are being simultaneously in more stages of development, whereby innovations with modest or substantial performance improvements are added to the technological principles or designs (see above subsection) placed in more advanced stages on the journey to the market-place.

Figure 2.8 *Development stages of a renewables-based technological approach targeted by the support systems - as proposed for analysis under the research model*



Consequently, we endorse the view that "the diffusion of technology is inextricably interwoven with its development" (Sahal 1981), but we adopt a mixed perspective on technological *diffusion and change*. An already consecrated technological principle or design can be the host of innovations with modest or substantial performance improvements in the sense referred to by Grubler et al. (2000). Innovations will go then through the same entire sequence of stages for market diffusion, from laboratory through the market place, as represented in Figure 2.8.

Based on these considerations, the 'target' of the support systems that will be analysed based on the proposed analytical framework is formed by the renewable technologies situated in the stages of 'project demonstration' or 'initial commercial availability', attempting to become 'technically and commercially mature'. Support systems will be analysed in terms of their capacity to bring on the market technological designs or principle designs of the analysed RET that are in one of these two stages. But we also look at them in terms of potential to launch the needed market signals and stimulate an industrial environment where new designs and principles could be expected to emerge in the research and development stages. The extent to which innovations have the potential to overcome diffusion obstacles and expand the potential for technology diffusion takes a central position in the range of our research interests.

The concepts of technical and commercial maturity need a clear definition, not only because of their position of 'technology destination', which needs to be specified as clearly as possible, but also because these terms have been widely used and seldom defined in renewables diffusion studies. In our understanding, a technology is considered technically

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[60] The emphasis is made by us. The way they formulate it is that "mature, existing technologies can be the host for all stages of technological change simultaneously". To illustrate this, they use the example of the automobile which continues to be the host of sometimes radical innovations, such as the intelligent transportation systems. This innovation brings new functions to the vehicle' performances, but also improves older performances, such as fuel consumption and environmental impacts.

mature when there are no remaining obstacles whose answers could lie in the technical sphere - therefore, from technical point of view, market diffusion processes can be sustained. But technical innovations can also result in cost competitiveness. A technology will be considered commercially mature when it reaches cost-competitiveness with competing conventional technologies.

In conclusion, we differentiate renewable electricity technologies based on types of resources used. Renewable technologies using the same type of primary resource, such as biomass can be engineered based on more than one technical principle, which in their turn can be diversified in more types of technological designs. Innovation can be brought to both technological principles and technological designs. But the analysis framework proposed in this research does not have the intention to focus on the processes underlying the emergence of innovations and technological change. The main focus is on technology diffusion, that is, to look at the extent to which the support systems for renewables are able to take renewable technologies into the market-place and to ensure a sustainable market diffusion process. However, due to the way its dynamic aspects are conceived, the analytical framework does touch, indirectly, upon the aspect of continuity of the innovation creation and market adoption processes, and consequently continuity in technological change. The analytical framework focuses though on the market adoption and diffusion of technological designs that attempt the journey between the demonstration phase to technical-commercial maturity stage.

Empirically we will study in this book the market introduction and diffusion of small hydropower technology, wind technology, and biomass electricity technology. But the same research model can be used for electricity technologies such as those based on solar energy, wave power and ocean energy or other renewable resources, once they are considered to have provided evidence of technical feasibility and reliability in the demonstration phase.

In the next section we take a closer look at the dependent variables of the research model and we address the second research question of the study: “What are the preconditions for sustainable diffusion processes of renewable electricity technologies?” We define the concept of sustainable diffusion and look at the circumstances that would enable the continuity of diffusion processes in the long term.

2.7 The effectiveness of support systems and sustainability of diffusion processes

Our research model takes two aspects of technology market diffusion as the dependent variables. The first is *the potential increase in the installed capacity* of a certain renewable electricity technology that the economic-policy support system studied is able to induce on a medium-term time-span. The second is the *sustainability of market diffusion processes* on a long-time span. In this respect, we are interested to understand if - after the predicted level of installed capacity has been reached, market diffusion processes can be expected to continue in the long-term too, allowing the power capacity based on that RET to further increase. The prospects for long term continuity of diffusion can be assessed by looking at: the cost performances in relation to the remaining technically feasible resource potential, technical performances of technologies, and the features of the socio-economic-industrial context for investments. The assumption is that no other obstacles face technology diffusion, except for the economic and financing obstacles, as well as those obstacles with answers in the technical sphere reflected in the level of technical performances.

The two dependent variables differ in two respects: firstly, in terms of their time dimension, and second in terms of their nature. These differences are explained in this order in the following two sections. Besides, Section 2.7.2 also discusses how the sustainability of diffusion processes can be defined and analysed in more detail given the selected indicators of diffusion results (see Section 2.4).

2.7.1 The time dimension of dependent variables

The two dependent variables regard different time intervals along the time-dimension of a support system, as shown in the Figure 2.9. The potential for installed capacity increase is studied for a short-medium time-span. We operationalise this as a period of five to ten years of stability in the support system used. The commissioning of renewables-based plants takes time and this depends on the particularities of technologies - which can have different construction times. But it also depends on the complexity of administrative and social approval procedures - which can vary in different countries and for different technologies. Therefore, even if in some countries with smoother approval procedures and for certain technologies, substantial levels of installed capacity increase can already be observed after a short time period, say 5 years, we choose to extend the discussion on the potential market penetration for a medium-time span too, that we defined as up to 10 years, in order to be able to accommodate more particular cases.

Although from policy makers viewpoint a 10 year period of policy stability might be viewed as a long period, we stress that the analytical approach taken in this study is that of potential investors. Both economic actors and financing agents need time to understand the details of the support system, to gain confidence in the political commitment behind it, and eventually to observe developments made by other project developers before deciding to invest. Because of all these reasons, we consider appropriate to operationalise the term of short-medium time span as a 5-10 year period and assume policy stability during a period in this range or close to this, in order to study the effectiveness of support systems. By 'long-term' diffusion sustainability we mean the prospects that diffusion processes would continue after more than ten years since the operation of the support systems. Continuation of diffusion could take place based on the same support system as initially implemented, or based on a new support system with a different risk-profitability profile - reflecting the maturation of technology and industry, or outside a support system when the economic and financing barriers have been overcome.

The short-medium time period since the application of the support system is marked in the Figure 2.9 below as moment T_1. Depending on the diffusion patterns underlying the installed capacity increase, it is possible that at the same moment T_1 the process of market diffusion can already be characterised as sustainable (See Section 2.7.2)[61]. But it is also possible that the risk-profitability characteristics of the support system do not favour the market adoption of RET through diffusion patterns able to facilitate the achievement of the diffusion continuity preconditions at T_1. In this case, two scenarios emerge.

A negative scenario would be when the forms of diffusion patterns and the slow rate of their dynamics cannot be expected to lead to sustainability in diffusion unless changes are being performed in the economic-policy support system. Here it is possible that factors exogenous to our research model also play a role. A positive scenario would be when market diffusion patterns are under (relatively) intensive dynamics, taking new forms that are able to contribute to the achievement of the preconditions for sustainability at a certain future moment

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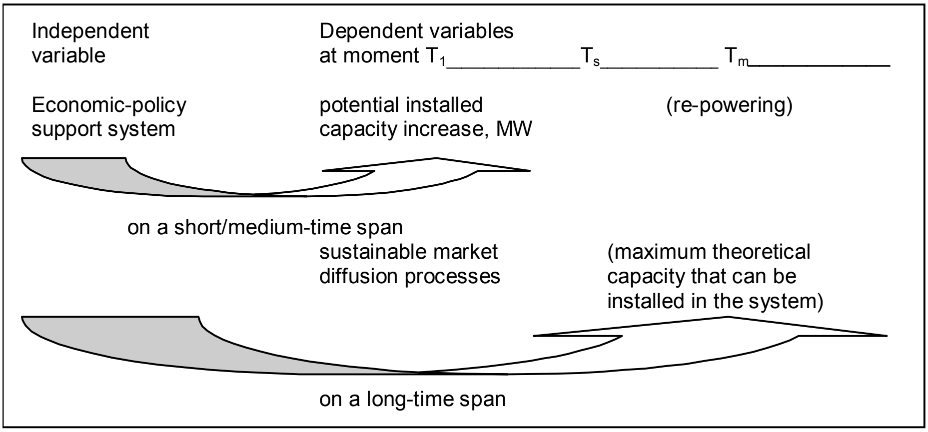
[61] Actually, if the support system is very powerful in attracting investments and if market dynamics are very intense, it is possible that a framework for sustainable diffusion occurs even before T_1. However, both in theoretical discussions and in empirical research it is more convenient to refer to, respectively to measure, the indicators for sustainable diffusion preconditions at the same moment when the increase in installed capacity is measured, that is T_1.

that can be referred to at T_s, without operating changes in the support system. In our more in-depth theoretical analysis in Chapter 3 we will look at the extent to which diffusion patterns can change endogenously towards the most favourable forms, or can also be affected or favoured by exogenous factors.

Figure 2.9 *The time dimensions of the dependent variables of the research model*



The moment T_s can occur somewhere between T_1 and T_m, where the index "m" stands for the maximum capacity that can be installed using the respective RET, defined by the specific fundamental barriers of the technology[62]. Improvements in technical performances could push T_m further by making possible the technical exploitation of available sites or resources that in the past could not be used with the technology available at that time.

But it is also possible that T_s occurs after T_m. From that time further, the sustainability of market diffusion processes does not refer anymore to the continuity of installed capacity increase but to the "re-powering" of existing RET plants, that is the replacement of the electricity plants whose economic life has ended with new plants using the same technology. If at T_m the sustainability conditions have not been met (see Section 2.7.2), the support system needs to be maintained to avoid the future loss of market share of that technology and the disruption of market diffusion processes. This way, one can imagine that for a very expensive technology, two generations of repowering, or even more, may be needed to bring that RET to the expected cost performances. The issue of cost performances of renewables based electricity technologies is a complex topic in itself, which we address in Section 2.8.

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[62] We refer to fundamental barriers as to the barriers of diffusion that no policy intervention or institutional conditions can push further in order to increase the potential for installed capacity increase. For example in a country wind energy resources may be large, but because of constraints related to siting, the potential that can be exploited is much smaller than the technically available potential. For example resources might be located in regions covered widely by infrastructure works, such as roads and rail networks, industrial production sites, and densely populated residential areas. However, within the frame of the fundamental barriers, the technically available potential can be lifted by means of technical improvements that allow the (technical and/or economic) exploitation of available sites where wind speeds could be, at the time of analysis, too low or too high or too erratic for the ability of state of the art technology to harness for electricity production.

2.7.2 The nature of dependent variables and approaches in the study of market diffusion sustainability

The two dependent variables differ in nature, through the fact the first one is in the form of a (tangible) diffusion result that can be directly measured, in MW, while the second variable is rather a characteristic of a process. Theoretical expectations can be straight-forwardly tested when they regard a measurable variable, such as the installed capacity. However, the testing of theoretical expectations regarding the characteristic of a process requires the intercession of a set of indicators. In Section 2.5 we argued that the discussion regarding sustainability of market diffusion processes needs to involve four indicators of diffusion results: cost performances, technical performances, the size of industrial basis and dynamics achieved, and the level of socio-economic embeddness reached. The last two indicators represent the level of national technology embeddness. The perspectives for the discussion of diffusion sustainability and their relationships with the support system are represented in Figure 2.10.

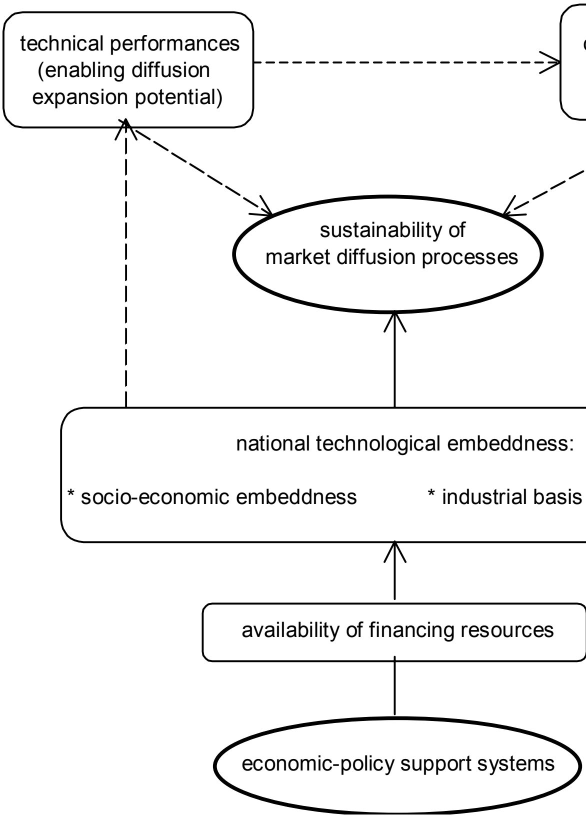
We consider a market diffusion process as sustainable when the cost performances of the supported technology, combined with changes in social and business preferences towards investments in renewable energy resources, do not necessitate anymore the use of an economic-policy support system that isolates the respective RET from the rest of generation technologies in the electricity market. When production costs per kWh for the technically exploitable resources reached competitiveness with production costs of competing technologies or resources, the economic obstacle has been overcome and the support system for the respective RET can be dismantled. When a large-scale change in the perception of financing agents with regard to renewables takes place, leading to confidence in investments beyond the economic protection of support instruments such as governmentally guaranteed purchase of renewable electricity, the financing obstacle can also be considered as overcome. Assuming that no obstacles such as administrative, social, and environmental siting constraints are facing RET adoption, long-term diffusion could eventually only be limited by the technical performances of the respective technology.

Innovation literature suggests that technical performances can improve by means of one or more mechanisms:

- governmental R&D and innovation policy;
- industry co-operation in innovation networks;
- the entrepreneurship of manufacturers or users of technology, or other actors such as research and academia agents, and economic actors active in other fields whose interests are expanding in the field of the renewable technology;
- learning by doing at the level of manufacturers or technology users.

The last three mentioned mechanisms are more likely to be functional and successful when the attractiveness of economic policy support systems to invest increases. The lower the economic-policy risks of the support system and the higher its profitability for RET power plants, the higher are the chances for technical improvements. But as discussed in Section 2.6.1 some technical improvements are neutral from the standpoint of the diffusion expansion potential of the respective technology. Others, however, are able to bring modest or substantial increases in the potential of the renewable technology to expand its market share in the electricity system. The more technological designs are patented and adopted into the market, that are able to eliminate the diffusion obstacles which bear answers in the technical sphere, the more the potential for diffusion expansion in the electricity system increases for the respective RET.

Figure 2.10 *Factors influencing the sustainability of market diffusion processes*



The relationships between technical performances, national technological embeddness, and cost performances were represented in Figure 2.10 with dashed lines because we do not formulate hypotheses between economic-policy support systems, on the one hand and the technical-cost performances, on the other hand. Hypotheses will only be formulated regarding the risk-profitability context of support systems and the market choice for technological design of project developers and financing agents. Aggregated at industry level, their choice defines the extent to which the technical performances of the respective technology are able to contribute to the expansion of its diffusion potential in the electricity system. As regards cost performances, we also do not formulate hypotheses, because as we explain in the next Section 2.8, in the case of RETs they are strongly influenced by factors outside the scope of governmental influence, such as by means of support systems.

The issues of technical and cost performances are discussed only empirically, in relation to the resource potential remaining available for exploitation in the long-term (or after the time of our empirical analysis T_1 - see Section 2.7.1). The relationship between cost performances, resource availability and technical performances with regard to diffusion expansion potential is very tight, resource-specific and country-specific. For different types of resources, different types of technical performances might be needed to enable the expansion of installed capacity. The national potential of any renewable resource can be roughly divided into:

1) not technically feasible;
2) technically feasible but not economically feasible given the applicable support system;
3) both technically and economically feasible - given the support system; and

4) cost-competitive without any form of support instruments.

The improvement in technical performances transfers the nationally available resources from the first mentioned category towards the later. Improvements in cost performances come also from the generally discussed mechanisms of economies of scale and economies of learning in technology manufacturing and use. However, cost performances of renewable electricity technologies are affected by many factors. They are discussed in Section 2.8, which explains that cost reductions may not always lead to cost competitiveness. Besides, not the entire available resource base might be exploitable at production costs that are competitive with the alternative generation technologies. A certain part of the potential could remain locked in the 'not-economically feasible' category unless support systems are put in place. However, even when cost performances do not enable at all, or do not enable for the entire available potential the cost-competitive exploitation of a renewable resource, we view diffusion processes also as sustainable when they already induced a level of dynamics and embeddness of technology in the industrial and socio-economic structure to a point where a total withdrawal of the support system would not be politically desirable.

In Section 2.5 presenting the research model, we pointed out three channels of socio-economic embeddness and three indicators for industrial basis and dynamics. The channels of socio-economic embeddness will be discussed both theoretically and empirically in terms of local and national socio-economic benefits by means of the indicators mentioned in Table 2.7. Both socio-economic and industrial embeddness influence the prospects for sustainable diffusion processes of RET. But they do so in complementary ways, playing also potentially different roles in different diffusion stages.

In the phase of market introduction, intensive industrial dynamics and a large expansion of the industrial basis are decisive for the fate of diffusion. The support system needs to attract in this stage a high number of companies offering products/services for RET plants, coming from a wide diversity of industrial and economic backgrounds. It also needs to create expectations for a large RET market so as to increase the specialisation of companies entering the renewable energy business. Such developments are essential to enable and speed up the rate of improvements in technical and cost performances. They are best stimulated by large size investments of industrial corporations and energy utilities, which are more likely to have access to financial resources for large RET power plants. Further, technical and cost improvements of technology are more likely to lead to an increase in diversity in the types of project developers, so as to include direct local ownership, and investments by individuals and small developers nation-wide. As a market analyst observed, by investing small, the renewable power industry "will be able to establish local economic and political roots, which have been key to the industry's entry into new markets in the last decade." (WPM June 1999: 30).

Beside improving social acceptance and local administrative approval, small developer ownership is more likely to be long-term committed by mixed motivations to invest, such as profit-making and self-generation opportunities, the attractiveness of environmentally friendly investments or the preference for local business opportunities. This complements the often strongly commercial reasons of industrial corporations and energy utilities to invest in RET generation plants, increasing the potential for political lobby that can be exerted by them and by the increasingly numerous, highly specialised and background-diverse companies with activities in the life-cycle of RET.

But the increase in diversity of economic actors interested to invest also brings about an intensification of competition among them to get site approval in good resource locations. This could generate a series of local benefits, as project developers compete to offer attractive land rents and local investments. Besides, the local taxes from renewable electricity generation activities as well as all secondary industrial activities they generate also strengthen the local socio-economic benefits. The local population, local companies and administrative bodies strengthen the basis of stakeholders that could lobby for RET support systems' maintenance. However, unless local administration authorities are sufficiently solidaire and mobilised, local stakeholders are less likely to be influential or even able to reach the political echelons, in contrast to large corporations and energy utilities that often have long established lobbying representatives.

Table 2.7 *Preconditions of sustainable market diffusion processes and empirical indicators*

Indicators for the socio-economic and industrial context of RET diffusion	
Socio-economic benefits	
Local	Direct: ownership
	Indirect: more attractive benefits than usual from ~ land rents; ~ local taxes; or for ~ local economic or social welfare investments
	Indirect ~ local employment
National	Ownership individuals (shares)
	Employment in industry
Industrial basis and dynamics	
Number companies offering products / services for renewable plants	
Types of companies involved in industry	
Degree of specialisation in renewables	

The enlargement of the national industrial basis is therefore crucial in the stage of market introduction in order to realise the necessary improvements in cost and technical performances. But in the same time, it contributes to the consolidation of socio-economic benefits. In the later stages of diffusion, as the potential for cost and technical improvements decreases, its main role in the sustainability of diffusion takes a shift. The size, degree of specialisation and types of companies involved in the industrial basis become important indicators for the potential role of the national RET industry in exerting political lobby towards the maintenance of support systems for diffusion continuation.

When companies choose to specialise only in RET related activities, their interest in the industry is very high. The termination of renewables' governmental support in a phase when the economic and financing obstacles have not been overcome yet assumes the termination of those companies' economic activities. In contrast, when industrial activities in RETs' life cycle are developed by industrial companies that do no take renewable technologies as core-business but only operate by means of small departments (that eventually are also concerned with other types of industrial activities) the effervescence of their political lobby will presumably take lower scales than in the first case.

The types of companies that become involved in RET activities (either by means of specialised RET-only subsidiaries or just departments for non-core activities) are also important for the potential of political lobby. The more diverse the industrial background of companies in the RET industry is, the higher their lobby potential could be. When the support system is not very attractive to invest and does not promise a large enough market for RET, mostly industrial companies with activities in conventional energy technologies will be interested to invest in RET products and services. They have the closest technology expertise and are more likely to attempt the expansion of business activities towards an innovative technological sector. Such companies could have in certain national contexts a strong influence at governmental level, especially through links with energy utilities. However, a large presence of corporations from a diversity of industrial sectors is likely to be more politically influential in favour of RET, when the support system has been sufficiently attractive to gain their business interest. The higher the diversity in their industrial background, the higher the chances that their lobby representatives could exert a positive influence on politicians to maintain or improve RET support system.

The number of companies and the national employment in RET industry, chosen also as indicators for diffusion results, suggest the size of the industry interest, and likelihood that meaningful political lobbying would be attempted at all when renewables' support is threatened with withdrawal.

In Figure 2.10 we represented the relationships between support systems, national technology embeddness and the sustainability of diffusion processes with continuous arrows, because we formulate (in Chapter 3) theoretical expectations on them. In the analytical framework we assume that the risk-profitability characteristics of support systems have systematic impacts on diffusion patterns. In their turn, they have discernable impacts on the socio-economic benefits emerging from diffusion and the size and dynamics of the national industrial basis.

As mentioned in Section 2.4.2, we consider the availability of finance as the motor putting into motion the diffusion process and strongly influencing the dynamics of diffusion patterns. As the financing barrier is lifted, the industrial basis and dynamics grow, the socio-economic benefits expand and increase, cost and technical performances improve and the chances for effective political influence towards sustained price support and sustained diffusion also grow. If external financing schemes do not become available, diffusion could continue but only as long as the involved types of developers could internally finance capacity expansion. The socio-economic-industrial context of diffusion could eventually become sufficiently politically influential, if many large financially strong developers contribute to large-scale investments. In this case, diffusion would also have good prospects of continuity when (in the absence of political initiative) political pressure is successful in ensuring the maintenance of financial support for a larger scale exploitation of available renewable potential. Diffusion would then only be confronted with the eventually remaining technical obstacles, when technical performances do not allow yet the exploitation of the available potential or its grid integration.

All these aspects of diffusion results influence the prospects for sustainability of market diffusion processes in the long-term, which is considered as the second dependent variable in our analytical framework. Consequently, as represented in Figure 2.10, in order to understand if a process of market diffusion can be characterised by potential continuity, it is necessary to look at diffusion from the following three perspectives:

- technical performances in relation to available resource potential;
- cost performances in relation to available resource potential;
- technology embeddness in the national socio-economic and industrial structure.

The three perspectives of defining the sustainability of market diffusion processes can also be seen as possible routes to arrive at a sustainable diffusion of RET. Some governments could embrace the ideology that improvements in technical performances are sufficient to bring production costs to competitiveness and ensure this way the long-term diffusion of RETs. These governments will focus their financial support through R&D and innovation policies, viewing market adoption programs as secondary or devoid of importance[63]. In other countries the sustainability of market diffusion processes could be attempted directly through the competitiveness route, placing the emphasis on the lowest costs for market adopted technology

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[63] For example in the Netherlands the government considered in the 1980s and early 1990s that the most appropriate way to support wind technology is by subsidising research and development activities.

designs. In this case, it is highly likely that improvements in technical and cost performances will be mostly ‘imported’ through the influx of foreign technology manufacturers on the domestic market[64].

When the political goal underlying the design of support systems is not only to overcome the financing and economic barriers of RET, but also to create a domestic manufacturing industry[65], developments could take the more durable (main) route of national technological embeddness. Technical and cost performance improvements are then viewed as spin-offs from national technology developments. The market entry of foreign companies would increase the competitive pressure on domestic manufacturers and service suppliers, and developments would then combine the above-mentioned routes. In practice, it is likely to observe a simultaneous political engagement along all these routes in the majority of countries.

In conclusion, we attempt to understand what kind of relations can be distinguished, if any, between the types of economic-policy support systems put in place and the prospects for sustainability in market diffusion processes. However, we acknowledge beforehand that the fate of market diffusion processes is not only influenced by economic-policy support systems. Policy interventions along other dimensions also contribute to this, by creating synergies in registering certain diffusion results. For example the governmental policy in the field of R&D and innovation could have a heavy weight in the progress achieved in overcoming the technical barriers, or other types of barriers whose removal might be helped by a technical solution. Various other factors that are outside the policy scope for renewables, such as international developments in fossil fuel prices, environmental constraints, international commitments, or the general evolution of the economy, can also contribute to the political decision to sustain the financial support of renewable resources. Therefore, we plan to:

- look in the theoretical part at the possible relations between the attractiveness of economic-policy support systems and the indicators for socio-economic and industrial embeddness of RET summarised in Table 2.8, given the assumptions formulated in Section 2.5;
- look only empirically at the technical and cost performances achieved under the support systems studied, which need to be analysed in relations to the resource potential nationally available[66]; and
- look also empirically at the spin-offs induced by diffusion in terms of other types of obstacles (theoretically ignored) - the way non-technical obstacles changed in time and which are the obstacles impeding the working of economic-policy support systems.

In Section 2.8 we address the third research question of the study: “To what extent can support systems influence the cost-performances of renewable electricity technologies?”.

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[64] This was for example the case of the United Kingdom where the support system for wind technology was characterised by a strong pressure to drive technology costs down (see Chapter 13).

[65] This approach was taken in Spain for the support of national wind technology (see Chapter 6).

[66] The empirical discussion on technical performances will be based on the empirical findings with regard to developers’ technological choice, which constitutes one of the five indicators of diffusion patterns. No theoretical expectations are formulated with regard to cost performances, except for general trends for cost-categories, which are discussed in Section 2.8.

2.8 Considerations on the cost performances of renewable electricity technologies

Many policy and market studies address the issue of the consequences of using different types of support instruments or combinations of them for the chances or the rate of cost performances improvement. More recently, there is the debate in the scientific and policy communities related to which of the three major policy choices politically contemplated, are able to bring more substantial and faster cost reductions: feed-in tariffs, competitive tenders or quota models (see Section 2.3.1.7). We argue in this section that these discussions are misguiding. Their underlying assumption is that policy choice is everything. While we agree that ‘policy matters’, we argue that policy has a limited potential of influence when it comes to cost performances. This potential can best be used in the first period of diffusion. Taking a long term perspective for the cost performances of RET, there might come a time in the diffusion processes when production costs cannot be lowered any further. They could even start to increase and there is little policy intervention could do to alter this evolution.

The production costs of renewable electricity, expressed as costs/kWh, are the reference generally taken by politicians, public authorities and policy analysis when comparing the progress in cost performances of renewable electricity technologies with that of conventional technologies or with the market price for electricity. We consider that taking production costs as reference for technology progress does not do justice to renewable technologies. Production costs of renewable electricity are influenced by many factors, of which only some are liable for influence by governmental intervention.

Governmental influence can be exerted directly or indirectly - through the market and industrial developments stimulated by support systems. There could also be intentional and unintentional effects of governmental regulations. But some factors that are strongly affecting production costs are not liable for manipulation. They depend on resource availability, quality and distribution, being country specific and rigid variables. Similarly, the total investment costs per kW installed is not an appropriate indicator of cost performances because they incorporate cost variables that are beyond the direct control of manufacturers and owners of RET plants. For a better understanding of production costs anatomy we propose to distinguish between four categories of factors influencing the production costs per kWh of renewable plants, as shown In Table 2.8.

Table 2.8 *Categories of factors influencing production costs and evolution during diffusion*

Categories of factors affecting production costs per kWh	at market introduction	after medium / long term diffusion	possible govern-mental influence
1. technology specific	high	decreasing	direct / indirect
2. technology complementary (influenced by resource location)	low / modest	increasing	no
3. context induced cost factors → financing / trade factors → project life-cycle stages → administrative(-social) consent / tax expenses	 high high uncertain	 possibly decreasing decreasing possibly sinuous evolution	 direct indirect direct / indirect
4. resource quality & availability	high	decreasing quality; increasing costs	no
overall production costs / kWh	high values	very wide range	limited

2.8.1 Categories of factors affecting production costs

Firstly, there is the category of *technology specific* factors, which includes technology costs per kW based on factory price, and technical characteristics that influence electricity generation such as availability and efficiency. As technological performances improve, competition intensifies, and economies of scale and learning are activated in the sector of renewable technology manufacturing, the weight of this component in production costs gradually decreases during diffusion.

Secondly, *technology complementary* costs refer to infrastructure, civil works, construction, grid connection, mechanical and electrical equipment costs. The equipment and services in this cost-category are generally conventional, and can be seen as accessories to renewable electricity technologies. They can be provided in principle by any company in related (long-established) industrial sectors, not necessarily the new sector of renewable technology manufacturing. But the location and accessibility of resources have a very large influence on the weight of this cost-category. Besides, for different types of renewable technologies, this cost category has different weights. It accounts for a very large contribution in the case of clean biomass plants (in relation to resource gathering and transport), large contribution for small hydropower plants (around 50% of investment costs per kW installed) and quite substantial for wind technology (up to 30% of investment costs per kW installed or more). Besides, these costs are influenced by project sizes, decreasing with the increase in plant size. The weight of technology complementary costs is likely to increase in time as diffusion progresses, since developers will make use first of the resource-sites with the closest to grid location. At a later stage of diffusion, these costs increase on the one hand because of distance of remaining resources to the grid. But on the other hand - in the case of intermittent resources - they increase because larger amounts of output are likely to need substantial grid reinforcement and back-up capacity from continuous resource power plants.

Thirdly, the category of *context induced cost factors* comprises a large variety of elements, such as monetary consequences of financing and trade arrangements, or expenses related to the preparation, (local) approval, construction and operation of electricity plants. The interest rates, equity requirements, debt maturity, equity-to-debt ratio, insurance expenses, investment recovery term requirements, and electricity purchase contract length (see Chapter 3) - all have impacts on the resulting production costs per kWh. Similarly, the costs for the numerous feasibility studies needed, for project development and management, engineering, construction, maintenance and operation should be placed in this category. The costs for such services are a reflection of the level of competition in the industrial basis of the respective renewable technology, and in different national contexts they can have different levels. But developers incur also costs related to the social and administrative permit approval, taxes of different types for various administrative authorities, land rent payments and even expenses for various local/regional social/economic benefits.

Therefore the category of context induced cost factors can be divided into three segments: monetary consequences of financing and trade arrangements; expenses in project life-cycle stages, and administrative(-social) expenses. One can expect that in the first diffusion phases, all three segments would be inflated. For example, the novelty of technologies often requires caution from developers and financiers, manifested in the form of higher requirements for returns on equity, shorter period for investment recovery expected, and higher insurance fees. When loan financing is available, interest rates will be also higher in the beginning (caused mainly by high risk premiums) and the period for loan reimbursement required will be shorter. When an electricity purchase contract is available but the guaranteed contract length is short, the same amount of investment costs has to be recovered faster which raises sharply the requirements of price per kWh to be received. Similarly, when diffusion is in incipient phase and the industrial basis is in process of formation, it is likely that the costs of the various services needed along the life-cycle of renewable energy plants will be high. As the industrial basis grows, these costs are more likely to decrease especially under competitive pressure from developers who can become themselves specialised in such services.

Finally, *resource quality and availability* is the fourth category influencing production costs. In the case of wind energy, for example, resource quality is represented by the annual average wind speed [m/s] of available sites. Wind availability is expressed in terms of hours per year when the wind blows with speeds that allow the turbine to function at rated power (see Chapter 4). In the case of small hydropower the head of water and the water volume are the key indicators of quality, as explained in Chapter 4. But availability is often difficult to predict as rainfall can have larger patterns of variation than wind energy. As concerns biomass electricity plants, resource quality refers to the energy content of biomass resources. Biomass availability regards the amounts annually available to offer continuity in power plant operation. Both hydropower and biomass resources could be manipulated to increase the energy content - for example by means of plant design for hydropower and by means of resource processing in the case of biomass. But these come with extra costs and the impacts on the production costs need to be carefully assessed.

Based on this differentiation of four categories of factors influencing production costs we argue that a fair reference of progress in cost performances would be that *of technology specific costs*, in terms of *factory costs per kilowatt capacity* expressed as €/kW. This is different from the investment costs per installed kilowatt capacity, also expressed as €/kW, because some factors from the technology-complementary and context-induced categories are also added to investment costs. This distorts the understanding of the extent to which the respective technology improved its cost performances.

As regards the evolution of production costs per kilowatt-hour, this will be influenced by the national resource potential and distribution, the geography and accessibility of that potential, the support system put in place to help renewables market introduction, and a series of institutional factors and national specific circumstances. As diffusion progresses, production costs are likely to decrease mainly due to reductions in technology specific costs and the use of high quality resources - in the case of wind and hydropower, or low costs resources - in case of biomass[67]. In some countries where all or most of the above mentioned factors are favourable, production costs may even reach cost competitiveness with fossil based technologies or market price. The capacity that can be installed at competitive production costs depends on the national availability of high quality resources, the remaining potential of technology-specific cost reductions and the possibility to minimise costs in the remaining two categories: technology-complementary and context-induced costs. But when these potentials are exhausted, production costs are likely to increase again above market price level. *Further installed capacity increase will be possible only if, and depending on the extent to which, the government agrees to allow for price support continuity.*

Table 2.8 summarises how each of the four categories of factors is likely to influence production costs per kilowatt-hour in the stage of market introduction and at a later time when diffusion already brought large capacity of renewable energy plants in the market. It also shows which categories of factors affecting production costs can be influenced directly or indirectly by governmental intervention and regulatory approach. This can be intentional, towards cost decrease, or unintentional when it can also induce sometimes cost increase.

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[67] In the case of biomass, resources formed by organic wastes are cheaper but have a lower energy content. Resources in the form of clean (yet unused forms of) biomass have a higher energy content but they are more expensive, spanning on a very wide price range.

2.8.2 Changes in the categories of factors influencing production costs during the diffusion process

In the market introduction phase, technology-specific costs are likely to be high[68]. In the long-term, the general expectation is that these costs would decrease. The rate of reduction could be influenced by direct governmental support for research development and demonstration. But it could also be indirectly influenced by the government, by means of the economic-policy support system put in place to address the economic and financing obstacles for the market adoption of the respective technology. Depending on the size and dynamics of the domestic manufacturing industry the support system is able to stimulate, as well as the (allowed) industry openness towards technology imports, the extent to which technology specific costs decrease in a certain period of time can be different.

Technology-complementary costs can vary strongly among countries. But they could also vary inside countries, since not all types of developers would be to the same degree successful in finding and getting administrative permits for good-resource locations. As diffusion progresses, this cost category is likely to exert an upward pressure on production costs. The rate of cost increase from these sources is outside the scope of policy influence, being determined by the geographic conditions and resource distribution inside countries.

Context-induced cost factors are a more complex category. The segment defined by monetary consequences of financing and trade arrangements is likely to be inflated in the stage of market introduction. The length of time during which such costs remain inflated, and the extent to which they decrease depend on the risk-profitability characteristics of economic-policy support systems. But these can also be influenced by a series of country specific factors such as: business requirements on profitability from financing agents and project developers, their willingness to accept economic and/or technology risks, or their environmental sensitivity and green image concerns which could be translated into lower financing costs and/or profitability expectations. Studies performed since the 1990s[69] showed that the design of support instruments can have negative impacts on economic performances of RET power plants by placing too high risks on the cash flows of projects.

High risks on price support are sometimes unintended, and other times considered unavoidable, acceptable or even desirable, in order to stimulate competition and production costs reduction[70]. But while reducing for example technology-specific costs to the same extent, context induced costs in the project life cycle stages, and the monetary consequences of financing and trade arrangements could increase to the point that all those cost reductions are being cancelled. Hence, assuming a constant low risk investment environment, it is quite likely that the factors influencing production costs in this category will decrease their weight after a longer period of diffusion. But this is no guarantee that when the investment risks increase again, the monetary consequences of these cost factors may remain the same low in the overall production costs per kilowatt-hour.

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[68] This does not mean that all innovative technologies are very expensive. There are examples of new technologies that are already very close to being cost-competitive from their conception, such as the wind technology based on the translation principle developed in Spain. However, these are quite rare cases.

[69] See for example Wiser and Pickle 1997; Kahn 1996; Wiser and Kahn 1996; Langniss et al. 1998; Jones and Eto 1997.

[70] Wiser and Pickle (1997) conclude one of their study on the impact of regulations on financing costs that "One of the key reasons that renewables policies are not more effective is that project development and financing processes are frequently ignored or misunderstood when designing and implementing renewable energy incentives. A policy that is carefully designed can reduce renewable energy costs dramatically by providing revenue certainty that will, in turn, reduce financing risk premiums".

Further, the costs incurred during the various stages of projects' life-cycle are likely to decrease in time. The rate of their decrease could be influenced by government policy indirectly. We assume that the characteristics of the support system put in place for market introduction and diffusion will be reflected in the size of and competition within the industrial basis emerging to serve the demand for renewable electricity plants. The extent to which the industry grows will be reflected in the costs for services such as project feasibility analyses and management, plant construction and maintenance-operation works. These costs are more likely to decrease when the industrial basis and dynamics are large.

As regards the expenses related to administrative and local social consent, their level in the market introduction phase is uncertain and their evolution after a longer period of diffusion as well. In some national contexts, it is possible that regional/local authorities or local people will be very cautious in grating consent for location of power plants using technologies new to them. When long delays are created in the approval processes or numerous and expensive studies are required regarding the technical, environmental, or economic plant performances, developers might incur high costs in this segment, in the market introduction phase. As administrative bodies and local populations become accustomed to that technology, these costs could decrease in time. But another scenario is also possible - alternatively or simultaneously to that just described - whereby developers have to accept higher local taxes and/or supplementary investments for regional development and social welfare in order to have their projects approved. As developments in Spain and more lately in the United Kingdom for wind power plants have shown (see Chapters 7 and 13), this could be a way to win site locations in market environments with tough competition to invest. But it can also be a unique option to deal with local opposition to RET plants' construction. In any case, this will increase the costs in the segment of 'context-induced' expenses.

The government could influence the evolution of these costs directly, by halting such practices or approval blockades that create financial leakages. The policy instruments for such intervention would be though outside the package used as economic-policy support system. But governmental intervention could also have an indirect influence, when the institutional framework stimulates or tolerates additional expenses compared to investments in other business areas or other locations. We argue, however, that the allowance of attractive local benefits from the profits of renewable plants is actually desirable in the stage of market introduction. When more actors are able to reap economic benefits from the new business coming in the region, this can only help acceptance of the new technology by a wider category of actors and speed up diffusion. But it is possible that as diffusion progresses this component of context-induced costs does not deflate. Communities and authorities in new areas might need similarly attractive offers to accept projects locally. Consequently, one can hardly make statements on the likely evolution of this group of context-induced cost factors - both for the market introduction phase and for the longer-term diffusion period.

Finally, resource availability and quality are of great influence for production costs. It is commonplace to expect that in the market introduction phase project developers will pursue the locations with best resources, and optimise the relationship resource location - resource quality and availability. In the case of biomass, 'best resources' should be interpreted as the free of charge or the cheapest resources since resource quality comes at a price often influenced by many factors. As diffusion progresses, sites with lower resources will be also exploited until the remaining sites are no more economically feasible with the available price support or for the market price, in case support instruments are no longer applicable. This category of factors influencing production costs is outside the scope of policy intervention.

Consequently, the following conclusions can be drawn based on these analyses. Firstly, only technology-specific cost factors and context-induced cost factors could be influenced by governmental policy in order to improve cost performances. The design of economic-policy support systems could indirectly influence the following factors: *technology-specific* cost factors; and expenses in the *life-cycle stages* of projects. Besides, support systems have a direct influence on cost performances by means of the monetary consequences of *financing and trade arrangements* that can be settled under the respective support system.

In addition to these, the government has also leverage on technology-specific cost factors (such as efficiency, availability of technologies), potentially, by means of direct support in research, development and demonstration. The expenses related to administrative and social consent could also be influenced by means of intervention in the institutional framework governing the relationships between investors, and local authorities or communities. But these intervention points are outside the scope of economic-policy support systems design. The technology-complementary costs and the factors associated with resource quality and availability are outside the scope of governmental influence. As technology-specific costs decrease with the increase in RET installed capacity, the weight of these two groups of cost factors in overall production costs increases, up to a point that production costs could increase again. For these reasons we argue that while policy matters, the scope of policy design for the influence of RET cost performances is limited, while the influence of support instruments addressing exclusively the economic and financing obstacles of RET (as presented in Section 2.3.1) is even narrower.

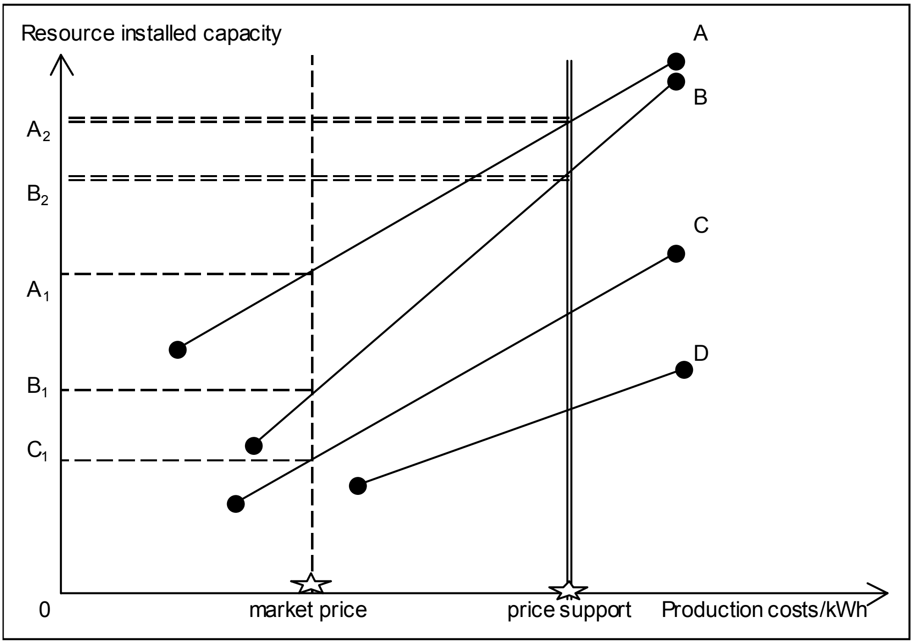
Secondly, this approach on cost analysis indicates that the use of production costs per kWh as indicator for cost performance improvements of renewable technologies and for comparisons with conventional electricity technologies is misleading. It indicates an insufficient understanding of the economies of renewable energy plants, which need a different analytical approach given the particularities of renewable resource-compared to fossil fuels. *We propose to use as reference for cost performance improvements the indicator of technology-specific costs in terms of factory costs per kW*. This is also the only indicator that enables fair international comparisons. The indicators currently used - of overall investment costs per kW and production costs per kWh - are contaminated by the influence of factors from the other two, respectively three categories, and hence inconclusive.

Thirdly, due to the multitude and complex interaction of factors influencing production costs, combined with the fact that some factors depend on the national geographic conditions and natural resource potential, it is not likely that expectations on production costs evolution can be more precisely formulated than we attempted in Table 2.8. But one thing can be ascertained, namely that as diffusion takes place production costs expand from ‘(very) high’ levels to a *range that can be very wide*. For the sites with high quality and availability of resources, and provided that the interaction of factors in the other three categories can keep the various cost components at low expenses, cost competitiveness could be reached with conventional electricity technologies. But the installed capacity of the respective renewable technology that can generate at competitive prices will depend on how abundant and how accessible the high quality resources are in that country, and whether low costs can be maintained in the other three cost categories. Different countries will have different ceilings of (maximum possible) installed capacity for the same technology at competitive/market prices.

Figure 2.11 offers examples of installed capacity - production costs per kWh situations that could be encountered in different countries. For example, for a certain renewable resource, country A will be able to install a larger capacity that can generate electricity at or below market price, represented here by A_1. Countries B and C will have lower ceiling of price-competitive capacity, represented with B_1 and C_1. But country D has so poor resources that with all cost reductions in the categories of technology specific, technology complementary and context induced costs, developers will not be able to generate renewable electricity at market prices.

When in a country, technology-specific costs cannot be lowered any further and context-induced costs have deflated to normal business terms and also cannot be lowered further, the production costs for remaining resource sites will only depend on geographical conditions and resource potential. The further capacity increase of the respective renewable technology will then be defined by the extent of price support the government is willing to accept. There would be no more scope of policy intervention for price reduction. At that moment, the situation for renewables' role on electricity supply systems becomes one of political acceptance of price increase. This price support will have to be sustained as long as the contribution of the respective resource in the electricity supply system is viewed necessary or desirable for reasons such as security or diversity of supply, climate change policy, or jobs and industrial activities preservation. In Figure 2.11 we suggested how the installed capacity could increase when the political decision is taken to allow and sustain price support at a level that is double to the market price[71]. For example, country A could increase its economically feasible resource potential, with an increase of installed capacity from level A_1 to level A_2. Similarly, country B will be able to almost double its installed capacity when price support is allowed up to double the market price level.

Figure 2.11 *Examples of country situations for the relationship: installed capacity - production costs (for a hypothetical renewable resource electricity technology)*



But while political forces define the border of diffusion through the extent of price support, market forces could create (through diffusion patterns) socio-economic-industrial contexts of diffusion that can exert political pressure on the extent and continuity of renewables price

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[71] These are imaginary cases for which the capacity - cost relationships were represented as straight lines purely for reasons of simplification.

support. We explore the emergence and features of such favourable socio-economic-industrial contexts of diffusion in Chapter 3. But, in this study, no theoretical expectations are formulated with regard to the extent of cost performance improvements a technology would be likely to be achieved under different types of support systems. Developments will be only analysed empirically in correlation to the country specific (remaining) potential, in order to see which of the four sources of costs distinguished have changed their weight in the overall production costs and in which direction (increase or decrease).

2.9 Summary

In this chapter, we discussed the building blocks of the analytical framework proposed in the study and their relationships. We defined first the approach to analyse the independent variable - that is the support systems for renewables market diffusion. We proposed then a set of intermediary variables to analyse diffusion more closely. After making a general presentation of the research model, we defined our approach to renewable technology analysis as target of support systems. In the last part of the chapter, we defined the perspectives for the analysis of the dependent variables and the extent to which support systems may affect its forms. The chapter contains the theoretical answers to the first three research questions.

We started the chapter with explanations on the economic and financing obstacles faced by renewable energy technologies. These pose a daunting challenge for the market entry and diffusion of the high investment costs technologies based on renewables. The electricity industry and energy intensive industries exert a strong political lobby against the externalisation of environmental and social costs of fossil fuels. Besides, the traditional financing community has financing criteria to which renewable technologies may in many instances not be able to respond. A perception of high technology risks is often balanced with the risk assessments on the economics of projects, resulting in negative reactions to applications for loan financing.

In order to overcome the economic and financing obstacles, governments taking the political decision to support RETsdevised a wide diversity of support schemes. We presented the support instruments used so far in industrialised countries and those that are possible to use in the near future. Our observation was that given the diversity of support instruments and of the possible ways they could be combined in designing support systems, policy researchers are have a difficult task when it comes to assess the diffusion potential of support systems already used, or being contemplated, or possible to conceive.

Current research approaches have in our view two main disadvantages. Firstly, they do not incorporate the aspect of the extent of financial support offered by support instruments. Secondly, the current approaches to describe support systems are not sufficiently suggestive with regard to the degree of attractiveness to invest for different types of economic and financing actors, from the perspective of risk acceptability. Consequently, we proposed to describe and analyse the support systems addressing the economic and financing barriers of RET in terms of two characteristics:

- *aggregated risks on the economic feasibility and profitability of* renewable electricity *projects* emerging from the support instruments used and their interaction, and
- *range of* p*roject profitability* that emerges from all support instruments that investors are eligible to use for the production of renewable electricity.

This approach was also seen to have the advantage of parsimony and easy international and temporal comparisons, taking into account the large diversity and complexity of support systems encountered in practice, and that could be theoretically conceived. We differentiated among for types of risk-profitability investment contexts that could emerge from support systems, as follows: (see Figure 2.2)

- *optimal investment context,* with low/moderate support system risks and high/very high profitability of projects;
- *entrepreneurial investment context,* with high/very high support system risks and high/very high profitability of projects (Area 2);
- *political investment context,* with low/moderate support system risks but low or modest profitability of projects or below cost-recovery financial support (Area 3);
- *minimal investment context,* with high/very high support system risks and also low or modest profitability of projects or below cost-recovery financial support (Area 4).

In continuation, we suggested to analyse support systems' risks by distinguishing between the economic and the policy component. The economic component of would refer to the forms of support that directly concern the trade arrangements for renewable electricity. This was referred to as the economic governance structure where the following elements were included to describe economic risks: the type of demand of renewable electricity, contract parameters, and price design. The policy component of support systems was considered to include forms of intervention that improve the economics of renewable projects or contribute directly to the reduction of the financing barrier, or improve the market position of renewable electricity in competition with conventional technologies. The approach for support systems' analysis proposed in the study concluded with explanations regarding how to analyse economic risks and policy risks from the investor's perspective. This part of the chapter formed our theoretical answer for the first research question.

Further, looking in the diffusion literature at the analytical perspectives taken on technology diffusion, we found affinity for the perspectives that considered the accessibility to finance, the adopters' perception of profitability, risk (perception) and motivation of adopters as affecting the rate of diffusion. But we adopted the view that the main diffusion mechanism is the availability of financing resources. Consequently, we proposed to monitor diffusion patterns of renewable technologies by means of five indicators: types of project developers, types of financing schemes, motivation to invest, project sizes, and choice for technological designs.

Section 2.5 outlined the analytical framework of the study. We assume that economic-policy support systems influence the market diffusion patterns of RETs through the characteristics of aggregated economic-policy risks and project profitability. In their turn, diffusion patterns influence the effectiveness of support systems and the extent to which the market diffusion process can be sustained in the long term. Diffusion patterns are therefore conceptualised as the interface between the characteristics of the economic-policy support systems, the effectiveness of support systems, and the sustainability of market diffusion. A set of assumptions was formulated for the theoretical analysis of the relationships between these building blocks of the research model, to be performed in Chapter 3. Besides, we also made a preliminary discussion regarding the way the different forms that diffusion patterns may take, could influence the selected dependent variables.

In the framework of the discussion regarding the concept of sustainable market diffusion processes, we explained in Section 2.6 the perspective taken in analysing technical performances and the types of technologies for our study' concern. In terms of types of renewable technologies, the 'target' of the support system is formed by those situated in the stages of project demonstration or initial commercial availability, attempting to become technically and commercially mature. Support systems will be analysed in terms of their capacity to bring on the market technological designs of the analysed RET that are in one of these two stages. The main concern is not for the degree of innovativeness of technological designs but for their potential to increase the market expansion potential of the type of renewable resource it uses, in the electricity system.

In the next step we defined the dependent variables and our analytical approach to them. More space was given to the perspectives necessary for the analysis of the prospects of sustainability of diffusion processes. We argued that in order to understand if a process of market diffusion can be characterised by potential continuity, it is necessary to look at diffusion from the following three perspectives:

- technical performances in relation to available resource potential
- cost performances in relation to available resource potential
- technology embeddness in the national socio-economic and industrial structure.

We considered a market diffusion process as sustainable when the cost performances of the supported technology, combined with changes in social and business preferences towards investments in renewable energy resources, do not necessitate anymore the use of an economic-policy support system that isolates the respective RET from the rest of generation technologies in the electricity market. However, even when cost performances do not enable at all, or do not enable for the entire available potential the cost-competitive exploitation of a renewable resource, we view diffusion processes also as sustainable when they already induced a level of dynamics and embeddness of technology in the industrial and socio-economic structure to a point where a total withdrawal of the support system would not be politically desirable.

We plan to look in Chapter 3 at the possible relations between the attractiveness of economic-policy support systems and the indicators for socio-economic and industrial embeddness of RET. But as regards cost performances, we argued that no hypotheses will be formulated, because RETs are strongly influenced by factors outside the scope of governmental influence, such as by means of support systems. The issues of technical and cost performances will be discussed empirically, in relation to the remaining resource potential. The relationship between cost performances, resource availability and technical performances with regard to diffusion expansion potential is very tight, resource-specific and country-specific. Theoretical expectations will only be formulated regarding the risk-profitability context of support systems and the market choice for technological design of project developers and financing agents. Aggregated at industry level, their choice defines the extent to which the technical performances of the respective technology are able to contribute to the expansion of its diffusion potential in the electricity system. The discussion with regard to the perspectives for the analysis of diffusion processes' sustainability constitutes our theoretical answer to the second research question.

We concluded this chapter with the analysis of the anatomy of cost performances of renewable electricity technologies, expressed as costs per kWh. We argued that expressed this way this is not a good indicator for the progress achieved by renewables in cost reduction. The indicator of technology-factory costs per kW should be taken instead as reference in policy effectiveness and industry studies.

In explaining why, we differentiated among four types of factors influencing the cost performances expressed as costs per kWh: resource quality and availability, technology-complementary costs, context-induced costs, and technology-specific costs and factors. Of these, only the last two can be influenced by means of support systems, as well as other forms of governmental regulations and by the institutional framework present in a country with regard to financing, administration and industry. Based on such ideas we concluded that as diffusion takes place, production costs expand from '(very) high' levels to a cost range that can be very wide. At places, where locations are of high quality, cost competitiveness could be reached with conventional electricity technologies.

When in a country, technology-specific costs cannot be lowered any further and context-induced costs have deflated to normal business terms and also cannot be lowered further, the production costs for remaining resource sites will only depend on geographical conditions and resource potential, and may rise again. The further capacity increase of the respective renewable technology will then be defined by the extent of price support the government is willing to accept. But while political forces define the border of diffusion through the extent of price support, market forces could create (through diffusion patterns) socio-economic-industrial contexts of diffusion that may exert political pressure on the extent and continuity of renewables price support. The considerations on cost performances made in Section 2.8 formed our theoretical answer to the third research question. In Chapter 3 we develop the theory regarding the influence of the risk-profitability characteristics of support systems on the diffusion patterns of RET, the effectiveness in inducing the increase of installed capacity and the prospects of markets diffusion continuity.

Appendix 2.1

Countries	Governmentally guaranteed purchase of renewable electricity		Green pricing	Economic or fiscal incentives	Voluntary Actions
	Volume-focused or Mixed-guarantee	Price focused or Weak-guarantee			
Australia	Yes		Yes	Yes 2,3	
Austria			Yes	Yes 1,2	Yes
Belgium	(Yes)			Yes 1,2,3,5	
Canada				Yes 1,3	Yes
Denmark	(Yes)	Yes	Yes	Yes 1,5	
Finland				Yes 1,3	Yes
France	Yes (wind)			Yes 1,3,4	
Germany	Yes	Yes	Yes	Yes 1,2,3,4	Yes
Greece		Yes		Yes 1,3	
Ireland	Yes			Yes 1,3	
Italy	Yes	Yes		Yes 3	
Japan	Yes	Yes		Yes 1,2,3	Yes
Luxembourg		Yes		Yes 1,3	
Netherlands	Yes	Yes	Yes	Yes 3,5	Yes
New Zealand				Yes 3	
Norway				Yes 1	Yes
Portugal	Yes			Yes 1,2,3	
Spain		Yes		Yes 1	
Sweden		Yes g/f	Yes	Yes 1,3,5	
United Kingdom	Yes		Yes	Yes 1	Yes
United States	Yes (PURPA)		Yes	Yes 1,5	Yes

Source: http://www.iea.org/pubs/studies/files/renenp2/ren/39-ren.htm

1. Grants and subsidies involving direct transfers
2. Credit instruments (interest rate loans, soft loans, loan guarantees)
3. Tax exemptions (tax reliefs, credits, deferrals)
4. Other types of support instruments
5. Output credit for renewable electricity (on top of normal electricity fixed prices).

3

The diffusion potential of economic-policy support systems

3.1 Introduction

This chapter concentrates on the consequences of the risk/profitability characteristics of economic-policy support systems for RET diffusion. The main line of the argument is that the diffusion potential of a support system can be inferred from considerations regarding:

1. the types of project developers likely to be attracted to invest in the risk/profitability investment created,
2. the types of financing schemes that they may be able to use in the respective investment context, and

- certain details of their *investment decisions*; from these investment details we consider as suggestive for the diffusion potential the following:
    3. the drivers to invest;
    4. the size of RET power plant;
    5. the choice of technological design.

These indicators for diffusion patterns were selected because we assume that with their help one can derive expectations regarding both the rate of installed capacity increase and the prospects for sustainability of diffusion processes (based on the three perspectives on market diffusion sustainability discussed in Section 2.7.2).

Our theory consists of two parts. The first part regards the impacts of the risk-profitability characteristics of support systems on diffusion patterns, and is presented in Sections 3.2 to 3.5. This first part of the theory represents our theoretical answer to the fifth and sixth research questions. The discussion starts with some considerations on investment risks, profitability, the financing structure of investments, and financing sources, made in Section 3.2. This section makes in the same time some assumptions based on which we elaborate the theoretical expectations of the first theory. The theoretical analysis continues with the specification of typologies for the five selected indicators of diffusion patterns, and the discussion of the likely values of each indicator under different levels of economic-policy risks and profitability of projects. In Section 3.3, we focus on the drivers to invest and technological choice of project developers.

In Section 3.4, we propose a typology of financing schemes and discuss in which risk-profitability investment contexts they are likely to be used, and which types of project developers could make use of them. Besides, we also discuss the likely ranges of plant sizes one could expect to see emerging under each type of financing scheme in the four risk-profitability environments. After that we bring together the considerations made in the previous two sections and suggest some probabilistic relations among the indicators for diffusion patterns. These will take the role of assumptions based on which we formulate theoretical expectations regarding the influence of economic-policy support systems on the forms of diffusion patterns. These theoretical expectations are formulated in Section 3.5, which concludes the first part of our theory.

The second part of the theory regards the consequences of diffusion patterns for the RET capacity increase potential and for the sustainability of market diffusion processes. This part constitutes the theoretical answer to the seventh research question. In these discussions, we take into consideration the influence of three intermediary factors on the long-term diffusion potential:

- the business culture of traditional financing community,
- the level of entrepreneurship of domestic economic actors, and
- the average levels of welfare among domestic, private, and corporate economic actors.

Taking as a point of departure the expected forms of diffusion patterns after short-medium term of support system application, Section 3.6 explores the prospects for long-term diffusion continuation. For each of the four risk/profitability environments differentiated, theoretical expectations are formulated with regard to the likely installed capacity increase in short-medium term, and whether sustainable diffusion processes of RET could be expected in the long term. Section 3.7 makes a summary and presents the conclusions of this chapter.

3.2 General considerations on risks, profitability and financing

In Section 3.2.1, we briefly discuss the concept of risks and the consequences of economic-policy risks for investment decisions. In Section 3.2.2, we make some general considerations on the financial structure of projects, and review the main sources of financing based on financing management literature.

3.2.1 The concept of risks and the consequences of economic-policy risks for investors

The literature reflecting on risks is wide and with a long tradition, but it revolves around two major topics: the differentiation between risks and uncertianty and the perspective of defining them as either chances of success or prospects for failure.

In financing literature, the view on risks expressed by Osteryoung et al. (1997: 211) on the difference between risks and uncertainty is representative "Risks relates to the set of unique consequences of a given decision to which probabilities can be assigned; uncertianty is a situation in which such probabilities cannot be assigned."[1]. The distinction between risks and uncertainty is generally not viewed as as critical in financing theories.

In our study, the risks emeging from support systems are ultimately political risks, in that the support instruments and their regulatory details could change during projects' economic life time lowering the profitability of RET projects or making them no longer economically feasible. But to some extent they can be also market risks when certain price or trade aspects are left for bilateral negotiations between buyers and sellers of renewable electricity in the industry. In the financing sector and electricity industry methodologies exist in assessing market risks, both in formal terms and qualitatively. In the same time, experience of financiers and economic actors of doing business in certain national policy contexts - with specific policy styles and culture - could support the assessment of political risks. Although we do not consider the distinction critical, we view support systems as posing risks - and not uncertainties - on investors.

According to Larry Jarrett[2] (in Branscomb and Auerswald 2001: 45), "Risks can be characterized as a probability of success, but it is always a probability given a set of premises, an expected environment and a pattern of response with a correlated expectation of success". In this study we support the view on risks of Megill (1988) who argues that risk refers to an opportunity of loss. Hence, we take an approach to risks that defines the *possibility of failure,* given a 'set of premises' constituted by the design of the support system. This means that *from the perspective of economic-policy support systems, risks can be seen as the likelihood of not*

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[1] Similar definitions can be found throughout financing theory, e.g. see Robichek and Myers (1965: 67-94).

[2] Larry Jarrett is director of the Industrial Research Institute and former vice-president of OrganoSilicones R&D of Witco Corporation.

getting a certain targeted profitability on projects[3]. The 'expected environment' is shaped by the combination of 'certain' and 'uncertain' aspects of the support system in terms of type of demand, contractual relations, price design, contractual price methodology, and the level and duration of price support in policy support mechanisms.

Investors make forecasts on the cash flows likely to be obtained under a certain support system, targeting certain levels of project profitability. But in fact, given the uncertainty in the patterns of change (or constancy) of price support level and market protection, they will calculate a likely range of project profitability. When economic-policy risks are very high, the likely range of project profitability will be very large. In some cases project profitability can lower even below the posibility to reimburse the loan and pay the interest rate, meaning that the economic feasibility of the project is uncertain. Each investor has his own preference in terms of how low the range of project profitability may expand, seen as a continuum on a scale. The financing literature refers to the 'cut-off returns' as the minimum level of equity returns that an investor would consider acceptable (Wissema 1983: 30). A financing agent providing loans will require that the lower end of the likely project profitability range is higher than his requirement for interest rate on loan. But how much higher this should be, depends from financier to financier. When the likely range of project profitability expands (too much) in the area below the business cut-off requirement of investors, the risks posed by the economic-policy suport system will be considered unacceptable and investors will abstain from financing RET projects.

Consequently, *for investors, economic-policy risks are considered to represent the possibility of not receiving certain equity returns and the expected interest rates given the design of the support system*. The overall possibility of failing to receive the targeted project profitability (assuming that no other risks exist except for the economic-policy support risks) for a RET project could be qualitatively described as outcome of a series of possibilities, each representing a design element in the support system. For example:

- the possibility of failing to ensure demand for renewable electricity purchase;
- the possibility of failing to have the purchase contract renewed, or to find contracts on the free market at all, when no governmental guarantee on demand is offered;
- the possibility that the price per kWh in the economic governance structure will change (more than expected at the moment of investment);
- the possibility that the application of each policy support mechanisms envisaged will be prematurely terminated or substantially reduce the financial support offered.

The overall chance of success for a project is then approximated as the product of the underlying negative possibilities taken into account. Beside their aspect of possibility for failure, risks also have a price aspect, which intertwines with the profitability of projects, and with their financial structure. McGroddy[4] (in Branscomb and Auerswald 2001: 47) defines risk as "the price of doing something that appears to be worthwhile. Risk is not desirable in itself, nor is risk necessarily something to be minimized. An important attribute of risk taking is that a project is deliberately undertaken because the rewards, multiplied by the (presumably known or estimable) probability of achieving those rewards, exceed the cost of taking the risk".

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[3] This approach to risk, in the sense of 'failure to achieve', is also taken for example by Crum, Laughhunn and Payne who "contend that a dominant characteristic of the decision-making process (of investment) is the existence of a target or aspiration level for performance and that risk is defined by managers in relation to expected deviations of performance from the target (in Derkinderen and Crum 1981: xi).

[4] James J. McGroddy is former Senior Vice President at IBM.

Investors will accept risks because "Killing the project minimizes risk but it also eliminates the reward".

Economic and financing literature maintains that when investors decide to invest in a project, the higher the risks to which the project is exposed, the higher the equity returns required. The increase comes from what is referred to as 'the risk premium'[5]. While we agree that risk acceptance comes at proportionally higher returns in the case of loan financing agents, we do not fully support this assumption as regards equity financiers.

A large body of the entrepreneurship literature discusses that there are wide differences among the risk propensity of economic actors. Entrepreneurship theories differ in their explanations as to what enables some investors to engage in risky undertakings, such as a new market, a new technology, or a new company. But empirical studies show time and time again that some companies/decisions-makers take the decision to invest in risky environments, while others prefer - for the same rewards - to abstain from investing (Tiessen 1997; McGrayh et al. 1992; Kent et al. 1982; Forlani and Mullins 2000; Aitkin and Pablo 1992). Empirical observations on RET power plant investments provide evidence of investments in conditions of high risks and modest or even low profitability (Langniss 1995; 1998). Investors with lower cut-off profitability requirements may identify investment opportunities that do not appear sufficiently attractive for the large corporations or the dominant economic actors in the market. Not having to compete with them for guaranteed contracts or other privileges of the support system, high economic-policy risks would then not be seen as a deterrent to invest.

Consequently, as regards equity investors - and by implication project developers as indicator for diffusion patterns - *we do not embrace the assumption in financing literature that equity returns requirements increase proportionally with the increase of investment risks*. Instead, *we make the assumption that each type of equity investor has his own preference for the range of risks and returns considered acceptable for investmenst*. For some economic actors the acceptable risk range expands upwards towards high risks only with the increase on equity returns. For others, the risk-range of commercial operation is either limited to low or modest levels - no matter the returns to be expected, or their willingness to invest in higher risk environments is not constrained by proportionally equity return expectations.

In the case of financing agents investing by means of loans based on external financing schemes[6], the consequences of accepting investment risks go, however, beyond the increase of the risk premium reflected in the interest rates. Other key financing parameters of loan financing will also change, namely the debt-to-equity ratio of the project, debt maturity and the debt service coverage ratio. The general scheme of influence of risks on the four main characteristics of bank loan financing is represented in Figure 3.1. These parameters influence each other's level in complex ways, and for this reason we represented their relationship in Figure 3.1 with double arrow, at places. Debt maturity is the period of time in which both the loan-principal[7] and the loan interest rate have to be paid to the financing agent. But when risks are high, the loan financier will require a shorter period of debt maturity. This implies that investment costs have to be recovered faster which requires that renewable electricity be paid a higher price per kWh, increasing the economic obstacle of RET.

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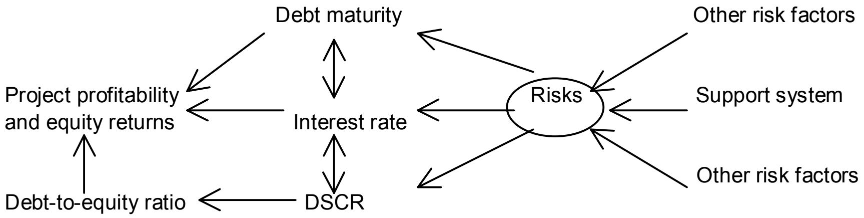
[5] "The market price of risk is the difference between the expected rates of return on the market portfolio of risky assets as a whole, and on a risk free asset per unit of equity of the market portfolio" (Friend and Blume 1977: 133). For a more detailed discussion on risks and returns for equity investors and risk premiums see for example Samuels et al. (1999: 257-270).

[6] As mentioned in Chapter 3, we use the term external financing schemes when loan financiers take RET project assets and cash-flows as loan quarantees.

[7] 'Loan principal' is the amount of money lent by the bank.

The expected debt-service coverage ratio (DSCR) represents the minimum amount of cash that the project developer has to make available annually to ensure its capability to pay back the loan-principal and interest-rate. This ratio is calculated based on projections on costs and benefits of the project. These scenarios draw on changing assumptions related to project performance, operating costs or revenue forecasts (Kahn 1996). The minimum level of debt service coverage required is set based on the worst scenario[8]. This parameter influences the share between bank loan and equity in the capital structure of the project, referred to as the debt-to-equity ratio. If a developer is not able to prove a certain minimum debt service coverage ratio, then the bank will require the project developer to increase the contribution of equity. This increases the overall financing costs, since equity returns are often higher than interest rates. Consequently, this raises again the level of prices per kWh that project developers need to receive under a given support system.

Figure 3.1 *The influence of economic-policy risks on financing parameters, equity returns and projects' profitability under external financing schemes*



When a price increase is possible, the overall profitability of projects also increases, but this takes the form of risk premiums towards the loans financier and perhaps also towards the equity financier. But when a price increase is not possible, equity investor(s) will have to accept lower equity returns for the same overall level of project profitability. Since different types of investors have different cut-off return requirements, a high-risk assessment by the loan financing agent will have the consequence of driving away project developers and equity investors who otherwise might find the risks of the investment context acceptable.

In conclusion, the economic-policy risks of RET support systems could influence the investment interest of equity investors and loans financiers in complex ways. The higher the risks, the higher the project profitability requirements will be, especially when external financing schemes are used, with the consequent increase on the societal costs of renewables' diffusion. For lower risks, the elimination of risk premiums and of the consequences for the financing structure of projects is more likely to lead to similar or even better[9] diffusion results at lower societal costs.

3.2.2 The financing structure of investments and financing agents

There are two main forms of financial resources for any project, including RET power plants: equity and capital borrowed in the form of loans, also referred to as debt. Their relative shares

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[8] This means that the least favourable, but yet likely forms of the support system elements will be taken into account when setting the debt service coverage ratio.

[9] Since lower risks would attract more types of investors into the market, the number of projects would increase, leading to a larger-scale diffusion.

form the debt-to-equity ratio. Equity suppliers are the project owners. Equity may come only from the project developer, in which case it is referred to as ‘internally generated’. Donaldson (1971: 37) mentions the following sources of internal equity: “(1) funds currently generated from operations; (2) funds released by the liquidation of working assets; (3) liquid assets (cash and marketable securities) accumulated from the operations of previous periods. Management need not consult anyone in determining the disposition of these sources of funds”. In the case of small firms the equity comes from the financial reserves of the owners, their family and friends. As the firm grows retained earnings can also be used as equity, recycling them back into the business (Osteryoung 1997: 250). For individual investments equity comes from the private capital of the individual(s) contributing.

But equity may also be externally generated, when investors in the private capital market are approached by the project developer to complement the cash needs of the project, when they overcome the developer’s financing capability. External equity may however also be required as a means of the developer to pool the risks facing the project’s profitability or economic feasibility.

As the loan is concerned, this may be guaranteed by the assets and cash-flows of the project for which financing is required, in which case it is referred to as ‘project finance’. In the financing literature, this financing scheme is also referred to as ‘non-recourse financing’ because it does not make recourse to the financial reserves and other (non-project) assets of the equity suppliers. Alternatively, the loan may be entirely guaranteed by means of the financial reserves and non-project assets of some or all equity suppliers. When the project developer is one company, this is referred to in the literature as ‘corporate financing’. In this case, the risks to which the project is exposed do not have implications on the financing parameters discussed in the above sub-section. These parameters, with the consequences for equity returns and project profitability will depend on the financial strength of the company and its relationship with the financing agent.

Project finance and corporate finance have been so far the dominant types of financing schemes used in the electricity sector for generation power plants. With the liberalisation of the electricity industry and entry of independent power suppliers the diversity in the types of financing schemes increased. The desire of some economic actors to develop RET power plants in the context of financing obstacle has lead to even more innovative ways of financing. Drawing on empirical literature, we propose in Section 3.4 a typology of financing schemes that we use as the set of values of this diffusion indicator in the study.

As regards the debt-to-equity ratio, projects can take any combination, from 100% equity to 100% debt (although the latest is quite seldom). For project financing, when the investment is considered to have low/moderate risks, a frequent formula is 80% debt - 20% equity. As a financing agent explains (Davies 1998) “the minimum level of involvement which lenders need from the equity investor is around 20% of the project cost. The argument for this minimum level of equity is because banks are relying on the developer to build and operate the project correctly and maintain their keen interest in its success.” But the risks to which the project is exposed play an important role, possibly drawing the debt contribution down to 50% or lower. For corporate financing, debt could be as high as 95% for a large corporation with long-established ties to the financing agent, to 50% or lower for a new entrant or small company (Mitchell 1993).

Let alone the financial structure and the nature of loan guarantees, loans and interest rates are always the first to be paid from the profitability of projects. When external equity is used this is often paid as the second in line, while the last to book profits from the project is the internal equity provider - or project developer, as referred to in this study. This way he takes the highest project risk. When the cash flows of the project are worse than predicted in the targeted project profitability, the developer could end up without returns. When the cash flows are larger than targeted, he would book all the extra returns.

3.2.2.1 Financing structure decisions of project developers

In financing literature, the ‘pecking-order’ theory with regard to financing structure decisions is widely used and discussed in textbooks (e.g. Osteryoung et al. 1997). The theory describes the order in which funding is presumably preferred by owners of business, by looking at the level of financing costs attracted by each source of finance. The pecking order theory suggests that firms prefer to use for the funding of their growth internally generated equity, i.e. funding from the profits retained by the firm from its business activities. Internal funding does not require financing costs, and then it would always be preferred before other financing sources. The second choice would be debt, because debt assumes lower costs than the externally generated equity. Only in the last resort would investors resort to equity from other companies or financing agents. The theory considers that the order of preference is the same for both large and small firms. For the latter however the de facto availability of external equity is more difficult and less affordable.

The ‘pecking-order’ theory received confirmation in many empirical studies. However there are financing experts that argue (Robichek and Myers 1965: 105), that due to the tax advantages of investing based on debt rather than internal equity, the order assumed by the theory is not as rigid as commonly considered. Donaldson (1971: 68), for example argues that: “Assuming that the primary objective of business is to maximise net revenue, it would appear to be highly desirable to use debt as a source of funds, and to use it as continuously as possible”. Besides, as he further argues based on a survery of corporate management attitudes (Donaldson 1971: 71), “when investment opportunities exceeded internal financial capacity there was good reason to consider debt as a source of funds”.

We propose an adjustment to this order for the case of RET diffusion. We consider that - *whenever the support system enables high levels of project profitability*[10] *- developers of RET power plants would prefer to use debt as main financing source. From the two types of debt, investors would prefer to use the project finance type first, followed by debt of the corporate finance type. The use of internally generated equity would come on the third place of preference, while the use of external equity remains the last option to be used*. There are several arguments for placing debt in the project finance approach as the main preference of project developers.

Firstly, by using majority debt, e.g. project finance with 80% debt and 20% equity, the developer can extent his equity and build a RET project five times larger than he could afford under a financing scheme with 100% internal equity, as the pecking order theory consider he would do. Most importantly, his equity return per unit of equity invested increases substantially. For example, for a project with 10% project profitability financed as 100% internal equity, the equity return of the owner will be also 10%. However when he uses 80% debt (and only 20% internal equity) based on the project finance approach whereby the interest rate on debt is 6%, his equity return will be 26% instead of 10% (Davies 1998). The developer can therefore invest in more projects or larger projects with the same amount of money, while gaining much higher returns on equity in the same risk-profitability investment context, only by choosing a different type of financing scheme.

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[10] The profitability of projects being (very) high, after the payment of interest rates on debt, developers may still be able to retain attractive level of equity returns.

Secondly, very high initial investment costs and low variable costs during project life assume a ‘financial shock’ for the developer at the beginning of the project. For larger plants, and when the technology is quite expensive, such as biomass gasification projects, only large developers such as industrial holdings and electricity companies utilities would afford such investment based on 100% internal equity. Thirdly, the economies of scale, high transaction costs, and high project development costs (see Section 2.2) stimulate developers towards larger plant sizes; too large projects and too many projects would put pressure on the equity reserves and debt corporate finance, stimulating a preference for project finance loans.

Fourthly, any type of economic actor would be interested in the preservation of sufficient financial reserves or asset liability for new, or yet undiscovered, profitable business areas. This view is also supported in some financing theories. For example Froot et al. (1993: 1629) argue that “if external sources of finance are more costly to corporations than internally generated funds, there will typically be a benefit to hedging: hedging adds value to the extent that it helps ensure that a corporation has sufficient internal funds available to take advantage of attractive investment opportunities”.

And fifthly, in the case of large developers the corporate policy for risk management may require the diversification of business risks, when operating in competitive environments. However, placing the financial guarantee of too many RET projects on company core-business assets (when debt with corporate finance is used) could lead to the decrease in the market valuation of the corporation, such as its value on the stock market when it is publicly listed. The same could happen when developers use internal equity, since the RET projects would appear on the list of corporation assets (Wiser and Pickle 1997). Renewable technologies still have a negative image in the eyes of many financing institutions and in many countries (Davies 1998). When a negative image on renewables is obvious among financing business partners and potential stock owners of a developer, he would be more likely to prefer to use a project finance loan whenever accessible[11].

It is however possible that for very large financially powerful companies these arguments are not strong enough reasons to give preference to debt based on project finance. They may prefer to invest only based on internal equity finance, having in view the advantage of not having to pay interest rates.

Aside from debt and equity, economic actors interested to own a RET power plant also have the option of leasing. This is an attractive option for small firms and individuals who do not have the required equity available, nor the opportunity for debt financing. Leasing is a financing instrument whereby the owner of a project (the leaser) is renting it to another economic actor interested to own the project in short or medium term. The lessee may use the power plant and pays rent for this. At the end of the contract the lessee may cancel it or buy the project from the leaser, by paying the difference in the case when the investment costs supported by the leaser and his required profits have not been recovered by the end of the contract.

3.2.2.2 Financing agents

The financing literature mentions the following sources of financial resources that investors in any types of projects, including energy projects could make use: commercial banks, universal banks, investment banks, savings banks, merchant banks, insurance companies, pension funds, special venture capital funds, building societies, credit co-operative banks, and finance

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[11] On a bilateral basis, when project risks are studied in depth, the attitude of a financing agent is likely to become more easily positive than in the case when detailed information are not at hand.

companies/houses[12]. Banks provide more frequently loans, but they can also be a source of equity when they find it attractive to take the role of equity fund managers. The other financing agents provide more often equity, but they can also finance projects by means of loans. We discuss here the main characteristics of financing agents and their preferences for investment risks and profitability of projects. Based on this, we highlight the environments where they are likely to be seen providing loans based on the project finance approach.

Commercial banks, universal banks and investment banks have provided so far both debt and equity to power plants, and in many industrialised countries also to RET projects. But due to differences in the regulatory framework they are often exposed to (in the same country) the risk-profitability terms under which they may provide debt and/or equity might differ. Investment and universal banks[13] are in a better position to raise funds for equity than commercial banks. They are also better able to offer longer-term loans, which are strongly needed for RET power plants as long as investment costs remain high. Besides, they are more likely to approve project finance loans when investment risks are increasing to modest, whereas commercial banks would only lend for low risk projects. But in all cases, empirical data show that the profitability of projects needs to be several percentages - generally at least 2% - above the interest rate to agree with debt financing.

Saving banks may invest in both debt and equity form in power plants. But since in industrialised countries they are offering savers good interest rates above inflation, they would require projects with high profitability, while "projects are relatively low or moderate in risk" (Hines 1997: 175). As regards *merchant banks*, they are "traders who earn their profits by a quick and profitable turnover of their capital. They aim to realise their investment in three to five years, either by means of public issue or take over." (Springman 1973: 9). Merchant banks support only companies and not individual developers. They offer preferable equity but possibly also debt financing and can be found in investment contexts enabling high profitability for investments.

Pension funds may be publicly or privately managed financial institutions. Given the generally high number of employees for who they store pension rights over long periods of time, they dispose of large financial resources available for long term. They are often willing to invest in large capital intensive projects with long term pay-back time[14]. For power plants, they have provided so far both equity and debt (Hines 1997: 171). The returns of pension funds need to exceed the rate of inflation, in order to protect prospective retirees. This implies that when inflation is relatively small like in industrialised countries, the project profitability requirement for RET projects could already start at modest levels. But given their financial responsibility for retirees pension funds would rather invest under low/modest investment risks. However, corporate pension funds would also invest smaller amounts of money in high risk environments for short pay-back investments when the returns promise to be very high. According to Hines (1997: 172) this may also include merchant power plants, i.e. or generation projects that do not have a (long term) contract for electricity purchase.

Insurance companies resemble pension funds in that they also take a long-term perspective on business and are more likely to approve long term loans for RET projects. Beside debt, they

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[12] The presentation of financing agents is based on Hines (1997: 170-181), Gregory et al. (1997: 60-72); Tamari (1977), Springman (1977: 8-19), Solomon and Pringle (1980: 33-43).

[13] Universal banks are a combination of commercial and investment banks, characteristic for Europe.

[14] The 'pay-back time' has here the general meaning given in economic literature, expressing how soon the estimated cash flow benefits expected from the project will repay the total investment costs (Solomon and Pringle 1980: 316).

also can provide for equity. Insurance companies accept to invest in higher-risk environments but only if the returns are proportionally high to the risks taken.

Venture capital firms and finance companies/houses are the financing institutions making available funds to invest in the equity of businesses where there are prospects of very high returns. Some firms would only accept to finance low/moderate risk projects. Others would also accept to finance high risk projects but for this they generally require the possibility to exit the business after a short period of time, usually 3-5 years.

Building societies and credit cooperative banks can be good sources of debt for small developers, including individuals and community projects. The major advantage is that they do not have stringent collateral requirements (Gregory et al. 1997). This implies that they might invest even in high economic-policy risk environment. Some may also finance low/moderate profitability projects. But in principle, there can be more substantial difference in the levels of investment risk and profitability accepted from country to country, than in the case of the other types of financing agents mentioned.

Ethical banks are not so frequent, but when they do exist they are good financing sources for renewables. They usually finance by means of debt at below market interest rates projects that in their view risks are socially desirable but put at a disadvantage by the traditional financing agents on the financing market. In line with their willingness to support de-favoured project ethical banks have often not so stringent requirements for the profitability of projects they have, which may start in the 'low' range. In the same time they may accept also to give loans for projects exposed to higher risks than commercial banks would do in standard circumstances. Beside debt, ethical banks may also manage equity funds, and even take the role of project developer. Table 3.1 summarises the ranges of risk-profitability preferences for operation associated with the main financing agents, as it turns out from financing textbooks and the empirical information on the financing of independent power plants globally (Hines 1997). The table also mentions the possible forms of finance each type of financing institution may supply for RET power plant investments.

Table 3.1 *Financing institutions and their likely risk /profitability ranges of operation*

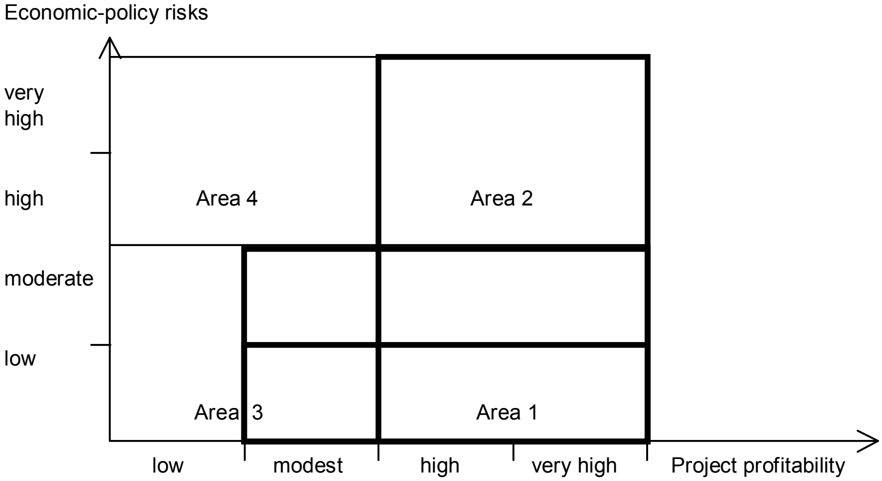
Financing institution	investment risk	minimum project profitability border	possible forms of finance
commercial banks	low	modest	mainly debt
universal banks	low / moderate	modest	equity and debt
investment banks	low / moderate	modest	equity and debt
savings banks	low / moderate	modest	equity and debt
pension funds	low to high	modest	equity and debt
merchant banks	low to high	high	equity and debt
venture capital firms	low to high	high	mainly equity
insurance companies	low to high	high	equity and debt
credit co-operative banks	low to high	low / modest	mainly debt
building societies	low to high	low / modest	mainly debt
ethical banks	low to high	low / modest	equity and debt

In Figure 3.2 we represented the areas of risk-profitability operation of the financing agents that usually dominate national financial markets (the first nine categories in Table 3.1), under non-recourse financing approach by means of bold rectangulars. This suggests that it should be possible for project developers to obtain financing from this type of institutions when support systems are characterised by economic policy risks in the areas low to very high and for project profitabilities in the ranges of modest to very high. However, in optimal investment contexts (Area 1) there would be a much higher number of financing agents that developers would be able to approach. The overall pool of financing resources would also be considerably higher, since this is the area where all types of banks operate, as well as institutional investors. Besides, in such as risk-profitability context financing agents would approve not only debt, but also develop equity funds for investments in projects, further increasing the financial pool for RET diffusion.

In political investment contexts (Area 3) one can find mostly ethical banks, credit cooperative banks and building societies. Besides, it is possible that most types of banks and pensions funds would finance projects with debt, but only if profitability of projects can be in the 'modest' range. Debt could also be publicly secured by means of bonds. In entrepreneurial investment contexts (Area 2) developers could only approach merchant banks, pension funds, insurance companies, venture capital firms, finance companies/houses or publicly secured stock. However, from country to country there are differences in the extent to which these types of financing agents agree to invest in high risk regulatory environments. The same holds for ethical banks, building companies and credit bank cooperatives who are likely to be the only financing agents lending money in minimal investment contexts (Area 4) under non-recourse financing approach.

We use the general considerations made in this section in the discussion regarding the likely types of financing schemes in different risk-profitability contexts made in sections 3.4 and 3.5. In the next section we discuss the influence of national risk/profitability environments on investment decisions from the standpoint of dominant drivers to invest in different contexts and the likely dominant choice of technology design from the standpoint of diffusion expansion potential of technologies.

Figure 3.2 *The risk-profitability areas of operation of traditional financing agents, based on the non-recourse financing approach*



3.3 The influence of national risk/profitability environment on investment decisions: drivers to invest and technological choice

In our theory, the analysis of diffusion patterns takes a double perspective: that of project developers and that of financing agents. The analysis from project developers' perspective is based on the assumption that developers are not only and not always profit maximisers.

Strategic and self-generation reasons can also influence their decision to enter the renewables' market even in (apparently) adverse investment climates.

We differentiate among two main groups of project developers: large developers and small developers. In the group of large developers the following types of economic actors are included: energy utilities/electricity companies, long-established financially-powerful corporations, and publicly-owned companies. In the group of small developers we include medium/small-size industrial production companies, small new-entrant firms (who do not have an economic background in the form of legal ownership in which they are organised to invest in RET projects), cooperatives, communities, associations and individuals.

In implementing their investment plans, developers may choose between two financing approaches - internal financing schemes or external financing schemes. We consider investments as being based on internal financing schemes when the project initiators use either only their financial resources to commission and operate the RET plant, or complement their financial resources with loans guaranteed by private or corporate assets, other than the RET project and its cash flow. This implies that the risks associated with the RET investment, including the economic-policy risks are only assumed by the project developer. He is also the only actor making considerations on the attractiveness of the profitability that the support system enables. Investments plans co-driven by non-commercial motivation can more easily be implemented. Investment decisions with regard to plant size and choice of technological design are also under the sole decision latitude of the project developer. When a loan is used, as long as the developer disposes of sufficiently reliable non-RET assets to guarantee its reimbursement, the financing agent would not interfere with the investment decision of the project developer.

We defined as external financing schemes the cases when the economic actor initiating the project involves, beside his internal financial resources, also bank loans guaranteed with RET project assets or generated cash flows, or/and financial resources in the form of equity from other economic or financing agents. External equity suppliers become then co-owners of the projects, being therefore technically shifted to the position of project developers, side by side to the project initiator. Under these schemes, the repayment of loans depends on the capacity of the RET project to generate cash-flow under the respective support system. Providers of loans under the external financing approach, and profit-driven external equity suppliers will adjust the extent of their financial contribution and the financing terms to the risk-profitability characteristics of the economic-policy support system. They will enter the market only when the aggregated economic-policy risks and the profitability of projects correspond to their business requirements.

But as discussed in the previous section, business requirements differ among types of financing agents. Besides, they also could differ among countries for the same type of financing agent. In addition to the financing parameters, both loan financiers and external equity financiers will have a say in the details of investment decisions, including plant size and technological design choice. The economics of the RET project are crucial for loan reimbursement and the payment of the required interest rates and equity returns. Consequently, under this financing approach, investment decisions will emerge from the interaction between the project initiator and the rest of external financing agents contributing to the project.

We assume that relations could be established between the five diffusion patterns we have chosen to focus on: types of financing schemes, types of project developers, drivers to invest in RET projects, projects sizes and technological designs of the RET used. This section makes a discussion on the drivers to invest and technological choice. The following section proposes a more refined typology of financing schemes. In Section 3.5 linkages between diffusion patterns' forms are suggested. These relationships lay at the basis of the formulation of hypotheses regarding the sustainability of market diffusion.

3.3.1 Drivers to invest

Project developers are the economic actors who initiate the idea and provide for the internal equity of the project to develop it from concept to operating power plant. The analysis of factors motivating developers to start and carry out a project offers an understanding of the extent to which the installed capacity could increase in short and long term. The analysis of drivers to invest enables further an understanding of the investment behaviour of project developers that the sole study of developers' behaviour in their position of internal financing agents would not be able to capture. As Jahraus et al. (1991: 527) explain, "Calculated economic (resource) potentials are not by any means a direct indication of the capacity that will be realised in practice. The decisive factor is the motivation of the operator to invest in this technology, and the acceptance of the utilisation of wind energy by investors, but also by the public".

We did not identify many studies looking specifically at the motivations of project developers to invest, but those who tackled this issue suggest a quite large range of drivers[15]. For example Burns (1985) looked at the drivers to innovate and adopt renewable energy technologies in early 1980s in several countries[16] and found that the motivation for introducing new energy technologies range from economic considerations, such as new immediate business area or no other alternative ways to expand and grow in long term, to the technical attraction for RET of decision-makers developing projects, "the desire for social recognition, political motives, ideal interests (anti-nuclear feeling, environmental concerns, worry about oil dependence and vulnerability)."

A study for the European Parliament in early 1990s also looked at the motivation to invest in six countries[17]. The authors differentiated among "six typical investor types (…) which differ mainly concerning their individual motivation": anonymous investors, industrial companies, large utilities, house owners, municipality, and energy community[18] (Langniss 1996). The types of motivation underlying the investor typology are: strongly economical, economical, strategic, political, and ecological.

Another research project funded by the European Commission studied the prevailing financing schemes, constraints and financing parameters of renewable energy projects in eight European countries, which also looked in the empirical case studies at the motivation driving project owners (Langniss et al. 1998)[19]. The study proposes a typology of financing schemes differentiating between: private finance, corporate finance, project finance, participation finance and third-party finance. In describing the key features of each type of financing scheme and the main findings regarding their use in the eight countries, the report also

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[15] The issue of drivers to invest is also sporadically addressed in business updates of specialised journals such as Wind Power Monthly, Renewable Energy World, Energy, ReFocus, the Electricity Journal, and Renewable and Sustainable Energy Review.

[16] The countries studied by Burns (1985) were California, Israel, Denmark, England, Finland, Germany.

[17] The countries studied by the project for the European Parliament includes: Austria, Denmark, France, Germany, the Netherlands and United Kingdom (Langniss 1996).

[18] This study also looked at the readiness for financial risks of each investor type and the types of financing schemes used in each country. We mention some of the main findings in Section 3.4.

[19] The report Financing Renewable Energy Systems studied the financing of five renewable technologies - solar thermal, photovoltaic, wind, hydropower and biomass systems - in Austria, Denmark, Germany, Italy, the Netherlands, Spain, Sweden, and the United Kingdom (Langniss et al. 1998).

mentions the (range of) motivations that developers using each financing scheme are likely to have. This way, investments were observed to be "not economical in business terms" or having "an appearance of environmental concern and public acceptability", ideologically motivated or fostering RET through track-record building[20].

Building on the empirical findings identified, we consider in this study that project developers may invest in RET plants motivated by one or a combination of three main drivers to invest: commercial, strategic and/or self-generation of electricity. Commercial projects are those were profit making is the only reason to invest. Profit-making is almost always involved in decision making but sometimes this is *the only* motivation that brings economic actors in a new market such as that of renewable electricity generation. The strategic drivers are more complex and they are often accompanied by profit-making considerations. But developers can also be steered by both profit-intentions and by the interest to generate electricity for their own consumption with part of the capacity they install. This would be a case of 'partly-self-generation' motivation to invest. Self-generation projects can also have a strategic interest such as a green image or a learning wish in order to take over a new market position at a later time. Therefore, this classification needs to be seen flexibly, in the sense of differentiating among the *dominant* drivers behind investments. Table 3.2 summarises some main drivers for project developers to invest in RETs.

Table 3.2 *Drivers for project developers to invest*

Type of motivation	explanation / form
Commercial	Profit-making is the strongest reason to invest
Strategic	Early market-positioning reasons, such as: - future competitive advantage through lower production costs - specialisation for new roles in the industrial arena (in different stages of projects' life-time - feasibility, development, construction, operation) - improved overall market position in the electricity system - capture green demand: market share and knowledge specialisation
	Green image
	Ideology / genuine environmental concerns
	Local business opportunity
	Testing upgraded / new technological designs
Partly-self-generation	Industrial, commercial or residential needs for electricity generation

The investment behaviour of developers will depend on how their drivers to invest can be accommodated in the environment where they are supposed to operate, from the perspective of financing schemes practically available and that of their own assessment of the risks and project profitability enabled by the support system. Most project developers are able to choose among more types of financing schemes to go ahead with their plans. But the feasibility of using the theoretically possible types of financing schemes will differ depending on the specific combination of risks and project profitability offered by the support system. It is useful therefore to suggest relations between types of financing schemes and drivers of project developers to invest under different risk-profitability circumstances. When profit-making is the strongest reason to invest, developments can be considered *commercial projects*. When for such projects external financing schemes are used, developers will have to comply with the risk-profitability criteria of financing agents. Having in view the distribution of preferences for

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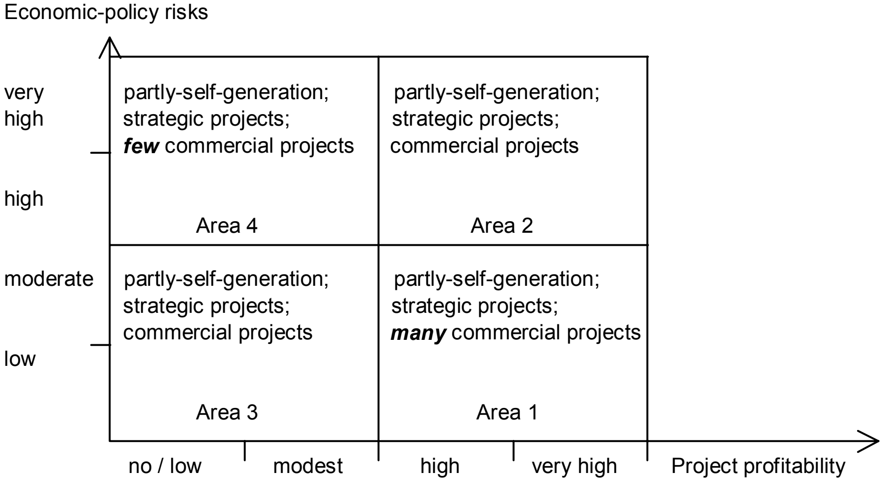
[20] The FIRE research project highlights empirical findings regarding the relation between types of financing schemes, project sizes in terms of total investment costs per project, and the legal ownership form of project. We mention and use these findings in Section 3.4 and 3.5.

risk-profitability investment contexts among financing agents represented in Figure 3.2, one can hypothesise that in minimal investment contexts (Area 4) there would be only few externally financed commercial projects, in political (Area 3) and entrepreneurial investment contexts (Area 2) they would be present to some small extent, while in optimal investment contexts (Area 1) they would be very numerous.

When commercial projects are internally financed, they would have a similar distribution. In political investment contexts, small developers may find a good niche market to invest since large industrial corporations and energy companies will not be so much interested to invest, unless they are under a direct obligation such as a quota demand for renewable electricity purchase or investment (see Chapter 2). Small developers have generally lower profitability requirements than large developers. In some contexts, depending on the business culture dominating at national level small developer may even expand their investment interest in minimal and entrepreneurial investment contexts. But in order to attract the participation of large developers in RET diffusion, profitability opportunities would need to be higher. Large developers are likely to invest in more projects under entrepreneurial contexts than under political investment contexts. Consequently, commercial projects are likely to dominate the investment picture only in optimal investment contexts. The expected presence of commercial projects under different risk-profitability environment is represented in Figure 3.3.

Figure 3.3 *Drivers to invest under different risk-profitability investment contexts*



Strategic projects form a more complex category of investments. Five categories of strategic drivers can be differentiated: early market positioning, green image, ideology, local business opportunity, and demonstration of new or upgraded technological designs. In the first case developers are driven by ‘tomorrow's advantages’ considerations. They see the new technology(ies) as a promising market segment where, the earlier they enter and acquire competitive knowledge and experience advantage, the more can they consolidate their position both in that new market segment - domestic and foreign - and more generally in the electricity industry. Entrance can be seen in this case worth doing even in conditions of high investment risks and low or no profitability in the short-term. One of the benefits that project developers expect in the long-term is the possibility to generate electricity at lower costs than competitors, based on the learning experiences during the different stages in project’s life-time - feasibility studies, project development and construction, and project operation. But similarly important are their chances of acquiring other profitable positions in the new market segment, by specialising in some or all activities that have to be carried-out during the life-time of RET projects. Building on the expertise acquired with their own projects, these early developers will later be able to offer services to other companies investing in RETs and to achieve cost/performance improvements due to economies of scale both for them and the clients they serve.

Beside these two strategic reasons, developers may also be interested to capture the green demand segment. If investments are targeted on the environmentally-sensitive consumers, an early approach of green consumers could give them the advantages of reaching a better understanding of consumers' preferences and willingness to pay in terms of most efficient pricing schemes and time fluctuations of payment-level fluctuations. But this involvement can also help them gain experience in designing green marketing programs that can become a business opportunity in itself where these early developers could be key players.

But strategic projects can also be commissioned by economic actors who do not necessarily believe in a real bright future for RETs in which they can play a role. They can be developed even by sceptics who wish however to take advantage of current opportunities that these technologies could offer. If there seems to be already a worth-to-consider green demand on the market, both commercial generators and industrial self-generators may be interested to invest in RETs as a public-relations tool. For electricity generators this can support an increase in the sale of conventional electricity, while for industrial self-generators RET projects may help attract the competitors' green clients.

Two other equally important strategic reasons to invest in RET refer to green ideology and local business opportunity. In the first case project developers commission renewable energy plants wishing to serve other potential developers and financing agents an example that these new technologies work, are reliable and can be profitable. Would-be investors might await from them information regarding costs and procedures for early development stages for different types of technologies and projects.

Strategic projects can also be aimed at proving that there is a reliable green demand that can absorb the output of other projects as well. Non-governmental environmental organisations are a good example of possible economic actors who would proceed with such projects. But strategic projects can also be developed in order to make use of the advantage of having good resources and infrastructure closely and/or cheaply[21] available. Increase awareness or economic opportunities to invest in RET projects might induce companies or individual private investors and associations to become self-generators and save on their electricity purchase expenses in the long-term. But they can also be interested in becoming commercial generators when, having in view the cost-advantage offered by local resources (in the general meaning, not only energy-resources) and eventually also a favourable economic-policy framework, they can get a good competitive position. In other contexts, the choice to invest in RET might be only motivated by the fact that a project located in the physical proximity of the financing agent is preferable to a distant more conventional type of project, offering the investor a better control position over their plant (Langniss et al. 1998).

Strategic projects are more likely to be developed based on internal financing schemes, especially in the minimal investment context, and they could be seen under any economic-policy configurations. It is important however that developers have sufficient signals from the political echelon that there would be a market for renewables at a certain moment in time, even if the support system is not sufficiently supportive yet. When the traditional financing

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[21] This refers especially to biomass resources and the necessary transport and processing infrastructure.

community becomes more accustomed with renewables-based technologies, after having invested with positive results in commercial projects, then it might become possible to see certain types of strategic projects financed with the help of external financing schemes. Figure 3.3 shows the spread of strategic projects in different risk-profitability contexts.

The *partly-self-generation* motivation is potentially a powerful driver for RET investments, especially in liberalised electricity industries. The utilisation of the no-cost local renewable resources can be an incentive to invest even under a general prognosis of lowering consumers' prices especially when, in the developers' perception, future prices of fossil fuels and conventional electricity are likely to be volatile[22]. In time, developing skills and expertise, some self-generators may also expand their activities through commercial projects thriving even towards the acquirement of new positions and roles in the RET industry segment. Investments in partly-self-generation projects could be expected basically under any risk-profitability contexts and are also more likely to be developed based on internal financing schemes. The reliability of demand and price per kWh are important but not crucial as long as the capacity is chiefly dedicated for auto-consumption.

For such projects, the availability of support instruments such as investment subsidies, soft-loans, and some forms of fiscal benefits could improve the extent of RET adoption as compared to schemes based on price support per kWh delivered to the grid, since a part of the electricity generated is consumed. But it can be considered that a certain willingness to invest would still be present even in the absence of such support schemes, in some niche markets when advantages such as high resource availability or uneconomic grid-connection costs can still make RETs an attractive choice.

Figure 3.3 represents the expected presence of the three types of projects with the evolution of the two main characteristics of economic-policy support systems. In minimal investment contexts, one might see dominance of projects driven mainly by self-generation interests and strategic interests. Few commercial projects could however also be seen in the context of an entrepreneurial business culture in the respective country. From the strategic drivers discussed above, developments would be rather driven by ideology, local business opportunities and green image considerations. Investments based on early market positioning reasons are also possible if there are sufficient signs that the domestic or foreign market will develop, so as to compensate later for the low/modest profitability at the moment of engagement in the new business.

In entrepreneurial and political investment contexts, both commercial and strategic projects may be more numerous than under minimal support environments. In principle one can expect a balance among commercial, strategic and partly-self-generation reasons to invest, in these two risk-profitability contexts. Given the too high risk for many types of economic actors in the first case, and the too low profitability in the second case - when new entrants in the industry ponder to invest in renewables, they would rather do so when they also have a secondary benefit, such as partly self-generation or a clear strategic reason. But while commercial projects are most likely to be developed by large companies under entrepreneurial environments, they will be more probably owned by small developers under political investment contexts. Since the financial strength of the first group is larger than that of the latter, this implies a likely higher rate of installed capacity increase under entrepreneurial contexts than under political contexts - both due to likely more numerous projects and larger

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[22] When confronted with a legal obligation to generate or consume certain quotas of sustainable electricity, RET investments by industrial consumers, but also by residential and commercial consumers, might take a substantial leap forward.

size projects. In optimal investment contexts, commercial projects will have a dominant presence in the investment landscape. In the next sub-section we discuss the possible choices for technological designs under the four risk-profitability investment contexts differentiated.

3.3.2 Technological design

Given our interest in the sustainability of market diffusion processes, we are interested in the circumstances under which project developers may chose technological designs with performances possibly able to contribute to the expansion of diffusion potential of that technology in the electricity system. In Section 2.6.1 we differentiated among the following types of technological designs: conventional designs, designs bringing modest contribution to diffusion expansion potential, and designs with substantial contribution to the potential for installed capacity increase. As a technology advances through the diffusion process, the innovation process accompanying it may bring new technological designs into the market, enriching the choice for investors. Nevertheless, both existing and new technological designs could have technical performances able to reduce - with modest or substantial contributions - (some of) the obstacles to diffusion with answers in the technical field. The market adoption of these technological designs may contribute to the increase in the technically, economically and/or socially feasible diffusion potential of that renewable resource in the electricity system, on a long-term basis.

The question is, however, to what extent project developers may be interested in - or aware of - the fact that some of the technological designs they have available for choice are able to support the long term growth potential of the respective renewable resource type. Theoretically, one can expect that such designs would be adopted by project developers when they have ambitious long-term investment plans based on the respective RET. In this case they are more likely to become aware that sooner or later the technical specifications these ‘diffusion-optimal’ designs have, are desirable to expand their own business’ market share. Or they may even become required by competent authorities, for example in the approval process or at the time of renegotiations of the electricity purchase contracts.

But in order for developers to arrive at a long-term commitment for large-scale investments in a renewable technology, the investment context needs to attract them by means of high profitability levels. This requires however that the purchase of renewable electricity is not limited in terms of amounts per owner or the involvement of individual economic actors in RET investments.

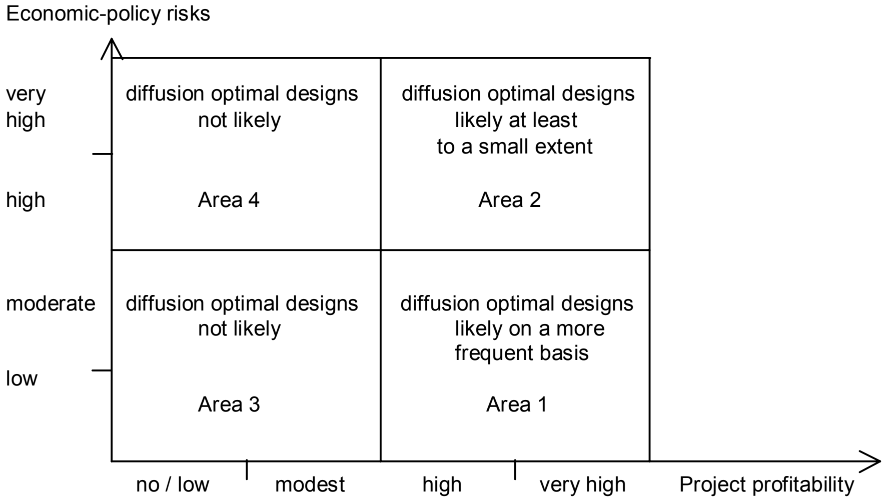
When investment risks are high, such as in entrepreneurial investment contexts, developers and manufacturers would need an understanding of the political motivation for the high risks. This way, when these are motivated by the goal of encouraging competition among investors while political commitment on renewables’ diffusion support is perceived as reliable, more developers may take a long term business view in renewable electricity. This may bring into focus the issue of technology design and optimal technical specification for large scale investments. When the high economic-policy risks appear to be a side effect of confusion, uncertainty or weak commitment at the level of political and administrative echelons, investors are more likely to take a short-term business view with possible impacts on the concern for technology designs. In this case, developers are less likely to give the same priority to such technological designs as in the case of an optimal investment context.

In political and minimal investment contexts there may also emerge economic actors interested to take a leadership position in renewables’ long-term investments. However, this is more likely to happen in the more attractive ‘sub-context’ (of Area 3), where economic-policy risks are low and profits with modest profitability could be built. But in principle, in the two contexts, investors would rather pursue conventional technological designs, that have a proven track-record and do not pose additional technology risks to the project's cash flow', given the fact the support system enables only low or modest profitability for projects.

When new technology designs become available with technical performances that enable project developers to yield higher profitability, we refer to them as 'investor-effective' designs. Due to the fact that they will stimulate investments, both by attracting more types of economic actors to invest and by stimulating more numerous investments, investor-effective technological designs can be considered as bringing modest contribution to the diffusion expansion potential of the respective technology. Although the stimulation of economic actors to invest is the key to diffusion, in this context we consider cost performance improvements as 'modest' contributors to diffusion sustainability because, diffusion processes remain under the threat of stagnation when the technical or economic barriers cannot be pushed any further. Hence, the expansion of installed capacity could still be halted, in spite of the fact that there may still be investors attracted by the cost performances of the respective RET under that support system.

Consequently, we expect that in optimal investment contexts the adoption of new or existing technological designs with potential for *substantial* contribution to diffusion expansion could be quite frequent. In the entrepreneurial context (Area 2) the adoption of such designs is likely, at least to a small extent. However, in political and minimal investment contexts, the main concern of developers will be for conventional technologies or investor-effective designs with modest contributions to long term diffusion expansion potential. Figure 3.4 represents these theoretical expectations.

Figure 3.4 *Expectations on the adoption of diffusion optimal technological designs*



The next section refines the two-group classification of types of financing schemes - internal financing schemes and external financing schemes. This serves for a better understanding of the accessibility to financial resources in different risk-profitability investment contexts created by support systems. This section builds on the typology made by Langniss et al. (1998) in the research project regarding the modes of financing for renewable energy systems in European countries. But the typology is refined by differentiating among eight, instead of five, types of financing schemes. In addition, it helps to get a better insight into the types of project developers, their motivation (using the classification made in Section 3.3.1) the likely sizes of projects and eventual consequences for the choice of technological designs. The original typology on which it builds concentrates on the legal ownership form instead of groups of project developers and refers to project sizes in terms of total investment costs. A discussion on the likely sizes in terms of installed capacity is however more helpful for the purpose of deriving expectations regarding the rate of diffusion expansion.

The considerations in Section 3.4 are at the end formulated in the form of assumptions regarding the relationship between investment risks and projects' profitability, financing schemes, project developers, and investment decisions regarding projects sizes and technological design. These assumptions are built by combining theoretical considerations in financing literature with empirical literature and observations on renewables diffusion in Westerns European countries during the 1990s. In this way, the proposed refined typology of financing serves our research interests by hypothesising linkages between the selected indicators for diffusion patterns.

3.4 The influence of the national risk/profitability environment on financing schemes, project developers and sizes of RET power plants

The financing of renewable energy projects has long been a major barrier in the market introduction and diffusion rate of these innovative technologies. The novelty of using renewable - and especially intermittent - resources in power generation technologies has made many investors and financing agents sceptical regarding their technical and economic feasibility. For decades they hesitated on whether and under which conditions they would be willing to contribute to the financial needs of new types of power plants. To overcome the financing obstacle, various innovative financing schemes were designed, especially during the 1990s, adding to the more traditional ones used in the electricity industry - corporate finance and project finance. Innovative financing structures were resorted to either as a means of risks sharing for investors, or as an effort of capital mobilisation. But empirical literature arrived to use a confusing variety of terms when referring to the options of project developers to fuel cash into sustainable energy projects. The capital structure of RET projects can be quite complicated, assuming combinations of financial sources. In this study, we propose to analyse financing based on a typology that differentiates between financing schemes, on the basis of two criteria:

1) main forms of financing in the capital structures of projects - i.e. the balance between internal equity, external equity, and debt, and
2) the assets and financial-reserves taken into account for debt repayment.

We distinguish therefore among eight types of investment financing divided in two large groups. The first group is that of external financing schemes where two approaches can be distinguished: project finance and institutional finance. In the second group, of internal financing schemes, we differentiate among: private finance, participation finance, in-house corporate finance, debt-corporate finance, third-party finance, and multi-contribution finance. The typology is inspired from Langniss et al. (1998) who classify financing schemes as: private finance, corporate finance, project finance, participation finance and third-party finance. To these, we add institutional finance and multi-contribution finance, and split corporate finance into two options: in-house corporate finance and debt-corporate finance. Under the in-house corporate finance approach the company uses exclusively its own financial reserves to invest while under the second scheme it uses debt having adding this way a second financing agent to the project. The adjustments we made are motivated by the interest to study financing schemes closer from the standpoint of the relationships between debt financiers, equity contributors and project initiator[23].

In the theoretical discussion following here, a RET investment will be categorised as a certain type when the main source of finance associated with that type accounts for more than 50% of project investment costs. When more financing sources are used without any of them holding more than 50% in the project's capital structure, this will be considered a case of multiple-contribution finance.

The following eight subsections discuss each type of financing scheme by presenting its capital structure and main financing parameters, the types of economic actors that are more likely to use each scheme, the types of projects in terms of drivers to invest feasible to implement under each scheme and the likely ranges of project sizes. Besides we also specify the issue of the risk-profitability contexts where each financing scheme is likely to be used and the consequences for project developers and project sizes when the risk-profitability environment changes. Regarding project sizes and the financing forms, we make three assumptions[24].

Firstly, projects developed with equity as the main form of financing in a project's capital structure have smaller sizes than projects developed with debt as main financing source (ceteris paribus). This assumption rests also on the idea that when an investment plan is cash-intensive and the developer does not manage to procure the needed financing, the only solution to go ahead with the project is to reduce project size to the level that his equity capacity is able to cover. Besides, as it is known from financing literature, a unit of equity invested will yield more profits the lower contribution of equity be in the capital structure of the project (Davies 1998; del Pozo 2001). This gives the incentive to equity investors to increase project sizes when debt is available as main source in the capital structure.

Secondly, projects developed with debt as the main financing form will have smaller sizes when the debt is guaranteed by private or corporate assets than in the case when debt is guaranteed by the RET project being financed (ceteris paribus). Thirdly, the sizes of externally-financed projects based on loan (project finance) have very low elasticity to both the risks and profitability levels surrounding investments (ceteris paribus); when approved, such projects will have medium or - most often - large sizes[25].

In continuation we discus first the two types of external financing schemes and then the six types of internal financing schemes.

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[23] The classification of Langniss et al. (1998) did not go in detail into the extent of financial contribution of the project owner in the capital structure of the project. For example, we differentiate between in-house corporate finance and debt corporate finance. Under the first scheme project owners contributes with majority equity financing. In the second case project owners uses mainly debt based on on-balance sheet approach. Besides, the schemes of institutional finance and multi-contribution finance do not appear in their classification.

[24] These statements are drawing on the assumption regarding financing structure decisions formulated in Section 3.2.2.1, which stated that "developers would prefer to use debt as main financing source. From the two types of debt, investors would prefer to use the project finance type first, followed by debt of the corporate finance type. The use of internally generated equity would come on the third place of preference."

[25] Both economic literature and empirical observations show that banks have minimum thresholds above which they are willing to issue loans. Some express this in money form, other put direct lower limits for the size plants that they wish to finance (ETSU 1996; Mitchell 1994; Wiser and Pickle 1997; Langniss et al. 1998; interviews in Spain with public agencies and private developers of wind power plants).

3.4.1 External financing schemes

We consider in the group of external financing schemes two approaches using non-recourse debt: project finance and institutional finance.

3.4.1.1 Project finance

Project finance has been so far the most frequently used means of financing power stations, especially by independent power generators (Finnerty 1996). In the financing literature a plant is developed under project finance when more than 50% of finances comes from debt, for the repayment of which lenders decide on debt terms by looking "*primarily*[26] to the cash-flow of the project to repay loans, and to the assets of the project as collateral" (Ingersoll et al. 1998). The rest of the contribution comes in the form of equity. Equity contributors can be any types of economic actor - small developers or large developers[27]. In categorising investments as based on project finance we look at whether one or more distinguishable economic actors are the equity suppliers in the project. However, when equity comes from institutional investors, we consider the project as being based on institutional finance (see next sub-section).

Theoretically, any type of economic actor can make use of this type of finance[28]. However, financing agents have often preferences for the types of economic actors for whom they agree to approve loans. Small developers and companies with no track record in the energy industry could find it more difficult to secure debt. Usually, when loan is approved, this attracts interest rates that can be several percentages higher than those required from large developers. Besides, a higher equity contribution may as well be required, while the debt maturity could be shorter than that asked from large developers. The *business culture* of the national financing community will have a large impact on the picture of project developers using project finance for renewables' diffusion.

But the picture of project developers will also be influenced by the risk-profitability context for investments. The higher economic-policy risks are, the higher the *interest rates* will be. Under the same project profitability, developers will experience a reduction in their returns-on-equity. When the equity returns fall below the cut-off equity requirements of the project developer, he will withdraw from the market. At industry level this could make entire groups of economic actors potentially interested in renewables, to stay away from the emerging market.

Besides, as the economic-policy risks increases, financing agents will lower the contribution of debt in the capital structure of projects. But also debt contribution can be diminished if the external financing agent considers the profitability of the project too small

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[26] The emphasis on the word 'primarily' is placed by us. When the only loan securities are project's revenues and assets, this is referred to in the economic literature as 'non-recourse project finance'. But there are cases when additional loan securities are also required, that are not specific to the RET-project. These can be private assets, general company's assets or other financial resources of project developer. This is referred to in the literature as 'limited recourse project finance' (DTI February 2000: 10). Although this has some consequences on the level of financing costs and the other financial parameters of loan arrangement, we consider 'non-recourse' and 'limited recourse' financing to belong to the same category in the typology that we propose here - the category of 'project financing'.

[27] For a more elaborated discussion on project finance for renewable energy projects see Ingersoll et al. (1998), Mitchell (1994) or (1993), Kahn (1995); Wiser and Pickle (1997); or Siddayo (1993).

[28] The project developer can be an existing company. But it can also be a new company that emerges from established firms. In this case the aim could be to invest only in the project at hand, or more generally in renewable power plants. In empirical research we refer to the first example as project vehicle company and to the second as RET-specialised company.

and risky for his debt repayment. When projects need more *equity participation*, the small developers who are not able to supply large amounts of cash for the projects would have to abandon the investment plans. In addition, the more equity a project bears, under the same level of project profitability, the lower the returns-on-equity will be. This, again, could drive away from the market large developers who often have higher cut-off equity return requirements.

But in principle, with the increase of risk levels, the *picture of project developers* will change towards the dominance of large developers. This is because only financially strong companies will be able to offer the large amounts of equity required by banks in order to approve loans. When the project initiator is a small company that does not have sufficient cash reserves, he will have to require external equity from a larger company or specialised institutional investment fund, changing the ownership of the project.

As the profitability offered by support systems for projects decreases, the number of financing agents willing to provide debt for projects will also lower. As summarised in Table 3.1, only credit banks and building societies are likely to finance low profitability investments. In some countries, commercial banks and pension funds may also approve debt for modest-profitability projects, as long as economic policy risks are low. In political investment contexts, when project finance is possible, the picture of developers using this scheme is more likely to be dominated by small companies.

In terms of the *motivation* of project developers to invest, commercial projects are more likely to implement by means of project finance. Project developers mainly motivated by strategic reasons may also receive project finance debt, as long as the risk-profitability context corresponds to the financing agent. However, it is unlikely that demonstration projects will be financed. Project finance is a scheme that is generally used for well tested, commercially mature technological designs. The energy technology needs to have a proven capacity to generate predictable volumes of cash flow. All technology risks have to be hedged through instruments such as technology performance insurance, or manufacturer guarantee for power curve[29] and maintenance contract.

Investments in partly-self-generation projects are also not very likely because only part of the plants' installed capacity will raise money from selling electricity to the grid, while the rest is consumed by the owner. The price per kWh or other forms of financial support received have to be very generous in order to enable the repayment of debt in the same period that a commercial project selling all power to the grid could do[30].

In terms of *likely presence* of the project finance scheme in different investment contexts, the information summarised in Table 3.1 and Figure 3.2 based on financing literature suggests that:

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[29] This means that the manufacturer is able to guarantee on that under certain operating conditions (such as wind speed, annual solar radiation or energy content of biomass resources) and maintenance schedule, the renewable power plant will produce a certain volume of kWh electricity per unit of time.

[30] For these types of projects, the electricity costs of the would-be self-generator are usually calculated over the economic life-time of the RET system (based on market price of electricity or local utility price). This part of the investment costs is not normally expected to be recovered from project's cash flow, as those expenses would have occurred anyway. But the extent of price support in the support system needs to enable the recovery of the difference between total investment costs and the multi-annual electricity costs that would have incurred, had the investment not been done. A period of 10 to 12 years is the most often debt-maturity requirement, in conditions of low investment risk (Gish 1999). In some cases it could also raise to 15 years when there is a power purachse contract that covers at least this period. Depending on its size and the price received per kWh, a partly-self-generation project, may need a much longer time to recover the investment costs.

- basically all types of financing agents would approve project finance under optimal investment contexts;
- the availability of project finance will be more restricted under entrepreneurial and political investment contexts, but the extent of presence depends on the business culture of financing agents active in the national market; in the first context the business culture with regard to investment risk is more important, while in the second the business preferences with regard to projects' profitability are more important;
- under minimal investment contexts project finance is likely to be used only when special types of financing agents such as credit cooperative banks, building societies and ethical banks are present in the domestic market.

As regards *project sizes*, banks usually set thresholds for the minimum amount of money they are willing to provide as loan. Sometimes these thresholds are directly formulated in terms of installed capacity of project in MW. This puts investments in small size projects at a disadvantage with the consequence of driving small developers away from the option of debt financing. Small developers can only resort to project aggregation strategy, which could be organised by a public agency (see Section 2.3.1.3). Alternatively they can invite other economic actors to provide external equity in order to allow the project grow in size to the requirement of the debt financier. Consequently, the *sizes of projects* developed based on this scheme will be most likely medium or large-scale systems.

As *diffusion stages* are concerned, in the first period of market introduction interest rates can be very high for all types of developers because of the risks associated with a new business. Besides, the debt maturity will be shorter while the debt contribution to the project's capital structure will be smaller. These adverse financing parameters are typical for any new technology or business area. Policy makers need to take account of this and compensate this by means of financial support that may still enable sufficient profitability of projects. When the use of a certain technology becomes a familiar business option, the financing parameters will gradually shift towards those typical for the traditional technologies and industrial sectors[31].

3.4.1.2 Institutional finance

In the typology of finance that we propose, we consider 'institutional finance' as the financing modality where the project initiator is a financing agent specialised in equity gathering for renewable energy project[32]. The specialised agent may supply equity to the project or not. His main role is to gather financial resources from the capital markets, organise them in equity funds, arrange non-recourse debt financing, and develop the RET project by carrying it out through all the necessary stages from feasibility study to construction[33]. We classify in this category both projects where the main source of finance is non-recourse debt and projects where the equity fund contributes to more than 50% of finances in the capital structure. The main difference as compared to project finance is that project owners are not clearly identifiable economic actors, and that the project initiator is generally not co-owner of the RET

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[31] The typical formula of project finance assumes 20% equity and 80% loan, with 6-7% interest rates and debt maturity between 8-12 years. But loan contribution can be sometimes as high as 95%.

[32] This does not mean that RET investments represent their only business area, but that they dedicate part of their human and financial resources to investments in renewable energy projects.

[33] In some cases the project initiator also takes care of maintenance and operation during project's life time. But more often, once a project is put into operation such tasks are taken by companies specialised in maintenance and operation.

power plant. We consider also as characteristic for institutional finance the exclusive *commercial motivation* to invest.

Any type of economic actor and financing agent - from households to industrial corporations and venture capitalists - may be a contributor to such equity funds. For example, the private equity raised by one European institutional investor includes: banks, government agency, private individuals, corporate investors, pension funds, investment trusts, insurance companies, and academic investors (Zemke 2001). The role of specialised project initiator can be taken theoretically by any type of financing agent mentioned in Table 3.1 for which the last column specifies 'equity' as possible form of finance. But the extent to which these financiers would be interested to proceed with such a business activity depends on the demand for debt for RET investments in the country, and how attractive are RET investments compared to the alternative business areas domestically and/or internationally available.

In principle the organisation of RET-specialised equity funds is time consuming, more bureaucratic and assumes higher transaction costs than the option of investing by means of debt. It is possible that as long as debt financing is highly demanded on the market, the demand for equity funds will not be so high. Besides, debt and the associated interest rate are always repaid before any equity dividends. Hence, the potential contributors to equity funds may prefer to invest in funds managed by financial agents who provide for debt for RET projects.

When the competition with other business areas and with the debt-financing of RET projects is substantial, the profitability of RET projects should be high in order to attract large participation. A British study into the institutional investors attitude towards renewable energy funds found that equity investors expect returns in the range that extends from 15% to 35% over at least five years (ETSU 1996; DTI 2000). In addition, the profitability of the project also needs to cover for other business profits of the project initiator. Often equity investors require the possibility to exit the investment within a short period of time: some would prefer 3-5 years, while other would stay for 6-7 years under circumstances of low risk (Zemke 2001; ETSU 1996).

The equity return requirements may differ per fund, depending on the financial expectations of the main contributors to it. But in principle, in the first stages of diffusion, institutional finance is more likely to be seen under optimal investment contexts. When the support system creates an entrepreneurial or political investment context, diffusion it may be possible to observe the use of this scheme at later stages of diffusion. Looking at Table 3.1 it appears that the following financing agents could theoretically take the role of equity gatherers and project initiators in political investment contexts (modest profitability and moderate risks): universal banks, investment banks, savings banks, ethical banks and pension funds. In entrepreneurial investment contexts, the main financing agents will be merchant banks, venture capital firms and insurance companies. The use of this scheme has an important role in diffusion, since it expands considerably the financial pool for renewables' investments. The likely presence of this type of financing scheme in different risk-profitability environments resembles, therefore, that expected for project finance.

In terms of project sizes, these could be lower than in the case of project finance. But, in principle, the project initiator could raise large financial resources in short time after a well organised marketing campaign, and provided that the competition on capital markets is not so high. This would enable large-scale RET projects which are also highly desirable because this type of financing scheme assumes very high transaction costs and administrative effort. Therefore plants of all sizes could be basically developed under an institutional finance scheme, but the probability to see mostly medium/large size plants is quite high. The considerations in terms of technological design will be focused on its maturity. Being only short-term commercially oriented, institutional investors and project initiators are interested in the least expensive and well-tested commercially mature technology design.

3.4.2 Internal financing schemes

In the category of internal financing scheme, project developers use either only equity, or equity in combination with 'on-balance sheet debt' - that is debt guaranteed with the private or corporate assets and financial reserves of equity contributors other than the RET project developed (DTI February 2000: 4). The project developer takes all risks associated with the RET plant. Therefore, as opposed to external financing schemes, the economic-policy risks do therefore not influence the financing parameters of projects, such as interest rate, debt maturity, and the debt-to-equity structure of capital when recourse-debt is used. Besides, the decisions on plant size and technological choice are not influenced by debt-financiers. We discus below each of the six types of financing schemes we include in this group.

3.4.2.1 Private finance

Private finance assumes the use of the personal funds of the project developer - exclusively or combined with a loan that is backed-up by his value-worth private assets. The financing agent estimates credit risks based on any private assets of the developer which are considered to have a market value during the debt maturity period. The project developer is in the same time the owner of the facility and bears unlimited liability for the projects' financial performances. This type of finance allows for higher debt maturity period and lower interest rate, compared to the use of project finance in the market introduction stage.

Project developers using this scheme are individuals or partnerships of few individuals who could be relatives or neighbours or work-colleagues. This type of economic actors are hardly likely to succeed in attracting project finance from banks, unless some financing agents in the country have a policy to support small developers' economic activities or ethical projects. As regards the drivers to invest, all three types of projects could be conceivably commissioned under private finance - partly-self-generation, strategic[34] or commercial. In terms of the types of technologies, because of their financing difficulties, these developers are more likely to show preference for well-tested low-cost ('investor-effective') technology design. Project sizes would be characteristically (very) small, given the reduced financial power and asset-value of individual persons or households.

3.4.2.2 Participation finance

Participation finance can be defined as the financial modality "where numerous investors participate (…) with a personally adapted capital amount" (Langniss et al. 1998) into funds aimed to supply more than 50% in a project's capital structure, by means of either equity or debt. The funds may be formed through contributions from private savings, money from bank loans secured by private assets, or internal reserves of firms, non-governmental organisations and cooperatives. The rest of the financial resources needed to complete the project comes from debt, from any other external financing agent. Given the ownership of projects under this type of financing scheme, external debt could only be in the form of non-recourse debt financing[35].

[34] Projects commissioned based on ideology considerations - green/ethical reasons, and local business opportunities are more likely types of strategic projects.

[35] When such a fund provides less than 50% in a project's capital structure, this would fall into the category of project finance.

The equity investors are mainly individuals (e.g. farmers or households), cooperatives, non-governmental organisations and small firms. The empirical literature refers to them as ‘community of interests’ or ‘community of neighbours’[36]. The community of interests refers to equity investors that have in common a special interest to invest in renewable energy resources or more generally environmentally friendly projects. Such a community can be formed by means of a company specialised in gathering equity funds and developing projects by harnessing the financial resources of this niche of investors.

The projects based on this type of financing may be developed either by a specialised company, in which case the literature refers to it as ‘developer-led’. But they can also be ‘community-led’. In the first case, as a British guide for community investment describes it: “The developer’s aim would be to establish a renewable energy project and sell power and, after the commissioning stage, to sell on the project at a profit to a group controlled through the investment of a large number of local residents. The developer would assist the new group in preparing to manage the project and might also take on a contract to operate the equipment on their behalf.” (DTI 2000: 21). Hence the developer need not be also co-owner though its minority equity participation is possible. Due to the need of the developer to raise profits for its activities, the support system needs to provide for at least some modest overall profitability on projects, so as the RET plant can remain profitable also for the community buying the project after completion. Under the community led model, “the project is initiated, owned and managed by the community itself” (Archer et al. 1999).

The difference between participation finance and institutional finance is on the one hand, in terms of minimum profitability and maximum risk acceptability. Only few types of institutional investors are willing to invest under modest profitability support systems or under high risk from the support system[37]. But communities of interests or neighbours are more likely to invest in projects with low/modest profitability and/or higher economic-policy risks. Examples of investments under such investment contexts have been empirically documented in Western European countries[38].

On the other hand, while the motivation of institutional investors is exclusively commercial, projects owned by communities of neighbours also bring inextricably the benefit of contribution to the local security of supply and local business opportunity for equity investors. Empirical research showed that in Western European countries the participation financed projects - especially the community of interest projects - were strongly motivated by environmental consideration. Besides, the RET power plants may also be designed as partly-self-generation projects.

When the main driver to invest may be self-generation purposes and selling the eventual extra-output to the grid, and when the main motivation is ideological or interest in a local business opportunity, project owners are more likely to accept to invest under minimal investment contexts. When more profit-oriented investors are substantially involved in equity/debt fund supply, the limits of acceptable risks and profitability may rise. Therefore, ‘participation finance’ scheme may be found under all four types of investment contexts we differentiated.

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[36] For more information on community projects for renewable energy see DTI (2000); Archer et al. (1999); Leaney and Heslop (2002). The most common form of legal entity is the cooperative, but it can also be a limited private company, or a partnership, or combinations of these (Langniss et al. 1998).

[37] The two types of financing schemes have in common only two main features: the fact that the project initiator and the project owner are different economic actors, and that the project owner is constituted by a multitude of economic actors.

[38] See Langniss (1996), Langniss et al. (1998), Archer et al. (1999), Mitchell (1994 PhD Dissertation).

As regards the choice for technological design of the type of RET used, it is less likely that a community of neighbours would be in search for a investor-effective design. Since such an owner will probably not invest in too much capacity beyond his immediate territory - that is village, city or province. The owner would then rather look for existing investor-effective designs or even new technological designs in so far as their cost-performances are good. A community of interest may take, however, also a longer term view and be interested also in the diffusion expansion performances of the design of their choice. In the case of 'developer-led' projects, however, the technological choice is strongly dependent on the communication between the project initiator and the would-be owners of the power plant.

As project sizes are concerned, it is more likely to observe mainly very small, small, or medium-size projects. The sourcing of more than 50% of the financial needs of a project from the types of economic actors mentioned in the introduction, combined with the first assumption on plant sizes and financing that we made[39], suggest that plants would rarely reach large proportions. As investment risks increase, project sizes may not necessarily decrease in size as long as the financial contribution of each economic actor participating in the fund remains in average small[40].

For governments, encouraging participation finance can also be regarded as a way of dealing with local opposition to RET projects. This opposition can be motivated either from environmental standpoint - e.g. noise and landscape intrusion, or from economic standpoint as locals disagree with the drainage of local resources by other economic agents having benefits out of this. However, the implementation of this financing approach requires very high transaction costs and is extremely bureaucratic. But, it can be particularly stimulated by means of fiscal incentives to investors in such funds.

3.4.2.3 Debt-corporate finance

Debt corporate financing is a terminology that we choose in this analysis, in order to better differentiate between consequences for the selected characteristics of investment decisions - motivation, plant size and technology design. In the theoretical and empirical literature, only the term corporate finance is used. This is not suggestive for whether debt is used or only the internal financial reserves of the company are involved. We assume that the presence of debt could make a difference for investment decisions.

We define debt-corporate finance as the scheme where the main source of finance - more than 50% - is constituted by a loan for the repayment of which financing agents take into account the developers' credit-worthiness and solvency. The project developer can be any economic actor organised as private partnership, corporation, or cooperative (Langniss et al. 1998: 8), as well as a public utility or public company. The company's financial strength and market-valuable assets will be therefore the guarantees considered when making decisions on loan terms - interest rate, debt maturity, and equity contribution. The debt maturity can be anywhere between 10 years and 30 years, depending on the flexibility of the financing agent[41].

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[39] This assumption stated that projects developed with equity as the main form of financing in a project's capital structure have smaller sizes than projects developed with debt as main financing source, ceteris paribus.

[40] That is to say: when the financial resources of the fund increase mainly by means of numerical investor participation than individual cash contribution.

[41] Donaldson mentions that loans provided by banks generally have a maturity of 10 years while those placed with long-term financiers such as insurance companies may have 20 year or 30 year maturity (Donaldson 1971: 10).

In principle, the balance equity-loan for this financing approach depends mainly on the financial strength of the borrowing company. The developer asks the financing agent for a loan but he does not necessarily have to justify how that loan would be spent. What the debt financier asks is to look into the company's financial reserves and to assess the value of its assets in order to understand whether in case the borrower fails to repay the loan the financier may recover the non-reimbursed amount and interest rate from the cash reserves and sale of liquid assets owned by the company.

This way a company may require a very large loan for more projects planned to pursue - many projects in more business areas. A part from this loan can be allocated to a RET project that may be this way financed even 100% with debt. Nevertheless, as the financial strength of the company decrease, the on-balance debt volume that a company may carry will lower accordingly. Medium and small size companies may not have the same capacity as powerful corporations to build large RET plants.

A combination of commercial interests and self-generation reasons to invest may underlie decisions to invest using this scheme even under conditions of low profitability. But the presence of partly-self-generation projects will increase under high profitability investment contexts where the period of debt repayment will be shorter.

But empirical research so far shows that investments based on this approach had a strong strategic driver, especially in the form of early-market positioning. Projects were commissioned using this scheme even under conditions of no-cost-recovery, but with the expectation of large future market in medium-term (Arrieta 2001). Therefore, when strategic and self-generation considerations drive investment decisions, the scheme can be used under any levels of economic-policy risks and project profitability, since loan guarantees are independent of the projects' economic performances.

The sizes of projects developed under this scheme can be very diverse, reflecting the financial strengths of the developer. However, taking into account the second assumption on project sizes and financing made in the introduction of Section 3.4, we may hypothesise that large-size projects for commercial purposes will rather be commissioned when project finance is not possible or when it has negative consequences for the return on equity.

Similarly, the types of technological designs adopted can be diverse. New designs may be likely to be tested with the help of this financing approach, especially under lower economic-policy risks. When the company has long-term investment plans in substantial RET capacity, or when it has ownership links to companies in the industry that might impregnate a long-term perspective on diffusion, a conscious search or choice for diffusion-optimal designs is also likely.

3.4.2.4 In-house corporate finance

We define the in-house corporate financing as a modality of financing whereby funds are mainly - more than 50% - coming from the internally available cash reserves. The project developers may be the same types of economic actors as in the debt-corporate finance case.

This type of financing can be done in two ways: through on-balance-sheet financing, when the RET energy system is considered a new asset of the company, or through parent-company financing when an affiliate/subsidiary company is especially created for the RET project (Langniss et al. 1998: 11). In both cases, project costs are covered either entirely by the (parent) company's equity, or by a combination of more than 50% internal equity with a bank loan that most frequently requires other assets of the company as loan guarantees, than the RET project being commissioned.

Taking into account the assumption on financial structure decisions made in Section 3.2.2.1, the in-house corporate financing scheme is more likely used when:

- economic-policy risks are too high, or project profitability is too low, to allow for project finance approval by banks;
- debt-corporate finance is not feasible due to internal company reasons, such as the preference not to worsen relationships with banks in case of project failure to perform as predicted, in a highly risky investment environment.

The scheme assumes a more than half contribution of equity in the capital structure of projects. This means that the returns on the unit of equity invested will be considerably lower than in the case when the project finance or a debt-corporate finance scheme was used, assuming the same project profitability. Therefore, if project profitability is too low for their cut-off requirements on equity returns, companies are likely to prefer postponing investments in commercial projects for the time when project finance or debt-corporate finance becomes available. Therefore, under political and minimal investment contexts (see Figure 3.5 further below), the most probable drivers to invest based on the in-house corporate finance scheme will be given by strategic and self-generation considerations.

For example, in the case of electricity companies, investments may be part of a business strategy to attract more buyers for conventionally generated electricity, as they can provide evidence for the company's concern for environmental problems, and a determination to start doing 'clean business'. But this scheme can also be used by an industrial company that prefers to retain its capacity to use debt-corporate finance for its core activities but wishes in the same time to become self-generator. Project profitability needs to have however levels that allow the developer to recover part of the investment costs by selling part of the output to the grid.

Commercial projects using this scheme are more likely to be observed at higher levels of project profitability, such as in the optimal and entrepreneurial environment (Figure 3.5). The scheme can therefore be theoretically found under any levels of economic-policy risks and project profitability, although its presence may be driven by different motivations under different investment circumstances.

The sizes of projects will be rather small or medium size, due to the cash-intensity of this scheme. For the same reason, more expensive technology designs are less likely to be adopted - maybe even when they would be cost efficient for the investor on project life time basis. Well-tested and commercially mature technology designs are more likely to dominate investments under this scheme, since developers would prefer to avoid to cumulate economic-policy risks and technology risks in the same project. However this does not exclude that investments by financially strong companies can be made in diffusion-optimal technology designs when such companies take a long term view on diffusion with large capacity business plans.

3.4.2.5 Third-party finance

Third party finance is a scheme that helps economic actors having difficulties in financing their investment plans. A private company, public agency or energy utility develops, finances, installs and owns the project and sells the electricity to the respective economic actor based on contracts under private law. Alternatively the owner can sell the power partly to the electricity grid company (or on the market) and partly to the consumer for whom it built the project. After all investment and variable costs have been recovered from electricity sale, plus the required project profitability, ownership of the project is transferred to the economic actor for whom the plant was intended. The flow of cost recovery can also be organised in the form of lease financing whereby the developer receives regular payments that are contractually fixed.

The additional advantages for the electricity user are that the new investment does not appear on the balance sheet (leaving him with a higher capacity to carry corporate debt), while the investment does not require a large capital mobilisation from the electricity user (Langniss et al. 1998: 17). For the third party financier this investment approach (with 100% output sold to the consumer) is more attractive than for commercially motivated investors, because the purchase of electricity is secured for the entire period of investment cost recovery of the project. The owner is protected from the political and regulatory risks for demand, contracts and price. Therefore, this scheme may be found under any level of economic-policy risks in the support system. Given that the risks on cash flow are very low, it is conceivable that the range of project profitability of developers can already start at 'low' levels, while the use of this scheme can be expected to increase the more the profitability of projects increases. The contractual price is set bilaterally. But this is likely to be at least at the level enabled by the support system, because otherwise it would be more profitable for the developer to sell to the electricity company under the protective support system.

In addition to the 'consumer application', third-party financing can also be used by a public agency or by a manufacturer of renewable technology to develop commercial projects for energy companies or industrial corporations when - even under attractive conditions of risks and/or profitability, the perception of renewable technologies is not sufficiently favourable to unlock the market introduction process. In this case, the developer is also a strategic investors. This scheme has also a large potential of market-catalizer by serving as example for potential project developers and financing agents who do not dare to be early-movers.

The project developer may use either external financing schemes, or one of the two forms of corporate financing. Having in view that the most likely type of consumers are households, farms, cooperatives, communities, non-profit organisation and small and medium size production companies, small companies, the projects based on this financing scheme are more likely to be (very) small or medium-size investments. The issue of project sizes is therefore related to the would-be owner and not to the risk-profitability profile of the support system. The choice of technology design is generally made by communication between the would-be owner and the commercial developer. The concern for diffusion optimal designs is likely to be low when the would-be owner is a small economic actor with limited investment interests in RET. When the project is developed for a large company that need to gather evidence regarding the technical and economic attractiveness for renewable technologies - and especially when the developer is a manufacturing company producing such designs - the likelihood to choose diffusion optimal design increases. In principle however this is a scheme more likely to be used in the first stages of market diffusion when long term consideration of technology features are of less concern for developers and owners.

3.4.2.6 Multiple-contribution finance

This scheme has the same characteristics as the in-house corporate finance scheme but there is a difference in terms of project developers. We define multiple-contribution finance as the case when equity dominates the capital structure of the project, but it comes from more economic actors who are co-owners and project developers. Any type of economic actor may be involved in such a scheme. The equity could come from internally available financial resources but also from loans procured based on private or corporate assets' guarantees. Projects can also have small contributions of loans issued based on non-recourse finance criteria and terms. This scheme may be a suitable tool for market entry of recently emerged firms or investments by small private companies encountering financing barriers in more conventional terms. But it is also suitable for demonstration projects, being able to help with the market introduction of new technological designs.

Project sizes could be larger than in the case of in-house corporate scheme, since equity contribution is split among more developers. The risk-pooling approach, assumed by the fashion in which the project's capital structure is built, indicates its suitability for any level of economic-policy risks. As Fabozzi and Nevitt (1996: 9) phrased it "risk sharing is advantageous when economic, technical, environmental and regulatory risks are of such magnitude that it would be impractical or imprudent for a single party to undertake them". As regards technological design, the pooling of support system risks may make easier the decision to adopt new types of design for testing or for commercial application. The use of this scheme - as in the case of in-house corporate financing - is more likely when:

- economic-policy risks are too high, or project profitability is too low, to allow for project finance approval by banks;
- debt-corporate finance is not feasible due to internal company policy.

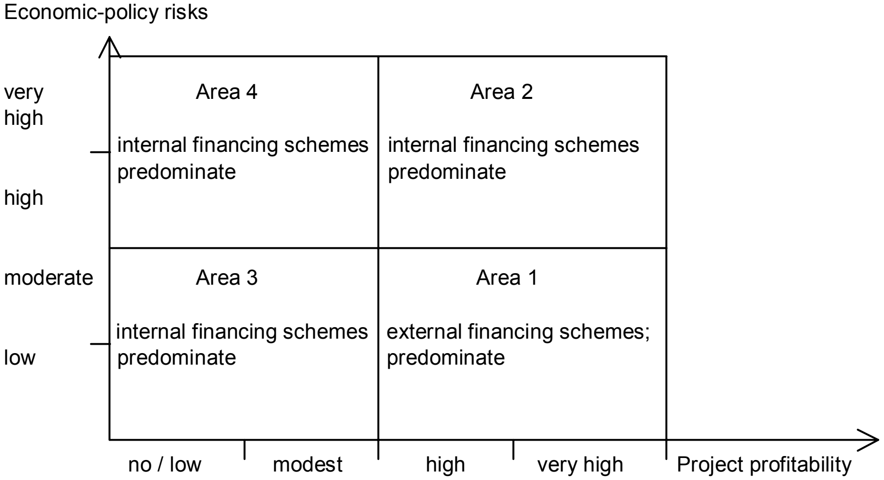
The developers are more likely to have commercial and/or strategic interests to invest - especially for the demonstration of new technical designs. Self-generation projects using this scheme are likely only in so far there is also a physical proximity of the would-be consumers, or in cases when only one of the equity investors consumes part of the plant power output, while the rest of the co-owners sell the remaining output to the local electricity company.

Commercial projects using this scheme are more likely under entrepreneurial and optimal investment contexts, because the high equity-intensity of this scheme requires higher levels of project profitability to ensure investors the same equity returns. Strategic projects and partly self-generation projects may be found in all four investment contexts.

3.4.3 The presence of financing schemes in the risks-profitability investment contexts

Based on considerations made in this Section, 3.4, Figure 3.5 shows the likely dominance of financing schemes in the risk-profitability landscape created by support systems.

Figure 3.5 *The presence of financing schemes in the risk-profitability investment contexts*



All internal financing schemes may be used in any risk profitability context. In order for the project finance scheme to become feasible, the support system for renewable electricity needs to create conditions for at least modest ranges of project profitability, and below moderate economic-policy risks. The use of project finance under high risk levels may be possible when institutional investors are present in the national market. Their use is especially expected at later stages of market diffusion, when technology risk perceptions disappear, leaving more space for accommodating the economic-policy risks.

The institutional finance scheme will be mainly used under optimal investment contexts (Area 1). Institutional investors and merchant banks may also be interested to invest based on this scheme under entrepreneurial investment contexts. Under a political investment context, banks, pension funds and building societies may also develop projects based on the institutional approach.

Based on these considerations we hypothesise that under entrepreneurial, political and minimal investment contexts internal financing schemes will predominate. Having in view the assumption on capital structure decisions made in Section 3.2.2.1, we further hypothesise that under the optimal investment context external financing schemes will take the lead and predominate.

The next subsection summarises the relations among the forms of diffusion patterns' indicators that we hypothesised throughout Section 3.4. They are presented in Table 3.3.

3.4.4 Probabilistic relations among the indicators for diffusion patterns

In Section 3.2, we discussed the likely willingness to invest of the traditional financing agents in various risk-profitability environments, on the basis on financing literature. Further, in Section 3.3 we looked at the possible motivation to invest that developers may have under different risk-profitability contexts and their interest in diffusion-optimal technological designs. The typology on financing schemes that we proposed in Section 3.4 relates types of project developers with investment decisions regarding motivations to invest, ranges of project sizes and technological choice. Looking from a financing perspective, the issue of technology designs can mainly be hypothesised with regard to their maturity, and only to a limited extent with regard to the relevance for diffusion expansion potential. Table 3.3 summarises the probabilistic relations among the indicators for diffusion patterns.

External financing schemes will be overwhelmingly used for commercially motivated projects. Commercially mature technological designs will rule investment choices. When diffusion optimal designs are perceived as commercially mature, they may also enjoy wide popularity among investors. Project sizes will be most probably medium or large-size. Project finance scheme can be theoretically used by any type of economic actor but national business preferences of financing agents will be decisive for who enters the market. In principle, the main difference is that banks in some countries are open for investments by small developers while in other countries they are not easily approachable.

In the case of the six *internal financing schemes*, the particularities of investment decisions could be more diverse than for external financing schemes. Project sizes, technological choice and the dominant drivers to invest will differ largely depending on the investment circumstances. In principle, it can be expected that the use of private finance, participation finance, in-house corporate finance, and third party finance will be associated with small or medium-size projects. The projects developed based on debt-corporate finance and multi-contribution finance are more likely to take also large sizes.

As regards technological design, investors using participation finance and in-house corporate finance can be expected to be interested only to a small extent in new designs and diffusion optimal designs. But more likely is the interest in such designs under the use of third party finance, debt-corporate finance and multi-contribution finance. Small investor using the private finance scheme would be rather focused on commercially mature technologies. Any of the three drivers to invest differentiated in this analysis can motivate investments based on internal financing schemes, with a low likelihood to observe partly-self-generation plants under multi-contribution finance. Table 3.3 mentions the types of project developers expected to make use of each of the six types of internal financing schemes differentiated.

Table 3.3 *Probabilistic relationships among indicators of diffusion patterns*

Types of financing schemes	Types of project developers	Investment decisions		
		Main driving factors to invest	Projects' sizes	Technological choice
A. External financing schemes				
Project finance	any economic actor	mostly commercial; rarely: partly- self-generation	Mostly medium / large size projects	Commercially mature
Institutional finance	any types of economic actor through specialised financing agents	commercial		
B. Internal financing schemes				
Private finance	individuals	partly-self-generation strategic commercial	Mostly very small / small / medium-size projects	Commercially mature
Participation finance	communities, NGOs, associations, cooperatives			New designs & diffusion-optimal designs likely to a small extent
In-house corporate finance	any economic actor organised as partnership, corporation or cooperative			
Debt-corporate finance			All sizes possible	New designs & diffusion-optimal designs can be expected
Third party finance	*Developer*: public agency / large companies; *Would-be owner*: mostly small developers	*Developer:* commercial and/or strategic. *Would-be owners:* partly-self-generation	Mostly small / medium size projects	
Multi-contribution	any economic actor	Mainly commercial and strategic	All sizes possible	

The probabilistic relations mentioned in Table 3.3, as well as the expectations summarised in Figures 3.3, 3.4 and 3.5 constitute the basis for formulating the theoretical expectations regarding the influence of support systems on diffusion patterns. The hypothetical relations are stated in the next section that concludes the first part of our theory.

3.5 National risk-profitability investment context and diffusion patterns of renewable electricity technologies

National economic-policy support systems influence the diffusion patterns of renewable technologies at which they are aimed by means of the risk-profitability investment context they create. In order to formulate the expectations on diffusion patterns more clearly, it is necessary to operationalise at this point the term of project profitability. We propose the following operationalisation of the profitability characteristic: ‘low’ - up to 4%; ‘modest’ 4% - 8%; ‘high’ 8% - 12%; ‘very high’ > 12%. This operationalisation is based on literature and expert knowledge obtained in interviews.

As regards the ranges of profitability preferences of different types of developers, these vary among countries. However, based on the empirical studies available so far that refer to the cut-off equity-return requirements of different types of economic actors, and our personal communications, the following minimum expectations appear. Small developers in some countries would be interested to invest in contexts offering equity returns that are at least one-two percentages higher than the saving interest rates offered by saving and commercial banks (WPM January 1996: 17; WPM October 1994: 46; interviews in the Netherlands). Taking into account that interest rates for in balance sheet debt start generally at 6%, and that saving interest rates may be around 3-4%, the minimum project profitability possibly acceptable by small developers may already start in the ‘low’ range (when the contribution of debt to the capital structure is small).

Energy companies/utilities (not exposed to profitability ceilings from regulations) appear in some cases to be willing to invest at equity returns of 6-7%. However more often they would require minimum levels of 9-10%. When on-balance-sheet debt is used as main source of capital, with 6% interest rate, their minimum expectations for project profitability will be in the ‘modest’ range. When 100% equity is used to finance the project, the profitability requirement could start only in the ‘high’ range for the more demanding electricity companies.

Table 3.4 *The influence of economic-policy support systems on RET diffusion patterns*

Minimal investment context (Profitability: cost-recovery / low / modest Risks: high / very high)	Entrepreneurial investment context (Profitability: high / very high Risks: high / very high)
- internal finance schemes only - small developers predominate - mainly partly-self-generation and strategic projects - very small size projects predominate - adoption of new and/or existing diffusion-optimal technological designs not likely	- internal finance schemes predominate - large developers predominate - balanced presence of partly-self-generation, strategic and commercial projects - small and medium size projects predominate - adoption of new and/or existing diffusion-optimal technological designs likely to a small extent
Political investment context (Profitability: cost-recovery / low / modest Risks: low / moderate)	Optimal investment context (Profitability: high / very high Risks: low / moderate)
- internal finance schemes predominate - small developers predominate - balanced presence partly-self-generation, strategic and commercial projects - small size projects predominate - adoption of new and/or existing diffusion-optimal technological designs not likely	- external finance schemes predominate - large diversity in types of developers possible - mainly commercial projects - medium and large size projects predominate - adoption of new and/or existing diffusion-optimal technological designs, likely to be more frequent

Large corporations entering the electricity sector from other industrial backgrounds may have in their first period of market operation higher profitability requirements due to the risk perceptions the operation in a new business area brings about. However when the business opportunities in their original field of action are shrinking offering them already decreasing equity returns opportunities, the market entry in the electricity sector may take place for investments with only modest profitability on projects.

As for the institutional investors their equity returns expectations vary between 10% and 35% (ETSU 1996, DTI 2000, Zemke 2002). Assuming the use of debt for 80% of the projects capital needs and a low interest rate of 6%, this means that the ranges of minimum project profitability would be for some institutional investors around 9% while for others 12%, that is in the ‘high’ and ‘very high’ range. However, the higher the interest rates would be (expectable in the first stages of diffusion for non-recourse debt), and the higher the equity contribution to projects capital is, the higher the requirements for projects’ profitability will be. Table 3.4 summarises the theoretical expectations on diffusion patterns, which we present in the following three sub-sections. The next sub-sections define theoretically the four investment environments.

3.5.1 Diffusion patterns under optimal investment contexts

Under *optimal investment contexts*, the use of all types of financing schemes is possible, since the system combines the attractiveness of (very) high profitability and low/modest risks. However, given the availability of external financing schemes, these are likely to be the dominant form of financing. A large diversity of types of developers can be theoretically expected. Nevertheless, the business culture of traditional financing agents may impede investments by small developers, and in some cases also by larger developers that are new entrants to the energy business. Although some developers may be mainly interested in self-generations, while others will invest also motivated by some strategic considerations - such as new technological designs testing, green image considerations, local business opportunity or ideology - commercial motivation will be the main driver to invest. Medium and large size projects will probably predominate. The adoption of new and/or existing diffusion-optimal technological designs is likely to be frequently observed in the diffusion boom expected.

3.5.2 Diffusion patterns under entrepreneurial investment contexts

Under *entrepreneurial investment contexts,* there will be a smaller number of financing agents willing to provide for non-recourse debt and institutional equity. This would limit the possibility of developers to use project finance and institutional finance. Therefore, internal financing schemes will be the predominant financing vehicle under this context. Given the high risks, not as many economic actors would be interested to invest in commercial projects as in the optimal context. This would be especially the case during the first stages of diffusion when technology risk perceptions are also high, increasing the risks on project cash flows.

Commercial projects in this context are more likely to be built by electricity companies and large industrial corporations who are more accustomed with doing business in high risk environments. But large developers are also likely to be motivated by various strategic considerations, when the political echelon gives reliable signals of long-term structuring of the electricity industry towards sustainable production. All aspects of early market positioning mentioned as strategic drivers in Table 3.2 may constitute reasons to invest under this type of support systems. The presence of projects combining a strong strategic motivation with the commercial interest in the high profitability of the support system may have a significant presence in the investment landscape. Industrial production companies of all sizes would also have a good opportunity to invest in (partly-)self-generation RET systems when they have a good availability of renewable resources locally or renewable electricity could be easily transported to their consumption points.

Small developers are also expected to invest but mainly when they have self-generation interests. The market entry of small and medium-size companies that never operated in the energy field exposed to high business risks is not probable to happen to a large extent. In the national contexts where they are accustomed to, and have a tradition of operating in high-risk business environments in their own core-business sector, their involvement in commercial RET projects may be more significant. But in principle, their presence will be lower than under optimal support systems, where beside lower risks they also would have had a chance for external financing. Consequently, we expect that in the motivational landscape at industry level the strategic, commercial and self-generation reasons would be equally represented.

As regards project sizes, given the need for internal financial resources - equity corporate debt and private debt - combined with the exposure of these financial sources to high risks, projects are likely to be on average at industry level in the range of small and medium-size. The project of large developers using external financing schemes could be in the large size range. But having in view that we do not expect the use of external financing schemes too frequently, small/medium sizes could be rather expected. The adoption of new and/or existing diffusion optimal technological designs is likely to a small extent. This will rather take place, though, mainly by means debt-corporate finance, third-party financing and multi-contribution finance. The forms for diffusion patterns expected for this type of investment context are mentioned in Table 3.4.

3.5.3 Diffusion patterns under political investment contexts

Under *political investment contexts,* internal financing schemes are likely to predominate. External financing might take place based on the project finance scheme but this is strongly dependent on the business profitability requirements of the banks operating in the respective national context. Only a few types of financing agents may be willing to approve project finance loans when the profitability range is low, while several more other types may join the investors when there are modest levels of profitability (see Table 3.1).

The presence of commercial projects will be smaller than in the case of the optimal context. This is mainly due to the shrinking of the group of large developers that would be attracted to invest, the more the profitability moves towards the low-levels area. Large corporations and electricity companies have often cut-off equity-return criteria of 8-10% or higher. When projects are based on equity-intensive financing schemes, such as the in-house corporate, participation finance or multi-corporation finance, the equity returns will be only slightly higher than the profitability of the project (or the same for 100% equity). Only debt-corporate finance or third party finance would enable a corporation to increase the equity returns. Hence, to the extent that corporations (can) use such schemes, they may have interest to invest in political investment contexts.

Small developers are more likely to be interested in renewables as a business with mainly-commercially motivated projects or for self-generation purposes. Large developers with lower cut-off equity requirements would as well find this type of context attractive to draw up more ample investment plans. In terms of technological choice, the expectation in Section 3.3.2 was to observe mainly existing conventional technologies or investor-effective designs. Small developers prefer to deal with simple technical designs, since they do not dispose of the technical expertise that large corporations may have or hire in consultancy. They will be more interested in improvements that offer them immediate financial benefits, or solve local technical challenges, rather than being concerned with designs more fitted for sustained diffusion.

Taking into account the expected predominance of small developers and the limited availability of project finance, projects are likely to be predominantly in the range of small sizes. The projects with dominant strategic motivations built by companies whose cut-off profitability requirements are above those offered by the support system (e.g. project aiming at early market positioning or ‘green image’ projects) will also probably be in the same of very small to medium size. Consequently, we expect the diffusion patterns to take the forms mentioned in Table 3.4.

3.5.4 Diffusion patterns under minimal investment contexts

Under *minimal investment contexts* internal financing schemes are likely to predominate. Only few types of financing agents would be willing to approve project finance. Also the number of economic actors interested to start a new business area with commercial RET plants is likely to be very small. Partly-self-generation and strategic projects will dominate. Small developers may build commercial projects and partly self-generation projects. But a small presence of large developers could also be observed, with investments in mainly strategically motivated projects. These are more likely to be electricity companies investing on the base of green image considerations or concerned with the security of conventional fuel supply. Projects could also aim at meeting the voluntary demand for renewable electricity from green consumers.

Strategic and partly-self-generation projects may also come from large industrial production companies interested to use local energy resources and save electricity bills. When the policy context does not suggest improvements in the features of the support system in the near future, projects are not likely to be motivated by strategic considerations such as future competitive advantage through lower production costs and specialisation for new roles in the industrial arena.

Numerically, the minimal investment context will not be able to stimulate as many strategically-motivated projects as the political and entrepreneurial investment contexts. Having in view the (very) high risks in the support system and the expected landscape of project developers with the dominance of small developers, the sizes of projects are more likely to be in the range of ‘very small’. In this type of investment environment, it is probable that developers would choose for existing conventional technologies or investor-effective designs, since the issue of long-term diffusion prospects is unlikely to be of interest for investors. All these considerations are represented in Table 3.4, which shows the most likely diffusion patterns for the five selected indicators under four basic investment circumstances represented by specific combinations of economic-policy risks and project profitability enabled by support systems. As we argued in Chapter 2, their analysis is needed in order to understand if a certain support system is effective in stimulating installed capacity increase in short-medium term and if the diffusion process can be expected to be sustainable in long term.

In conclusion, diffusion patterns appear to take substantially different forms in the four investment contexts differentiated based on the economic-policy risks and ranges of project profitability. These diffusion patterns have consequences for the rate of market growth. The installed capacity increase induced in short-medium term of support system application - assuming no changes in the risk-profitability context in this time - is likely to be different. Besides, the patterns of diffusion will have consequences for the prospects of long-term market growth of renewable technologies. The next section formulates the expectations with regard to the effectiveness of support systems in terms of potential for installed capacity increase, and with regard to the prospects for sustainable market diffusion processes. Section 3.6 forms the second part of our theory that answers theoretically research question seven.

3.6 National risk/profitability support environment, diffusion effectiveness and the sustainability of market diffusion of renewable technologies

We consider that diffusion processes for a renewable electricity technology would be sustainable when the level of costs and technical performances enable the expansion of installed capacity based on the respective resource to the level offered by the national siting-feasible potential, without the application of a support system.

But, even when technologies are not able to fully exploit the technically available resources base at cost competitive price, we view diffusion processes also as sustainable when they induced a level of dynamics and embeddness of renewable technologies in the industrial structure and the socio-economic fabric to a point where a total withdrawal of the support system would not be politically desirable. Governments may replace support systems in time in order to follow the improvements in cost performances of technologies and contain societal costs of diffusion. However, when sufficient support pillars emerged through stakeholders in the social, economic and industrial sectors, the political cost of totally abandoning the support for renewables would be higher than continuing to support them, when the economic and/or financing barriers have not been overcome yet[42].

In Section 2.7 of the book, we explained that the empirical analysis of the prospects for sustainability of market diffusion processes needs to be discussed from three perspectives (see Figure 2.10):

- technical performances in relation to available resource potential;
- cost performances in relation to available resource potential;
- technology embeddness in the national socio-economic and industrial structure.

Table 3.5 *Expectations regarding the features of the socio-economic-industrial contexts*

Diffusion results in short-medium term		Area 1	Area 2	Area 3	Area 4
Installed capacity increase		large	modest	modest / small	very limited
Diffusion context likely to emerge					
Socio-economic benefits		large	modest	modest / small	small
Local	Direct: ownership	likely	likely small	likely	likely small
	Indirect: more attractive benefits than usual from ~ land rents; ~ local taxes;or ~ local economic or social welfare investments	likely high	likely modest	not likely	not likely
	Indirect ~ local employment	Technology specific (construction and operation works)			
National	Ownership individuals (shares)	likely	not likely	likely	not likely
	Employment in industry[43]	likely high	likely modest	likely modest/small	likely very small
Industrial basis and dynamics		large	modest	modest / small	small
Number companies offering products / services for renewable plants		large	modest	modest / small	small
Types of companies involved in industry		large presence of corporations from diversity of industrial sectors		mostly industrial companies with activities in conventional energy technologies	
Degree of specialisation in renewables		high	modest	modest / small	small

It was pointed out, however, that theoretical expectations will only be formulated with regard to the impacts of diffusion patterns on the socio-economic benefits emerging from technology adoption, and the size and dynamics of the national industrial basis for the renewable

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[42] The core assumption of the analytical framework, is that *no other types of obstacles impede diffusion,* such as social opposition, environmental, or administrative obstacles.

[43] Employment in the renewable technology industry depends on the extent to which a price competitiveness policy is pursued like in the UK or a national technology embeddness policy is pursued, like in Spain. In the first case employment is rather created abroad as most developers are likely to import the cheapest technology.

technology studied. The selected indicators for diffusion results, based on which prospects of diffusion sustainability should be discussed, are listed in Table 3.5.

On the basis of the hypothesised diffusion patterns summarised in Table 3.4, we derived expectations regarding the likelihood that socio-economic benefits that would be optimal for diffusion continuity will be realised under each of the four types of investment contexts differentiated, and what the level of these benefits could be. Besides we also derived expectations regarding the size and dynamics of the national industrial basis for the supported RET.

In Section 2.7, we discussed the optimal forms of the indicators for diffusion results, that is forms that would improve the prospects of sustainable diffusion processes. A large diversity in the types of developers and the large-scale availability of external financing schemes were considered as core preconditions for a sustainable diffusion. They are likely to lead to more pervasive socio-economic benefits and to a larger, more competitive, and more politically influential industrial basis for the renewable technology supported. If external financing schemes do not become available, diffusion could continue but only as long as the involved types of developers could internally finance capacity expansion.

The expectations on diffusion results, including installed capacity increase, likely to be observed after short-medium term of diffusion (operationalised as 5-10 years) are presented in Table 3.5. In the following four subsections we explain them for each type of risk-profitability investment context and summarise them in hypotheses.

3.6.1 Diffusion patterns and results induced by optimal investment contexts

The first hypothesis regards the diffusion potential of optimal investment contexts and can be stated as follows.

Hypothesis 1:
A support system leading to a national investment environment of low to medium economic-policy risk and high to very high levels of project profitability will induce *diffusion patterns* that are characterised by:

- the involvement of all types of project developers, having
- predominantly commercial motivation to invest, using
- predominantly external financing schemes, in
- mainly medium and large size projects, based on
- the use of all types of technological designs where new and/or existing diffusion-optimal technological designs are likely to be more frequent.

Such diffusion patterns will result in:

- a *large installed capacity* increase in short-medium term; and
- *good prospects for the sustainability* of market diffusion processes in the long term for the renewable technology envisaged.

The following aspects of diffusion concur, in our view, towards the expectation for a large installed capacity increase in short-medium term:

- investments of mainly medium and large size projects
- numerous projects possible due to:
  - ~ the very large financial pool created through the potential interest of all types of financing agents to invest by means of both equity and debt, and

~ the attractiveness to invest based on commercial motivations for all types of economic actors.

The large demand for renewable technology products and services for the building, operation and maintenance of RET plants leads to (see Table 3.5):
- large number of companies entering the industrial sector to serve the rapidly increasing demand
- a substantial influx of corporations from a diversity of industrial sectors, attracted by the new business opportunity
- an increasingly high degree of specialisation of industrial companies in activities related to the respective RET in general or even for specific products or services in the life-cycle of RET plants, and
- likely high employment in the RET national industrial sector.

The strengthening of the industrial basis will potentially lead to fast and substantial progress in technical performances towards diffusion-optimal technological designs and decrease in technology-specific costs and the costs associated with project development, construction and operation contributing to the improvement of cost performances (see Section 2.8). In addition, these developments will also create a high potential for political lobbying in favour of RET financial support.

Socio-economic benefits in the form of local direct ownership and investments by individuals (households), communities, and other types of small developers investing locally are likely, since there is the expectation that all types of developers will be interested to invest. A different result may be seen however when there are financing obstacles for small developers drawing on the business culture and business requirements (plant sizes) of debt financing agents.

The intense competition of developers for sites where context conditions, such as resources and infrastructure, may improve the economics of their projects, is likely to lead to high benefits for local population and authorities that could contribute to projects' success. Enabled by the high profitability of projects in this investment context, high benefits could be expected from large developers, in the form of land rents, local taxes, or local economic or social welfare investments. Besides, local employment in construction and operation works is also likely to be maximised under this type of investment context. But since this is technology specific, it would be not appropriate to formulate theoretical expectations.

Finally, a large scale adoption of diffusion optimal technologies also contributes to the sustainability of diffusion by means of increasing the level of technologically exploitable resource potential and/or its integration in current electricity systems.

When the diffusion patterns and installed capacity increase did not lead to cost-competitiveness of RET and the support system is under threat of withdrawal, the political lobby becomes essential for diffusion continuity. The potential for political lobby for support systems' maintenance may be high and multidirectional under optimal investment contexts. It can act at the level of national competent political authorities through the channels of:
- local politics, by means of local and regional authorities interested in the economic and security of supply gains of RET diffusion, who would also carry the positive message from local people and local companies;
- representatives of a wide range of national industrial sectors involved in the manufacturing and operation of RET
- large corporations and electricity companies with ownership stake in RET plants.

The synergies of the multidirectional political pressure that this investment context is able to induce are more likely to contribute to the political decision of support system preservation than in any other support system.

3.6.2 Diffusion patterns and results induced by entrepreneurial investment contexts

The second hypothesis regards the diffusion potential of entrepreneurial investment contexts and can be stated as follows.

Hypothesis 2:
A support system leading to a national investment environment of high to very high economic-policy risk and high to very high levels of project profitability will induce *diffusion patterns* that are characterised by:

- predominantly large developers, and only to a limited extent small developers, with
- diverse motivations to invest - commercial, strategic and partly-self-generation, using
- predominantly internal financing schemes, in
- mainly medium and small size projects, based on the use of
- all types of technological designs where new and/or existing diffusion-optimal technological designs are likely to be used to a small extent.

Such diffusion patterns will result in:

- a *modest installed capacity* increase in short-medium term; and
- *possibly sustainable* market diffusion processes in the long term for the renewable technology envisaged.

Market diffusion processes could be sustainable if the *business culture of the traditional financing community* is characterised by flexibility in terms of willingness to accept risk and enable external financing schemes. A sustainable diffusion process could be then seen in long-term, through a gradual change in diffusion patterns towards those expected under optimal investment contexts. However, if the *investment interest of large developers* is substantial, given the available resource potential, diffusion processes have also good prospects of being sustainable in the absence of external financing schemes.

The following aspects of diffusion lead to the expectation of only modest installed capacity increase in short-medium term:

- investments of mainly medium and small size projects
- less numerous projects than in optimal investment contexts likely due to:
  - ~ reduced financial pool in the stage of market introduction (short-medium term) as a result of fewer non-recourse-debt financing agents operating in (very) high risk environments; and
  - ~ lower attractiveness to invest among large developers who would have the internal financial resources or access to on-balance-sheet capital to develop large size projects;
  - ~ the poor representation of small developers among investors.

The involvement of large developers in RET projects signals potential manufacturers and service suppliers the emergence of a serious business sector where the securing of early entry, experience and development of skills may pay-off. Investments in new designs of RET for demonstration projects will further strengthen the idea of a promising market, even when such designs are procured from foreign manufacturers. The stimuli for the emergence of a domestic industry can be assessed therefore as sufficiently strong.

However, the demand for products and services for the commissioning, operation and maintenance of RET plants will only come from a part of the theoretically available pool of large developers - those whose business risk acceptability expand towards (very) high levels. The number of companies becoming involved in the RET industrial sector is likely to be more reduced and slightly less attracted to specialise in technology and services for renewable power plants. But, given the high profitability possible for RET projects, the influx of corporations from a wide diversity of industrial sectors may still be high. When financial support from the governmental schemes is generous, the companies offering such services/products would still have prospects of profitable business. Hence, the migration from other industrial sectors may be the same wide as in the case of optimal investment contexts. This will lead overall to a likely modest-size industrial basis and dynamics. A dynamic rhythm of development of the manufacturing and support industry for RET plants creates the framework for fast and substantial reductions in technology-specific costs and the costs associated with project development, construction and operation.

We assess the extent of socio-economic benefits also as modest based on a similar logic. The employment in the RET national industrial sector and the local indirect benefits from investments by large developers will be of lower scales than under optimal support systems. The limited presence of small developers as investors implies that local benefits in good resource regions fail to be realised. In the same time, since investments by large developers will not be numerically as significant as under optimal systems, the socio-economic benefits from renewables' diffusion will be more limited nation-wide. This has consequences for the potential for political lobby, as the channel of local politics would probably not function or not be successful in reaching the central political echelon.

The long-term diffusion prospects depend in the business culture of the traditional financing community with respect to flexibility in willingness to accept risks. Financing agents often refuse to provide loans for renewable technologies when, in the first stages of diffusion investment/support systems risks are assessed as high, while in the same time there is a perception of high technology risks associated with RET. Handling two important types of risks in the same time is difficult even for many types of equity investors (project developers) who generally have higher risk ceilings than debt-financiers. However, when a successful track-record is domestically built and large developers, of whom perhaps many are traditional business partners of banks, continue to show interest in the RET industry for manufacturing, services and electricity generation, the attitude of financing agents may change[44].

When traditional financing agents are flexible in their risk requirement and external financing schemes become available in long term, this could possibly also attract a change in the other forms of diffusion patterns towards those expected under optimal investment contexts[45]. Project finance may bring a larger diversity in types of developers interested to invest. This could include small developers, as well as large developers with lower business risk preference, since debt risks are carried then by financing agents. More commercial

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[44] Large developers are more likely to hedge away the economic risks they face than small developers. For example they may involve electricity companies purchasing renewable electricity into co-ownership of proposed projects. This would create the conditions for a faster improvement in risk perception by traditional financing agents, as compared to the political investment contexts, where the dominance of small developers is expected.

[45] As explained in Section 2.3, the availability of finance is seen as the motor putting into motion the dynamics of diffusion patterns.

projects become possible. They may be developed as large-size plants since non-recourse financing is mainly associated with large loan volumes. Institutional finance may bring a wide variety of economic actors into renewables' diffusion, from households to venture capital investors. As socio-economic benefits expand and as the industrial basis and dynamics grow, the chances for effective political influence towards sustained price support and sustained diffusion also grow.

If external financing schemes do not become available, diffusion may continue but only as long as - and depending on the extent to which - the involved types of developers are able to internally finance capacity expansion. The industrial basis and group of ownership stakeholders could eventually become sufficiently politically influential, when many large financially strong developers contribute to large-scale investments. In this case, diffusion would also have good prospects of continuity when (in the absence of political initiative) political pressure is successful in ensuring the maintenance of financial support for a larger scale exploitation of available renewable potential. Diffusion processes may therefore become sustainable also in the absence of non-recourse financing, especially when the available resource potential can be fully exploited by means of internal types of financing schemes through large developers.

3.6.3 Diffusion patterns and results induced by political investment contexts

The third hypothesis regards the diffusion potential of political investment contexts and can be stated as follows.

Hypothesis 3:

A support system leading to a national investment environment of low to modest economic-policy risk and low to modest levels of project profitability will induce *diffusion patterns* that are characterised by:

- predominantly small developers, but also by energy utilities and large industrial companies to limited extent, with
- diverse motivations to invest - commercial, strategic and partly-self-generation, using
- predominantly internal financing schemes, in
- mainly small size projects, based on the use of
- mainly conventional technological designs that are not likely to be diffusion-optimal.

Such diffusion patterns will result in:

- a *modest or small installed capacity* increase in short-medium term; and
- *possibly sustainable* market diffusion processes in the long term for the renewable technology envisaged.

Market diffusion processes could be sustainable if *three conditions* are simultaneously met:

1. there is a national tradition of entrepreneurship among small developers
2. there is a high level of individual welfare that would enable the expected project developers to invest in such technologies
3. the business culture of the traditional financing community is characterised by openness towards small developers and less stringent requirements regarding the minimum profitability of the projects they finance.

If the conditions are met, a modest installed capacity increase may be observed in short-medium term. A sustainable diffusion process could be then seen on a long-term, through a gradual change in diffusion patterns.
If these conditions are not met, there will be a small installed capacity increase and diffusion processes will be unsustainable.

The following aspects of diffusion lead to the expectation of only modest/small installed capacity increase in short-medium term:

- investments of mainly small size projects
- less numerous projects than in optimal investment contexts likely due to:
  - ~ a reduced financial pool in the stage of market introduction (short-medium term) as a result of fewer non-recourse-debt financing agents operating in low to modest profitability contexts; and
  - ~ lower attractiveness to invest among large developers who would have the internal financial resources or access to on-balance-sheet capital to develop large size projects;

Under political investment contexts small developers are likely to be more interested to invest than large developers. The involvement of energy companies and large industrial corporations may also be observed when the support system enables 'modest' profitability. However, in national contexts where the first two preconditions formulated in the hypothesis are met, there are good prospects for faster market growth. When small developers are economically active and interested to expand their investment involvement into business areas that have not been traditionally their field of operation, their entry into the electricity industry will be a more frequent event. But entrepreneurship needs financial resources in order to be implemented. In industrial countries with high level of individual welfare, private savings, corporate financial reserves, as well as the market value of private and corporate assets may form a large enough financial pool to enable RET adoption. Hence when these first two preconditions are met, market may grow to more than 'small' levels of installed capacity. But in order to reach a modest installed capacity increase in short-medium term, a high number of investments need to compensate for the smallness of plants due to the limited availability of financial resources per developer.

A second wave of market growth may be enabled when the third precondition mentioned is met in the national context. When the business culture of the traditional financing community is characterised by openness towards small developers and less stringent requirements regarding the minimum profitability of the projects they finance, the successful track-record of the operating plants may enable small developers to receive non-recourse debt on a more regular basis and from a larger diversity of financing agents.

When project finance becomes predominant, one could expect substantial changes in diffusion patterns, towards those expected under optimal investment contexts. On the one hand, there will be changes in the picture of project developers. Economic actors who did not have adequate funds or market valuable assets available to use internal financing schemes may resort to non-recourse debt. But also the economic actors who did not find it attractive to invest for low/modest profitability based on internal financing schemes may find it worthwhile to develop projects under project finance, since the returns per unit of equity invested increase with the increase of debt at lower interest rates. In the same time, smaller amounts of equity will need to be invested and the developer avoids locking its market valuable assets into on-balance-sheet debt.

As Chicken explains (1996: 18), the economic assessment generally made in the investment decision making process includes the question: "will the benefits from the expenditure justify the expenditure?” When the expenditure is large such as in the equity intensive arrangements of internal financing schemes and in on-balance-sheet debt (having in view that RET are very capital intensive), investments that yield only low/modest profitability may be viewed as not interesting. But project finance may bring this group of economic actors into the RET market.

On the other hand, having in view the preference of many banks for large loans, one can expect to see more medium-size and even large-scale RET plants. These developments would help diffusion towards modest installed capacity in short-medium term.

But these changes will unlock the domestic potential of economies of scale and technical improvements, with the possibility to see a stronger domestic manufacturing industry emerging in the long term than in the first period of market introduction.

Under political investment contexts, the size of the industrial basis and dynamics are expected to be smaller in the first diffusion period, as compared to entrepreneurial contexts. Firstly, as long as a substantial presence of large developers with the potential for large-scale long-term investment plants is not perceived as possible in short-medium term, fewer companies will be attracted to enter the RET manufacturing and service industry.

Secondly, due to the fact that there is a high cost pressure from the support system on the profitability of projects, RET investors will more keenly search for lowest cost technologies. This will be detrimental to a nascent domestic industry facing high start-up costs, as long as other countries have more advanced manufacturing industries. The chances of survival of the domestic RET manufacturing industry will depend to an important extent on technology adoption abroad. Hence, both the number of companies and the degree of specialisation in RET may be small or modest - depending on the perceived domestic demand and the opportunities for export - under a support system encouraging predominantly small developers.

In terms of industrial background of companies that would enter the manufacturing and service industry, the risks of low and only slowly growing demand, as well as competition from lower cost foreign companies are more likely to encourage electricity companies and industrial companies with traditional activities in conventional energy technologies’ manufacturing, engineering and project development. Such companies will need to make lower start-up investment costs when the type of RET they become involved in is to some extent related to their core-business activities in terms of equipment needs as well as technical expertise.

But the industrial background of companies forming the RET industry may also be influenced to some extent by technological particularities and the national economic context. For example, conventional power technology companies may be more interested in biomass-based technologies since they assume the same technological approach (see Section 2.4) and they have much in common in terms of equipment. However in the case of wind power technology, this technological approach borrows know-how from the aeronautics industry, with a possible application of the manufacturing equipment to wind turbines and blades as well.

In the same time when the economic situation in a country is declining, industrial companies may be interested to enter the renewables industry even in the above mentioned conditions of risk. Consequently, this indicator for industrial basis can be theoretically associated with market developments in the renewable electricity generation to a smaller extent than the other two. In the framework of empirical research, we will look at the extent to which there are discernible relationships among these aspects.

As regards the socio-economic benefits, under political investment contexts they will take different forms than under entrepreneurial investment contexts (see Table 3.4). When diffusion takes place by means of small developers, they are likely to often invest locally. This will bring a new form of local development and source of welfare. In the case when the developer is a ‘community of interest’ using the participation finance scheme (see Section 3.4.2.2) households and small private companies across the country will get a financial benefit from the greening of the electricity supply. However, at national level socio-economic benefits can be described as modest/small because the reduced degree of investment involvement by small developers, as compared to what could be recorded for higher levels of profitability, does not enable to harness sufficiently the economic and non-economic benefits that renewables could bring in regions where resources are located.

Besides, the local economic benefits that large-scale investments from large developers could have eventually brought do not materialise under this support system in the market introduction period. In terms of the three channels of political lobby, the possibility to exert political pressure at central level through local politics is more reduced, while the other two channels may also be insufficiently activated even after the achievement of modest capacity increase by means of small developer investments. As Burns (1985) expressed it: “most often small entrepreneurs lack access to or influence in the corridors of central power”.

When the third precondition mentioned in the hypothesis is not met in the national context, diffusion may continue as long as the financial situation of small developers can support this. The market entry of large developers may still happen to some extent, when the cost performance improvements achieved through diffusion or import of lower cost technologies can lead to the improvement in the profitability of projects under the same support system. But when profitability increase is taken away by reductions in price support from the government, the issue of political lobby potential for financial support maintenance becomes very important for the continuity of market diffusion processes. The hope is then vested in the potential for political lobby of small developers owning RET projects and the renewables’ manufacturing and service industry. If large developers are driven away again from the market, when the financial potential of small developers is exhausted investments could stagnate, compromising the chances of creating a sustainable process of market diffusion.

3.6.4 Diffusion patterns and results induced by minimal investment contexts

The fourth hypothesis regards the diffusion potential of minimal investment contexts and can be stated as follows.

Hypothesis 4:
A support system leading to a national investment environment of high to very high economic-policy risk and low to modest levels of project profitability will induce *diffusion patterns* that are characterised by:

- the dominance of private investments for (partly)-self-generation,
- in the form of very small/small projects,
- using conventional, commercially mature technological designs,
- commissioned by small developers and industrial production companies,
- based on internal financing schemes.

These investments may be accompanied by:

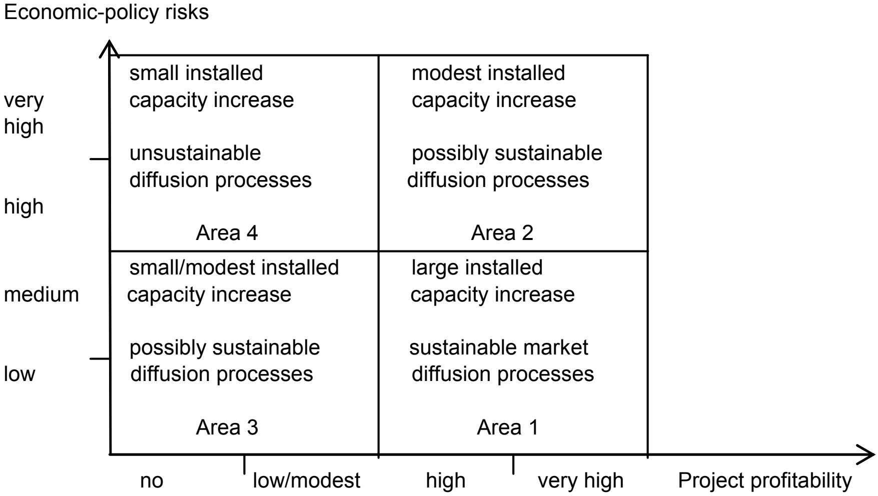
- small presence of energy utilities,
- driven by certain strategic reasons to invest,
- using also rather conventional commercially mature technological designs,
- based on internal financing schemes.

Such diffusion patterns will result in:

- *a small installed capacity* increase in short-medium term; and
- *unsustainable* diffusion processes in the long term for the technology envisaged.

These diffusion patterns cannot be realistically expected to produce more than a very small increase in RET installed capacity. Given the dominance of small developers commissioning plants for self-generation purposes, the chances to see emerging, domestically, companies for the manufacturing of RETs and companies becoming specialised in providing various associated services, are extremely low. Developers will rather use foreign technologies and services.

Figure 3.6 *The potential of economic-policy support systems to induce sustainable processes of market diffusion of RETs*



When support systems result in entrepreneurial (Area 2) or minimal (Area 3) investment contexts, we hypothesised that socio-economic benefits would only be partial, compared to what could be possible under optimal contexts. Likewise, the industrial basis and dynamics would be more reduced as a support system changes its risk-profitability characteristics from Area 1 towards Area 4. These expectations were derived again by looking at the likely diffusion patterns.

3.7 Summary

We started this chapter with some general considerations on risks. We specified that in this study we take an approach to risks that defines the possibility of failure to obtain a certain targeted profitability on projects under the economic-policy support system in place. The investment environment is shaped by a combination of certain and uncertain aspects of the support system in terms of type of demand, contractual relations, price design, contractual price methodology, and the level and duration of price support in policy support mechanisms.

Further, we made some general considerations on financing. We discussed briefly the main forms of financing - equity (internal and external) and debt - and presented the main characteristics of the main types of debt financing - non-recourse debt and on-balance-sheet debt financing.

With regard to equity investors we made two assumptions. Firstly, we assumed that each type of equity investor has his own preference for the range of risks and returns considered acceptable for investmenst. For some economic actors the acceptable risk range expands upwards towards high risks only with the increase on equity returns. For others, the risk-range of commercial operation is either limited to low or modest levels - no matter the returns to be expected. Alternatively, the willingness to invest in higher risk environments may not be constrained by proportionally high equity return expectations.

Secondly, we proposed an adjustment to the order of capital structure preferences often accepted in financing literature and referred to as 'the pecking order of finance'. We assumed that - whenever the support system enables high levels of project profitability - equity investors will prefer to use debt as main financing source. From the two types of debt, investors would prefer to use the non-recourse debt finance type first, followed by debt of the on-balance-sheet type. The use of internally generated equity would come on the third place of preference, while external equity remains the last option to be used.

The general considerations on financing continued with an overview of the main types of financing agents and their preferences for the risk environments and investment profitability ranges for which they traditionally operate. This presentation was based on financing literature, combined at places with published empirical literature regarding the investments in energy power plants. Based on this we highlighted the risk-profitability investment environments (as differentiated in Chapter 2) where the traditional financing agents are (theoretically) likely to be seen operating in the event of market introduction of renewables, and the probable extent to observe financing schemes using non-recourse debt and external equity.

In Sections 3.3 and 3.4 we concentrated on theoretically answering research questions five and six. We started by differentiating among two main groups of project developers: large developers and small developers. In the group of large developers the following types of economic actors were included: energy utilities/electricity companies, long-established financially-powerful corporations, and publicly-owned companies. In the group of small developers we included medium/small-size industrial production companies, small new-entrant firms (who do not have an economic background in the form of legal ownership in which they are organised to invest in RET projects), cooperatives, communities, associations and individuals.

After that we derived expectations with regard to the reasons to invest the different types of project developers might have under the four risk-profitability investment contexts. Differentiating among three types of drivers to invest - commercial, strategic and (partly-) self-generation we argued that under optimal investment contexts the dominant type of projects will be commercial, while under minimal investment contexts most of the investments will be dominated by strategic and self-generation drivers to invest. Under the entrepreneurial and political investment contexts it is likely to see a balance between commercial, strategic and self-generation to invest. The motivational landscape was assumed to have consequences for the rate of market growth, and therefore the effectiveness of support systems (see Figure 3.3).

Further, we derived general expectations with regard to the choice for technological design type under the four investment contexts. Given our interest in the sustainability of market diffusion processes, we were interested in the circumstances under which project developers would chose technological designs with performances possibly able to substantially contribute to the expansion of diffusion potential of that technology in the electricity system. These were referred to as 'diffusion-optimal' types of designs. We hypothesised that in optimal investment contexts the adoption of diffusion-optimal designs could be quite frequent. In entrepreneurial investment contexts, the adoption of such designs is likely, at least to a small extent. However, in political and minimal investment contexts, the main concern of developers will be for conventional technologies or investor-effective designs with modest contributions to long term diffusion expansion potential (Figure 3.4).

The next step taken was to propose a typology on financing schemes with the help of which project developers could materialise investment decisions. We differentiated among eight types of financing schemes that can be grouped in two categories. The first is that of internal financing schemes whereby project developers are in the same time the main financing agents. Six types of financing schemes were placed in this category: private finance, participation finance, in-house corporate finance, debt-corporate finance, third-party finance, and multi-contribution finance. The second is that of external financing schemes, where project developers contribute to less than half to the capital structure of the project, and the rest comes either from bank loans or from external equity investors: project finance and institutional finance.

Each type of financing scheme was discussed in terms of the risk-profitability investment contexts where the types of project developers expected to use it were likely to resort to such a financing approach and to what extent. Besides, we also referred to the likely investment decisions with regard to motivation to invest, project sizes, and degree of commercial maturity of technological designs that under different risk-profitability contexts would be taken by project developers - assuming they would take such decisions based only/mainly on support system characteristics.

Based on these considerations, we suggested some probabilistic relations among the forms that the five selected indicators for diffusion patterns could take. Following that, theoretical expectations were formulated regarding the various forms of the five indicators of diffusion patterns on the one hand, and different degrees of aggregated economic-policy risks and levels of projects' profitability on the other hand. These theoretical expectations represent our theoretical answer to the research question five, given the assumptions formulated in Section 2.5 (for an overview see Table 3.3 and Table 3.4).

In the last part of the chapter, hypotheses were formulated with regard to the effectiveness and sustainability of market diffusion under support systems resulting in different risk-profitability investment contexts. Their formulation was based on inferences from the forms of diffusion patterns. Effectiveness was operationalised as installed capacity increase in short/medium term (5-10 years). As regards the sustainability of market diffusion processes, theoretical expectations were only formulated with regard to the selected indicators for socio-economic benefits and embeddness and the industrial basis and dynamics (see Table 3.5). The other two perspectives based on which we argued in Section 2.7 that sustainability of diffusion processes needs to be analysed - cost performances and technical performances - are in our view best analysed empirically, in interaction with information on remaining available resource potential and the level of socio-economic and industrial embeddness achieved by the technology studied.

The next chapter answers research question four of the study for the three types of renewable technologies that we study empirically. In the same, time it operationalises the diffusion pattern indicator of technological design by looking at the extent to which the currently available technology designs are able to contribute to the diffusion expansion potential of the respective resource in the electricity system and which types of technical performances should innovations most desirably have from the diffusion expansion point of view. Chapter 4 concludes the theoretical part of the book. Before turning to the empirical part of the book, Chapter 5 first explains the research methodology and operationalisation. In Part II and III of the book, we test empirically the hypotheses of the theory.

4

The diffusion expansion potential of renewable electricity technological designs

4.1 Introduction

This chapter concentrates on the issue of technological designs for renewable electricity technologies are their potential to increase the market expansion of the respective type of technology. The content of this chapter answers theoretically the fourth research question for the types of renewable technologies whose diffusion is empirically studied in this study. In Section 2.5 we introduced the concept of technological design and differentiated between designs with ‘substantial’ and ‘modest’ potential for diffusion expansion. We then referred to the first group as diffusion-optimal designs, which we mentioned they may be existing designs available on the market already for some time, and new designs. Besides, conventional technological designs and the designs whose new technical features do not directly serve overcoming key obstacles to long-term diffusion, will compete with diffusion-optimal designs for market adoption.

The choice to analyse the technological designs adopted in the market was motivated by the interest to see to what extent the economic attractiveness of a support system can be correlated to the market adoption of the types of designs/innovations that are able to improve the chances of that technology for market diffusion continuity in the long-term. We aimed to understand to what degree the process of technology maturation could be correlated to the extent of support to remove the economic and financing barriers. In Section 3.3.2, we derived broad expectations with regard to the likelihood of market adoption of diffusion-optimal designs under the four types of investment contexts that support systems may create.

However, the competition among technological designs depends to large extent on their cost performances, that is to say if they are also ‘investor effective’. If a design is able to bring higher profits to the investors on the project’s economic life time basis, it will have a larger adoption share. But the diffusion expansion potential and the cost performances of technological designs do not have a straightforward relationship and may be different from one type of renewable technology to another. They need to be analysed also empirically per technology in order to get more insight into the context where diffusion-optimal designs will be on high demand in the market.

In this chapter we operationalise the concept of technological design and diffusion-optimal designs for each technology included in our empirical research. Section 4.1 is dedicated to wind technology, Section 4.2 to hydropower technology, while Section 4.3 focuses on four technological principles of biomass electricity generation - direct combustion, gasification, pyrolysis and anaerobic digestions. Each technology section follows a similar structure, reviewing the technological principles and designs that have evolved so far, the technical obstacles overcome and remaining, the requirements for technical performances in order to ensure long term expansion of the market diffusion potential, and - when possible - also the technical features of the diffusion optimal designs.

In addition, we also operationalise at the end of each section the ‘project size’ indicator of diffusion pattern[1].

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[1] The operationalisation of the other three indicators for diffusion patterns was already done in Chapter 3 when typologies were proposed for the types of project developers, types of financing schemes, and the drivers behind investment decisions of developers.

4.2 Wind technology for electricity production

This section operationalises the concept of technological design and diffusion-optimal technical performances for the case of wind technology and it makes a classification of wind plants' sizes that will be used in the empirical research of this study. The section presents first the technological principles used so far, at the end of 2000 to harness wind energy. Secondly, the section reviews the obstacles whose answers lay in the technical sphere, that are still facing the large-scale adoption of wind technologies. This review ends with the specification of the performance-perspectives based on which the analysis of the diffusion potential of new and existing technological designs based on wind energy needs to be made. Thirdly, it discusses the country-specificity and time dimension of diffusion optimal designs in the case of wind technology. In the fourth part it specifies the technical indicators for diffusion-optimal designs of wind technology, and in the fifth sub-section, it makes several considerations on the current indicators used in literature to assess the technical progress in wind technology. In the last sub-section, we operationalise the indicator of project sizes for wind technology.

4.2.1 Technological principles for wind energy harnessing

Electrical wind systems are based on a technological approach whereby electric power is generated by transferring the kinetic energy of the wind captured by blades into mechanical energy, which is used to move a turbine connected to an electrical generator. There are two technological principles that have been used so far for the extraction wind energy and its transformation into mechanical energy: the creation of a drag force or the creation of a lift force. Aerodynamic lift movement takes place when the direction of the tangential velocity of the rotor is perpendicular to the direction of wind. The mechanisms functioning on the basis of the lift principle have the rotating axis of the rotor parallel with the direction of the wind stream and are named 'horizontal axis systems'. Aerodynamic drag movement occurs when the direction of the tangential velocity of the rotor is parallel to the direction of wind flow. Because the rotating axis of the mechanism is perpendicular to the direction of the wind, the systems operating based on the aerodynamic drag technological principle are named 'vertical axis systems' (Hislop 1992).

The functioning of wind systems, based on both technological principles, is characterised by three main parameters: tip speed ratio, performance coefficient, and solidity. The tip speed ratio represents the ratio of the tangential speed of the rotor to the speed of the wind, and it is a dimensionless parameter. The performance coefficient is also a dimensionless parameter and it is a measure of the rotor's ability to extract the power of the wind. The theoretical value of the performance coefficient can never be 100% because a certain percentage of the kinetic energy is always retained by the air stream in order to move away from the interaction area, and part of the energy is lost in the form of heat due to the friction to the rotor's blades (Hislop 1992). It was calculated that the maximum value of the performance coefficient is 59%. In practice, the values are included within the limits of 5% and 45% (Johansson et al. 1993). The solidity of a wind system represents the percentage of the rotor's area that is constituted by solid material. A wind system is more efficient if it has a low solidity due to the fact that the energy consumed by wind in order to rotate a lighter turbine, with a smaller area of the blades, is lower. Most modern wind systems have two or three thin blades.

A comparison between vertical and horizontal axis technological principles, as regards their performance parameters and possible applications, results in the finding that vertical axis wind systems are most suitable for mechanical applications, such as windmills and windpumps, while horizontal axis technologies are more adequate for electricity generation.

Vertical axis turbines have high solidity rotor, with high starting torque, which results in a slow spinning movement of the rotor, a reduced performance coefficient and a small tip speed ratio, usually less than one (Hislop 1992). The horizontal axis technological principle assumes lower density rotors, with lower starting torque and higher angular velocity. Therefore horizontal axis turbines have a higher tip speed ratio and performance coefficient, being more indicated for electricity generation (Johansson et al. 1993). As a study of the European Commission Directorate for Energy observes that "While judgement on many design options in wind turbine technology has been deferred, there is now an overwhelming vote in favor of horizontal axis technology" (EC 1997).

4.2.2 Technical obstacles of wind technology

An overview of the technical literature reveals a series of technical obstacles that wind technology has been facing. In the first stage of market introduction, during the 1970s, wind energy systems were confronted with a series of basic technical problems. The reliability and availability of turbines were for example one of the drawbacks most frequently invoked by critics of the new technology. These so-called early problems that each innovative technology is facing in the beginning have now been overcome for all turbines that moved from the demonstration stage into the stage of large-scale commercial availability. For the on-shore state-of-the-art wind turbines, availability rates are generally between 98-99,5% (De Vries 2001). But wind technology has been confronted with some long-lasting technical obstacles too.

Firstly, technical obstacles for a significant market diffusion of wind technology have been related to the micro and macro-fluctuations of wind power availability. The variability of wind power availability leads to negative impacts on grid management due to voltage and frequency fluctuations of the electricity delivered[2]. In addition, when certain types of turbines are used, wind variability may even destabilise a weak grid because. When wind speeds are low and at start-up, turbines need to consume electricity from the grid in order to maintain their rotor' speed velocity. This is referred to as the need for 'reactive power'. The unpredictability of wind power availability makes it difficult to use wind energy in stand-alone applications without back-up power. But it also forms an inconvenient for grid-connected applications because when the generation of wind electricity cannot meet the level of demand, back up power has also to be ensured at system level. Both the micro and macro-fluctuations pose constraints on the extent to which wind power can be integrated in grid systems and the extent to which they can be used in stand-alone applications. Therefore any new or existing design that is able to make wind technology grid-friendly and compatible with stand-alone applications will be referred to in this book as a 'diffusion-optimal'. The indicators for this type of technical performances are explained in Section 4.1.3.

Secondly, the efficiency of wind energy harnessing and its conversion into electricity has long been a topic of critics for the technical performances of wind technologies. This has had a

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[2] The most frequently invoked impacts on the regional distribution grids are: modification of voltage traffic; negative impact on voltage quality: flickering effect and harmonics effect; fluctuations in electricity frequency; negative impacts on transitory stability. In terms of impacts on the electricity system as a whole, they affect: security of supply, because wind energy cannot respond to demand needs; uncertainty of generation programming - affecting the way in which power plants using other types of technologies have to be dispatched, because wind-based installations cannot be dispatched; the dimensioning of reserve capacity for the system; modification of voltage traffic and calculations regarding electricity transport losses and transitory stability of the entire electricity system.

large impact on the poor cost performances of wind technology. In the first years of technology development, comparisons regarding the efficiency of wind energy harnessing among different types and sizes of turbines were made by using the indicator of ‘capacity factor’. This expresses the ratio of the amount of electricity produced on an annual basis (kWh) per unit on installed capacity (kW). However the capacity factor proved to be a poor indicator[3] and the parameter of electricity produced per square meter of area swept by the rotor - kWh/m^2 - is currently the most preferred indicator of technical experts.

In the first decade of its use, wind technology did not have good efficiency performances. Important achievements in efficiency improvements have been booked, among others - although not always, as a result of increases in the hub height of turbines, the rotor diameter and the possibility of turbines to maintain their rated power at wind speeds above the nominal values[4]. In time, the efficiency of wind technology improved substantially. Some studies mention a doubling of efficiency in the last 15 years, with increases from 600 kWh/m^2/year in 1985 to around 1150 kWh/m^2/year in 2000 (Energia 2000: 23). However, there are still important efficiency differences among the many types of designs currently on the market and efficiency is still seen as a remaining technical challenge for wind technology - both by the industry and policy-makers supporting its development.

For the future, further improvements in efficiency are still expected[5]. As world-wide the exploitation of wind energy resources is often constrained by the availability of land-use for wind-parks construction, it is important that the available sites are exploited to the maximum levels possible. Consequently, the degree of improvement of the diffusion expansion potential represented by wind technological designs needs to be also analysed from the perspective of the contribution brought to increase the annual electricity production per square meter of rotor swept area at the site where the turbine is best used. But it would be arbitrary to trace a line for a level of kWh/m^2 efficiency above which technical progress should be considered as bringing substantial or only modest improvements to the diffusion expansion potential. The only thing clear about this aspect is that the higher the value of this parameter is, the higher the chances are for market share increase and the sustainability of wind energy diffusion is.

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[3] As wind energy experts argue (Windpower Monthly August 1994: 21), "One of best examples is to compare the world's biggest turbine (in 1994 - our note) with the most powerful. The biggest was the 100 m Growian machine in Germany, rated at 3 MW. The most powerful was the 78 m Hamilton Standard WTS-4 machine, rated at 4 MW. Since the rating was high for its size (only 78 m corresponding to the 4 MW), that capacity factor for the Hamilton Standard machine was lower, but this did not imply that the machine was inefficient". On the contrary this machine was more powerful than the German Growian machine, which shows how misleading the indicator of capacity factor is in comparing efficiency performances of different machines.

[4] Most turbine models start functioning at wind speeds of around 4 m/s, called the ‘cut-in speed’, and reach the maximum power for which they were designed only at wind speeds between 11 and 16 m/s. The maximum power is also called the ‘rated power’ of the turbine, and the specific wind speed at which this is reached is called the ‘nominal wind speed’ of the turbine. For wind speeds situated inside the interval defined by cut-in speed and nominal speed, the turbine functions at capacities below the rated power. When wind speeds increase above the nominal speed of the turbine, the conventional design technologies loose power and produce less kilowatthours. More recently developed technologies are however able to continue functioning at the rated power at wind speeds above the nominal speed, being more efficient. But the efficiency of wind energy harnessing of a turbine is a more complex issue and it is influenced by more factors. For example the higher the hub height and rotor diameter are, the higher are the prospects that the efficiency of the turbine increases, provided that the rated power of the turbine is adequate for the annual average wind speeds of the site where the turbine is used.

[5] Meyer (1995: 20) mentioned that in mid 1990s advanced wind turbines already reached efficiency of 30% - 35%, while 59% is the theoretical maximum that may be achieved.

Thirdly, wind technology has been criticised that it has not been able so far to enable the exploitation of areas with low wind speeds, 5 m/s and below, which are dominant in most regions across the globe. The aspect of wind speed is crucial for the extent to which wind energy can play an important role in the future electricity systems. As Menedez Perez (1998: 94) explains "A route for the extension of wind energy application is to advance the design of turbines with work in low wind speed regimes. In large regions of the world there are frequent winds but with average velocities below 5 m/s and their harnessing could be an important source of electricity, although now this is contemplated as a remote alternative claiming higher costs than the actual technological designs".

Most turbine models currently on the market are designed to function for wind speeds between 4 m/s and 25 m/s. But they are able to reach their rated power only at nominal wind speeds for 11-16 m/s, value that can vary from manufacturer to manufacturer. Although technical progress has been achieved by several manufacturers, there is still a long way to go. Some companies developed turbine models able to reach rated power at nominal speeds in the range of 8-10 m/s. The ability of wind turbines to operate in moderate wind speeds can be described as bringing modest improvements to the diffusion expansion potential. But given the world dominance of wind speeds of 5 m/s as annual average values, we will consider a design as 'diffusion-optimal' when it enables wind turbines to reach rated power at 5 m/s or below.

In Section 2.7.2 we considered that the cost-competitiveness of renewable technologies is a precondition for sustainable diffusion processes, defined from the competitiveness perspective. Hence, we propose a fourth perspective of the diffusion expansion potential of wind technological designs, namely the extent to which an innovation produced cost-convergence with the competing electricity technologies. This indicator will be considered for small hydropower and biomass technologies as well. Cost-convergence, expressed as costs/kWh, may occur both as result of a series of modest improvements that cumulate after some time, or as result of a single innovation.

In this context we consider that the analysis of the diffusion expansion potential of technological designs based on wind energy needs to be made from four performance-perspectives:

- contribution towards grid-friendliness and compatibility for stand-alone application;
- improvements brought in the efficiency of wind energy harnessing at a certain site;
- the ability to function in low wind speeds, below average annual levels of 5 m/s which are the dominant ranges across the globe; and/or
- the ability to close the cost-gap with conventional electricity technologies.

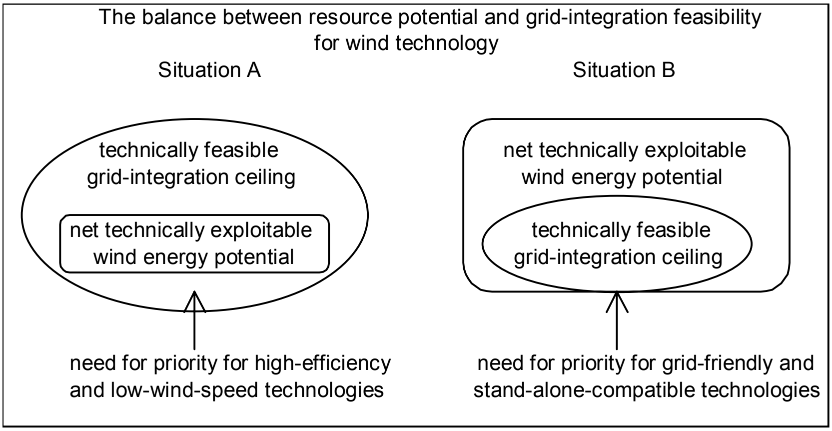
4.2.3 The country-specificity and time dimension of diffusion-optimal designs in the case of wind technology

We explained in Sub-section 2.7.1, the sustainability of market diffusion is a process that regards either the increase in installed capacity or the re-powering of the capacity already commissioned, when the technically exploitable wind resource potential has been exhausted. From this perspective two situations can be differentiated, with consequences for which types of designs are needed with priority in a certain country. The two cases are represented in the Figure 4.1. The first situation is when at a certain moment in time, the net technically exploitable wind energy potential at a country's level is lower than the technically feasible ceiling for grid integration of wind technology. In this case, technological designs that are able to increase the level of net technically exploitable resources are needed with priority. Unless designs able to harness wind energy substantially more efficiently and to exploit low-wind-speed sites are developed and become the main choice of market players, the balance between the two variables will remain the same. The sustainability of market diffusion processes will then become a case of market re-powering. If technical progress continues however to bring new and more performant models into a market able/interested to absorb new designs, it is possible that a reverse of the balance occurs.

When the technically feasible grid integration ceiling becomes lower than the net exploitable potential, other types of designs will claim priority in market adoption in order to ensure the continuation of market diffusion processes. These are the grid-friendly types of technologies able to supply high quality power - which cancel the micro-fluctuations in voltage and frequency and the need for reactive power. The market adoption of such technologies would improve the prospects for continuity in the increase of installed capacity both through grid-connected installations lifting the technical ceiling for grid integration and through stand-alone applications. The last would allow the resource potential that remains on top of the grid-integrated potential to be exploited off-grid - provided that suitable consumption areas are located nearby and are willing to shift to wind energy. The moment of market re-powering will be this way postponed and the overall contribution of wind energy to the respective electricity system would be higher than in the case when these designs were not adopted in the market.

The micro-fluctuations of electricity quality, but especially the macro-fluctuations of wind power availability brought about warning from grid managers that the degree of penetration of wind technology in the current electricity systems in the form of grid-connected installations is limited. Some suggest that 30% of the electricity flowing through a certain grid-system, at national level for example, could come from wind-based plants (Menendez Perez 1998: 97), depending also on the strength and characteristics of the grid itself. In general, many argue that the smaller the grid, the lower the ceiling of grid penetration for wind energy is. The most serious problems are in island systems.

Figure 4.1 *The sustainability of diffusion processes and requirements for wind technology*



Complementary to this, some experts argue that the ceiling of grid-integration is rather country-specific and it depends on the balance between flexible and inflexible generation technologies in the energy system of a country. Harnell and Landberg (2000) explain that power plants have different levels of ability to respond to fast changes in electricity demand. Nuclear power plants for example are best operated at constant load due to safety reasons. Landfill-gas plants and power plants based on combined cycle gas turbines also have limited flexibility. But coal-based plants and open-cycle turbines based on gas or oil can be flexibly operated.

From the category of renewables, hydropower plants with storage systems and plants based on energy crops of wastes' burning are able to be flexibly operated, while pumped-storage hydropower plants are actually the most flexible energy systems. Run-of-river (see next section) small hydropower, wind systems and solar systems and inflexible intermittent systems. From this point of view, the higher is the market share in a country of power plants using flexible types of technologies - based either on renewable or conventional resources, the higher the contribution of intermittent and unpredictable renewable resources such as wind can be. Discussing the constraints to wind power generation in more detail, Meyer (1995: 23) explains that "Although there is no technical limit to wind penetration, there is a steady decline in its value as more is installed. The rate and form of this decline varies, but in most systems wind should be able to contribute from 25 to 45% of the total electricity before operational losses become prohibitive, even in the absence of electricity shortage".

4.2.4 Indicators for the diffusion expansion potential of wind technology design

Sub-section 4.2.2 offered a simultaneous image of the indicators for the analysis of technology designs for three of the chosen perspectives:

- turbine efficiency - kWh/m^2/year;
- ability to work in low wind speeds - turbines able to reach rated power at nominal speeds of 5 m/s or below;
- cost competitive - costs/kWh comparable to conventional technologies.

This sub-section refers the forth perspective of innovation analysis - grid-friendliness and compatibility to stand-alone applications and looks at possible technical indicators for this. Based on an overview of technical literature (see reference list) we consider that three technology characteristics are directly relevant for the analysis in terms of progress to reduce the negative consequences of micro- and macro-fluctuations: the type of voltage regulation, rotor speed, and the type of generator. The voltage of the electricity that a wind turbine supplies can be regulated through two systems: pitch control and stall control. In pitch regulation the angle at which blades are positioned relative to the area described by the rotor's blades in their circular movement can be adjusted, either collectively or individually. But in a stall control system the angle is fixed during manufacturing.

The difference in performance is very important as pitch control turbines are able to keep the voltage level stable when wind speed increases above the nominal level for which turbines are designed. In contrast, stall-controlled turbines experience reductions of voltage levels as wind speeds increase above the nominal speed, meaning that turbines will function below the nominal installed capacity for which they were designed. Under this design, "power is regulated by the progressive loss of rotor efficiency" (EC 1997), and the voltage control system is also referred to as 'control through aerodynamic losses'[6] (Avia Aranda 2000: 24). The higher is the ability of wind turbines to stabilise voltage, the higher the penetration of

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[6] At the website of the European Wind Energy Association explanations are given over this alternative of power control. Stall control "is sometimes described as passive control, since it is the inherent aerodynamic properties of the blade which determine power output; there are no moving parts to adjust. The twist and thickness of the rotor blade vary along its lengths in such a way that turbulence occurs behind the blade whenever the wind speed becomes too high. This turbulence causes some of the wind's energy to be shed, minimising power output at higher speeds." http://www.ewea.org/scr/technology.htm available at 2.11.2001.

wind technologies in current grid electricity systems can be. In addition to this advantage, pitch regulated machines are also able to generate more electricity in terms of kilowatts per square meter of rotor area[7], since the voltage at which turbines generate power at winds above the nominal level does not decrease as in the case of stall regulated turbines[8].

The second technical characteristic that, in our view, is relevant for the sustainability of market diffusion processes is the speed of the rotor. At the end of 2000 there were three technological designs on the market: constant speed rotor, variable speed rotor and two-speed rotor. Technical literature indicates that the most advantageous are the designs with variable-speed rotor and two-sped rotor because they are able to deliver power voltage of higher quality[9], higher levels of electricity production, and to extract wind energy at lower wind speeds[10]. For variable-speed turbines, in order to maximise the benefits mentioned, a large range of variable speed is necessary, around a factor of 2,5 to 3.

In 1996, of all commercial wind turbine designs, 21 had variable-speed, 50 were based on two-speed rotors, and 40 models were relying on fixed-speed. In the first category, only about one-third of designs were using a wide range of variable speed, that is higher than 2,5. However, in terms of MW market share, constant rotor speed turbines were still dominating the market even in 2001. For the future, many manufacturers seem to continue favouring the two-speed option, since most of the large turbines with rated capacities above 1 MW are designed with two speeds for the rotor (EC 1997).

In terms of efficiency improvements, recent studies comparing the electricity output from three wind turbine designs reveal that “two-speed machines produce 6,4% more energy per unit swept area at a wind speed of 6 m/s than a variable speed machine with similar ratings. At 10 m/s the two speed turbine produces only 1,6% more” (Windpower Monthly May 2000: 48). But, in its turn, the variable speed machine produces 10,5% more energy at 6 m/s site, down to 5,2% at 10 m/s than a constant speed turbine. Therefore, at low wind speeds, the two-speed turbines have the best performances in terms of the capacity to harness wind energy (kWh/m^2), followed by variable-speed turbines. But at higher wind speeds the differences in efficiency performance are smaller.

The third technical characteristic that we consider relevant for the prospects of integration of wind technology in the electricity systems of the future is the type of generator that turbines are using. Two types have been used so far: the asynchronous and the synchronous generator. Asynchronous generators have the disadvantage that they need to consume electricity, especially at start and during low speed winds of low intensity (Menendez 1998: 92). For grid-connected installations this reactive energy comes from the grid itself and creates negative synergies with the impacts on grid management attracted by the intermittent and unpredictable nature of wind availability. But, still, asynchronous generators are a feasible option for grid-connected application. Some manufacturers are even supplying their turbines together with

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[7] Antonio Lara, MADE Spanish wind turbine manufacturing company, interview for "Las Energias Renovables", 4 November 2000, http://www.energias-renovables.com available at 31 October 2001.

[8] As the report of the European Commission mentions "Concern about power quality of stall regulated machines (also especially in the German market) has deterred some manufacturers, who supply medium size stall regulated machines, from continuing this design feature in their megawatt designs" (EC 1997).

[9] As a technical study explains (EC 1997), "Wind turbines result in fluctuations in real and reactive power, and hence in voltage level. Voltage fluctuations can cause consumer annoyance through the phenomenon of flicker where the light intensity from incandescent lighting fluctuates perceptibly. Variable-speed wind turbines generally produce significantly lower flicker than fixed-speed machines. Flicker can be an important issue for weak networks. Flickers and harmonics, and other related issues, come under the heading of power quality."

[10] Antonio Lara 2000; Menendez Perez 1998; EC 1997.

compensation units, such as condensers, in order to minimise the effects of reactive energy demand (Lara May 2001). However, when asynchronous turbines are used for stand-alone applications, it is necessary to accompany the wind installation by a special system that is able to generate electricity for the reactive demand of turbines. This system can be a diesel motor, an energy storage system or an accumulator, for example, but the economic disadvantage is that it can represent in the end 30% of the total investment costs of a stand-alone wind-based electricity installation (Avia Aranda 2000).

The best option for stand-alone applications is to use synchronous generators. In 1992, the German company Enercon launched its 500 kW E-40 synchronous model, which was also the first design to combine the variable rotor speed concept with the synchronous generator option, giving the company a strong international position[11]. But, as De Vries (2001) explains "Enercon's success attracted a limited number of followers. To date, only one commercial competitor has emerged: Lagerway of the Netherlands. Other direct drive pioneers include Heidelberg Motor, Neptun, Genesys, and Siemens/Seewind, all from Germany. Newcomers to the field include Norwegian Swedish ScanWind, the Dutch H-Energiesystemen and the French Jeumount Industry." More recently, the Spanish Made manufacturer has also embarked in the use of this type of generator. Among the turbines with more than 1 MW commercialised around the world, synchronous-generator based wind turbines had a market share of 15% (De Vries 2001).

In 1999, the first autonomous wind-park has been installed in Spain, through the cooperation of Enercon, the Canary Technological Institute and an industrial company of Las Palmas. The project consists of two Enercon generators of 240 kW each and proved to be able to maintain constant the voltage and frequency of electricity supplied to the isolated small grid, without need for additional load and for all wind speeds. But synchronous turbines are also better options for grid-connected applications than asynchronous turbines because, by avoiding the uptake of reactive energy from grid that causes voltage and frequency fluctuations, they avoid the disturbance of grid management. This way they are also able to contribute to the lifting of the ceiling for grid-integration of wind technology that grid managers are so frequently warning about. The general director of the Spanish manufacturer Made argues[12], "Only the synchronous turbines are authentic generators, as a conventional power plants can be. (…) We believe that they are better options for the future because when the capacity of installed wind power increases considerably, distribution companies could place restrictions on the turbines that are not synchronous"[13].

Consequently, given the superior technical performances of synchronous generators, which make them the best choice both for grid-connected application and for stand-alone

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[11] The British Wind Energy Group (WEG) claims to have installed its first MS2 prototype of a synchronous generator directly connected to the electrical grid already in 1992. The Dutch company Lagerway started in 1993 its R&D efforts for development of the 750 kW direct drive synchronous machine, tested only in 1995 (Windpower Monthly April 1996: 6; "Still a paradise of possibilities", October 1997: 46; March 1995: 52).

[12] Antonio de Lara, interview in the journal "Las Energias Renovables", 4 November 2000, on line at www.energias-renovables.com in November 2000.

[13] A sign that the turbine of the future will need to have synchronous generators and variable speed rotors has already emerged through the announcement of the Electric Power Research Institute - the R&D group of US utilities - that "No more wind turbines should be installed on Hawaii's Big Island unless they are advanced variable speed wind turbines or unless there is automatic generation control". By advanced wind turbines it was meant installations which do not require reactive power. The utility Hawaii Electric Light Co (HELCO) has 12,5 MW of wind installed on the island, while the minimum load was 54 MW, which posed problems for the stability of the grid unless turbines were equipped with variable speed rotors and synchronous turbines (Windpower Monthly, November 1996: 32, 'Integrating wind').

systems, we will consider this as a 'diffusion-optimal' design based on the horizontal axis turbine technological principle. An important note on this design is however that they are more expensive than technologies based on asynchronous generators (Ackermann and Soder 2002: 92; Kamp 2002). Their market adoption is therefore more likely in stand-alone application, as long as no technical specifications are made for the grid-connected wind systems. Therefore, having in view the current technical barriers impeding the continuity of market diffusion processes of wind technology in the long-term, both through grid-connected installations and stand-alone systems, we consider as diffusion-optimal designs based on horizontal-axis technological principle those wind machines that have the following technical characteristics:

- synchronous type of generator; and
- variable speed rotor, or two-speed rotor; and
- pitch control type of voltage regulation.

When turbines only have the last two characteristics they can be viewed bringing modest contribution to diffusion expansion potential because of they are 'investor-effective'. They are able to provide in the same time higher power quality and slightly higher efficiency of wind resources harnessing than the conventional designs[14]. In spite of higher investment costs, designs with these two features are able to yield more electricity per plant life time that compensate for the higher initial costs and bring more profits[15]. Being attractive for investors, they may increase the extent of market adoption, contributing this way modestly to the long-term diffusion potential. But if these designs are not endowed with special devices in order to deal with the negative aspect of asynchronous generators, namely the demand for reactive energy, they are not sufficiently grid-friendly nor are they compatible for use in stand-alone applications.

In conclusion, the characterisation of the technological designs from the perspective of diffusion expansion potential needs to take into account to what extent do the performances of the existing and new designs overcome the classical technical problems of the technology on which it builds, while contributing in the same time to the improvement of the prospects for market share increase. We consider as diffusion optimal the new or existing technological designs based on wind energy having one or more of the following performances:

- grid-friendly and stand-alone-compatible application, through pitch control of voltage regulation, variable speed rotor and synchronous generators;
- substantially high efficiency rates in transforming wind energy resources in electricity;
- function in low wind speeds, below average annual levels of 5 m/s which are the dominant ranges across the globe; and/or
- are cost-competitive with conventional electricity technologies.

Consequently, we operationalise the terminology *substantial and/or modest contribution to diffusion expansion,* in the form of the technical characteristics mentioned on dark background in Table 4.1.

We do not include in the indicator of technological choice (the intermediary variable on which we hypothesised in the form of diffusion patterns) the reductions in technology specific

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[14] Based on a contrasting definition approach we consider as *conventional wind turbines* those which have dominated investors choice since the market introduction of wind technology, namely the turbines with the following characteristics: asynchronous generators, constant rotor speed and stall control of voltage.

[15] Personal communication with project developers and financing agents during conference Global Wind Power Conference in Paris, 2 - 5 April 2002 and The Annual Summit on Renewables' Financing in Brussels, 20-21 November 2001.

costs, because we treated this issue under the topic of cost performances explored in Chapter 2. Further we do not include in the indicator of technological choice the technical characteristics of 'improved technical processes or materials' and 'surface of rotor area' because such data are generally not made publicly available by manufacturers to the extent that national level analyses and international comparisons can be made[16]. Moreover, the complexity of such analyses is overwhelming and disproportionate to the purpose of technology understanding aimed at in this study.

Table 4.1 *Obstacles to diffusion expansion and technical features of diffusion supportive technological designs for wind energy*

Obstacles to diffusion expansion	Objectives (technical performances)	Technical characteristics with potential to reach objectives (existing)	Contribution to diffusion expansion (as used in hypotheses)
1. micro and macro fluctuations	grid-friendly and stand alone compatible	synchronous generators	substantial
		pitch control of blades; variable / two rotor speed	modest
2. efficiency wind use at given sites 3. cost / kWh performances	increased availability	achieved by the end of1990s (98-99,5 %)	
	increased efficiency (kWh/m^2)	improved technical processes or materials; larger rotor area	modest / substantial (substantial improvements achieved by the end of 1990s through gradual small steps; improvements still possible)
		pitch control of blades; variable / two rotor speed	modest
	reduction technology specific costs	weight and material of components; technical interactions and processes	modest / substantial (substantial improvements achieved by the end of 1990s through gradual steps; but improvements still expected)
4. low ability harness low wind speeds	nominal wind speeds for rated power < 6 m/s		substantial
	nominal wind speeds for rated power 6-9 m/s		modest

4.2.5 Final considerations on current indicators used in the literature for technical progress in wind technology

After 1970 a large variety of technological designs were developed and tested. Innovative features were continuously added to these designs, which improved the technical and cost performances of horizontal wind turbines. But technical studies reporting on progress have been traditionally very detailed, and too un-transparent for policy makers and market analysis in terms to what do the various technical improvements mean for the technological status of wind technology among the other conventional and renewable energy systems.

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[16] Also, manufacturers do not normally publish the technical parameter of efficiency per square meter of rotor swept area kWh/m^2 in the material available for the general public. Information regarding the value of this technical parameter cannot be found for example at the websites of manufacturers or in their marketing brochures or annual reports. In addition, a variety of technical articles reviewed did not reveal the value of this parameter for individual turbine types, but rather as an average level for modern turbines. This parameter is likely to be available only for potential buyers of turbines, during bilateral negotiations, or inside the closed circles of technical experts and industry associations.

Most policy studies and market analysis documents have assessed, so far, the progress achieved by wind technology by looking mainly at the increase in the level of installed capacity of individual turbines. This is sometimes further specified through details on the rotor diameter and hub height of the new turbines[17]. We consider that these indicators are not sufficiently representative for the technical performances of wind technology, but they rather suggest cost-performance improvements. Beurskens and Jensen (2001) explain that "the demand side of the market is the main driver of the trend towards larger machines. The most important arguments for larger machines are to utilize economies of scale, to lessen visual impact on the landscape per unit of installed power, and the expectation that multi-megawatt machines are needed to exploit the offshore potential".

Moreover, higher installed capacity per turbine does not always mean that turbines are more efficient in terms of wind energy harnessing[18]. So far the emphasis of manufacturers and the R&D interests of governments was to produce technologies with ever-higher installed capacity. Towards the end of the 1990s increasingly more manufacturers started to produce turbines in the range of 1-3 MW. In 2001 turbines of 5 MW were being tested and discussions were emerging about 10 MW turbines. However at a certain moment this upscaling will reach a ceiling. Engineers explain that the main constraining factors will be the "actual engineering of turbines and the ability of using and handling them. (...) Turbine blades may be the factor that puts a physical limit on the size of turbines. Rotor sizes of around 150 meters - suitable for turbines of about 5 MW - are generally thought to be the largest that could function (…) due to their weight" (Jones 1999). The question Jones (1999) asks is: "Are bigger turbines more efficient?"

Theoretically speaking, in terms of efficiency of wind energy harnessing at a certain site the answer is 'yes' because the energy harnessed increases with the cube of the wind speed. The higher can the towers go, the higher will wind speed be, and the more efficient can a wind turbine at a certain site be. However, in terms of practical applicability the answer is not always 'yes', because the turbine needs to be suitable for the annual average wind speed of the site. If wind speeds are moderate or low for a considerable range of heights, it does not help to install large capacity turbines because they will probably not reach their nominal power for which they were designed and they will always function at inferior capacity. Therefore, turbine capacity is not a clear-cut indicator of technological performance because, if high wind speed resources are missing, the use of larger turbines does not lead to higher rates of energy resource harnessing.

Besides, in terms of other aspects of technical performances of wind technology, such as power quality, possible degree of integration in the current electricity grid systems and feasibility for stand-alone applications, looking only at turbine sizes does not suffice. In this context, we do not consider the installed capacity of turbines as a sufficiently good indicator, in itself, for the extent to which technological progress contributes to the improvement of

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[17] The first parameter is indeed important, to some extent, because larger rotor diameters increase the ability of turbines to harness wind energy, even when the height of the rotor's hub is the same. "As a rule of thumb, the annual energy output of modern wind turbines can be estimated by means of the expression: e = 3,2V3A (kWh/m^2 swept area rotor), where V(m/s) is the annual average wind sped at the hub height and $A(m^2)$ is the rotor swept area". The second parameter is also important because wind speed increases with height and the higher the hub of the rotor is, the more wind energy will a turbine be able to harness, even when the turbine is located at the same site.

[18] "The power installed should be appropriately matched to the wind speed and the rotor swept area, to achieve economically optimum energy output. (...) For this reason, manufacturers supply wind turbine types with different values for the specific installed power. The higher this value is the more suitable is the wind turbine for use in higher wind speeds" (Beurskens and Jensen 2001).

prospects for sustainability in market diffusion processes of wind technology. In empirical research we will use however this indicator for an initial mapping of technological progress and complementary discussions on the designs that the new models or principles of wind technology represent.

4.2.6 Operationalisation of the indicator of project sizes for wind technology

We propose to operationalise the indicator of project sizes of wind technology for the study of short-medium term of diffusion as follows: very small <1 MW; small 1-5 MW; medium 5-15 MW; large 15-25 MW and very large >25 MW. We propose this division by taking into account the stage of technology development for the period for which we studied market introduction and diffusion. During the 1990s the size of wind turbines was increasing from an average of 150 kW to an average of 600-700 kW. However, as technology matures, sizes tend to grow and what is viewed as large in the market introduction period can be seen as small after a longer period of diffusion.

The next section discusses the technical progress, obstacles and technological designs of small hydropower technology in relation to the diffusion expansion potential.

4.3 Small hydropower technology

Small-size hydropower plants (small hydropower) were the first installations to produce electricity in 1880. Of all renewable electricity technologies, small hydropower enjoys the largest market adoption world-wide. In 1989 there were more than 100 countries where small hydropower systems, considered as capacities below 10 MW, were operating or in construction phase. In the same year the total installed capacity using such plants was around 23.500 MW, 38% of this capacity being installed in China. After more than one century of use, many technical improvements were brought and production costs lowered to a substantial extent. However, by the end of the 1970s, when oil crises brought small hydropower again on the energy agenda, the technology was not yet commercially competitive and it needed governmental support for market adoption. Besides, although it was generally considered as technically mature, the need was signalled to further improve certain aspects of its technical performances, which were considered as essential for the continuity of its diffusion.

In Section 2.6.2, it was argued that we intend to differentiate technologies in terms of their stage of technical and commercial availability. Since we chose to analyse the market potential of support systems that address the economic and financing obstacles of RET, their technology target was considered as those RET that are attempting the journey towards technical and commercial maturity[19]. Apparently, in spite of being known and used in some parts of the world for a very long time, small hydropower did not reach commercial maturity and - arguably - also not the technical features needed to ensure an undisturbed market diffusion.

Based on these considerations, small hydropower is a technology whose diffusion can be empirically analysed with the help of the analytical framework proposed in this study, in spite of not being a new technology. The indicator of technological design will be used to analyse if small hydropower may indeed be seen as fully technically mature from the perspective of

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[19] We consider a technology as *technically and commercially mature* when there are no more obstacles with answers in the technical sphere that would prevent its sustained market adoption, and when it has already reached cost-competitiveness with competing conventional technologies.

diffusion expansion potential. Further, it will serve to see what innovations, if any, are still needed to dislocate the remaining diffusion obstacles whose answers might lie in the technical sphere.

The choice for this technology as a case-study has one disadvantage, namely that the indicator - the values of projects sizes - cannot be tested as intended, by differentiating among small, medium and large size plants. In the theoretical part we assumed that there are no direct constraints on the forms or values that the selected indicators for diffusion patterns can take. But by definition, small hydropower technology assumes a limit on project sizes[20].

But the choice of this case study has an important advantage, namely that it is an example of slow-down and stoppage in the market diffusion of a technology. Small hydropower was, in the beginning of the 20th century, the only and later the dominant electricity technology in many countries. Later it was pushed away from the energy picture by fossil fuel technologies. Its come-back has often been a long and difficult road. The analysis of market revival processes could suggest the fate of RET when diffusion processes are unsustainable, that is when the economic-policy support system used does not allow for the long-term continuity of market diffusion processes and investments are interrupted for a period of time.

This section is organised as follows. In the first part it presents the types of small-scale hydropower plants that were developed so far. After that it presents the technological principles for hydropower harnessing, which although were launched already at the end of the 19th century, were also the main ones used at the end of 2000. The third part summarises the technical progress achieved by small hydropower technology up to the end of the 1970s, when the first attempts for its market revival were made in industrialised countries. The fourth part reviews the technical challenges still facing small hydropower technology in order to remove all its remaining obstacles to market adoption. In its framework some considerations are also made on the exploitable potential for small hydropower development. Based on this we trace the performance-perspectives based on which the designs need to be analysed in the case of small hydropower technology.

4.3.1 Types of small hydropower plants

From the standpoint of the capacity to store water two types of small hydropower plants can be differentiated: run-of river plants and storage plants. *Run-of-river hydropower plants* do not generally attempt to store water with a dam or earth works. The functioning principle is based on diverting water into a canal and further into a pipe, known as penstock. At the end of this, a turbine takes over the kinetic energy of water in the form of mechanical energy transferred to the electricity generator (Hislop 1992). Using the natural flow of the river the incoming volume of water per time unit is subject to seasonal fluctuations, which makes the power output to vary or even be interrupted during draught periods. Water changes can also determine diurnal fluctuations in power output that can inflict upon the functioning parameters and lifetime of the electrical equipment, when it is supplied with varying electricity voltage. This shortcoming of run-of-river power plants is sometimes compensated by the construction of a barrage with a small reservoir aimed to store water for short length of time that can vary from one day to one week.

Storage hydropower plants incorporate a dam and an artificial lake or reservoir behind it. They are designed to store enough water, so as to offset seasonal fluctuations in water flow,

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[20] In Chapter 3, inferences on likely project sizes were used in combination with inferences on forms of other diffusion indicators, in order to make predictions over potential for installed capacity increase.

compensate for temporary variations in power demand, and supply the end users with constant voltage throughout the year. Beside water storage, dams can perform other important functions, such as raising the water level to increase the hydro energy potential, flood control, reserves of water supply for human needs and irrigation. From the standpoint of the installed capacity, four types of hydropower plants are generally differentiated in the specialised literature (Johansson et. al. 1993):

- micro-hydropower systems, with an output power ranging from a few hundred watts up to 300 kW or even 500 kW;
- mini-hydropower systems, producing up to 1 MW;
- small hydropower systems, considered to have an output power between 1 MW and 30 MW according to the standards of certain countries, such as the United States of America or Brazil, and between 1-10 MW according to European standards;
- large hydropower systems, that can have an output power of more than 30 MW.

The output of each type of hydropower system is an indicator for the dimensions that civil works must have, and consequently, of the impacts on the environment. Environmentalists support the idea that run-of-river systems are the most environmentally benign because civil works do not involve the construction of dams or reservoirs. In terms of sizes, micro and mini hydropower plants can be generally constructed in the form of run-of-river systems. This would also be feasible for small hydropower plants. But the larger the installed capacity, the more difficult is to run it, technically and economically, using only the intermittent naturally available water energy potential. Small hydropower plants, with capacities between 1-10 MW, are more often constructed as storage systems.

4.3.2 Technological principles for hydropower harnessing

The amount of power available in a hydropower plant depends on the head of water, the amount of water flowing per unit of time, the efficiency of the turbine and the efficiency of the generators. The head of water is the total vertical elevation from the point where water begins to fall, to the point where the water turbine is located. The water flow depends on the seasonal and annual availability of rainfall and water resources in the river. It is measured in cubic meters per second. The efficiency of turbines can vary from 60% to 90% and the generators' efficiency oscillates between 80% and 90% (Hislop 1992).

Depending on the principle on the basis of which they operate, two categories of turbines can be identified: impulse turbines and reaction turbines. Based on our definition of technological principle formulated in Section 2.6.1, these can also be seen as the two technological principles of transforming water energy into electricity. Impulse turbines make use only of the speed of water, that is its kinetic energy. They have overall efficiencies varying from 70% to 93% (Fraenkel 1991; Tiemersma 1988). The most widespread types are Pelton and Turgo turbines. They are generally used for installations with high head of water - more than 100 meters, and reduced water flow, such as run-of-river systems in mountain regions. Reaction turbines make use both of water speed and water pressure, as they are completely immersed in the water flow. Their efficiency can range between 65% and 90% (Fraenkel 1991). The Francis turbine is the most frequently used for medium water heads of 15 - 120 m, while the Kaplan turbine is mostly used for low heads of water, between 1 m and 20 m. Further, "The turbine's rotating shaft drives an electric generator, which transforms mechanical power to electric power. Three types of generators are available for use with hydroelectric plants: for lower capacity plants the generating may be either an alternating current induction type or a direct current type; at higher capacities, a conventional synchronous type is used" (Johansson et al. 1993: 74).

4.3.3 Technical progress in small hydropower technology - achievements in late 1970s

Technical progress was achieved, already before the 1970s, in many aspects of small hydropower technology performances: turbine efficiency, the range of exploitable water heads and water flows, control and adjustability of power quality, as well as flexibility in matching supply and demand profiles. The most frequently used turbines, Francis, Kaplan and Pelton were developed in the second half of the 19th century[21]. Their efficiencies improved very fast. As early as 1930 the Pelton turbine reached 85% efficiency in converting water energy into mechanical energy, while Kaplan and Francis turbines touched the still valid ceiling of 90% (Johansson et al. 1993).

An increasingly high number of turbine models and complementary pieces of equipment were developed in order to allow the use of a wide range of water heads and water flow volumes. Currently water flows as small as 0,1 m^3/s and water heads as short as 0,1 m can be exploited (Tiemersma 1988: 71). Besides, improvements in the control and regulation systems made also possible to obtain good quality power from rivers with low water heads or small water flow volume. However, the harnessing of water energy at sites with water heads lower than 3 m is still prohibitively expensive because they require extra civil works and additional supportive equipment[22].

Progress was also booked in the area of power quality, allowing to maintain frequency and tension constant. In the first decades of hydropower use, regulation of power quality was done mechanically, by controlling the water flow entering the turbine. Later, electronic regulators and load controllers replaced mechanical control. This lead not only to the increase of power quality but also to the reduction of operation costs. For run-of-river plants the problem still remains however, due to the diurnal fluctuations of water flow. The innovations for electronic control of power quality can be used for the case when water flow - or electricity supply - is higher than electricity demand[23]. When the water flow or water head are too low, compact turbine-generator groups can also be used to improve power quality. But when supply falls below demand level, the voltage and intensity of electricity will flicker. This does not pose too high problems when the entire output of the plant is fed into a large grid. But it can pose serious problems when the small hydropower plant is used for self-generation, and especially when it functions as a stand-alone system. In this case three technical solutions can be used to address the problem of power quality fluctuations. The first is to use small reservoirs that can store water of 1 - 7 days, to help in such cases of diurnal water flow decrease. The second is to use back-up systems for electricity generation based on technologies that are able to respond very fast to demand request. And the third is to use storage systems such as batteries to compensate for diurnal variations.

Advances in storage systems for electricity were also booked during the 20th century, which made possible to adjust the balance of supply and demand. Battery systems are able to

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[21] In 1989, about 70 % of the turbines ordered worldwide for installations below 1 MW were Francis (27%), Kaplan (24%) and Pelton (17%) (Johansson et al. 1993: 86).

[22] "Small Scale Hydro - Future Research and Development" at the EU Energy Directorate website http://europa.eu.int/comm/energy_transport/atlas/htmlu/hydrtdf/html, 21.02.2002.

[23] When the surplus electricity is not used for direct electricity consumption or storage, it is possible to discharge it into resistance systems for hot water supply of thermal energy supply of residential or industrial systems. Therefore, hydropower plants can also function on the co-generation principle.

transform the stored direct electricity current into alternative current, at standardised parameters, following the demand needs. Progress was also booked in the field of integrating the use of water energy with other electricity production systems, in order to compensate for the intermittent availability of water energy. The use of hydrid systems with diesel motors is the most popular[24]. Improvements in power quality and the options for compensating for the daily and seasonal fluctuations in water availability means that the use of small hydropower systems for stand-alone applications has become technically feasible.

Consequently, at the end of the 1970s, the small hydropower technology was technically-advanced from the following performance-perspectives:

- technological efficiency, through high conversion efficiencies for turbines and generators;
- technical feasibility of exploiting low resource sites - with low flow and head of water;
- compatibility for stand-alone applications and grid-friendliness[25], through the innovations for power quality and back-up electricity.

In addition, technical solutions also helped in the past to reduce the costs of hydro-electricity production and the environmental impacts of small hydropower systems. The main cost reductions were achieved for the components of operation and maintenance, especially when control and regulation systems shifted from being done manually to being performed electronically and based on automatic processes. The technical measures enabling lower environmental impacts were mainly formed by:

- systems allowing for the traffic of terrestrial and aquatic fauna[26];
- systems regulating the water flow in the river branch that continues following its original bed, to avoid that it dries up and to preserve its ecology.

4.3.4 Remaining technical challenges facing the market diffusion of small hydropower at the end of the 1970s

At the end of 1970s the small hydropower technology was cost-competitive with conventional energy systems only in niche locations. Besides, it was still in need for some technical improvements. In the European Union countries, the price for hydro-electricity production was in the range of 3-20 €c/kWh, while the cost of coal based electricity was around 4-5 €c/kWh[27]. The small hydropower technology encounters two barriers in reaching cost competitiveness. On the one hand, technology complementary costs are very large, which claim around 50% of investment costs. They are split into civil works (35-40%) and engineering (10-15%). These costs increase the smaller the project sizes become, and especially for mountainous locations. But technology experts argue that there is still some scope to achieve cost reductions as a result of some technical improvements.

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[24] After 1980, with the technical advance in the field of other renewable technologies, hydridisation with wind energy, solar energy plants have also been increasingly considered.

[25] In contrast to wind technology, the power fluctuations produced by small hydropower plants do not pose threats to the stability of electricity grids because their sizes are small - e.g. when defined as < 10 MW. Besides, they are normally more dispersely attached to grids, because - due to resource availability reasons - small hydropower installations cannot be built one close to another as a chain along river.

[26] "Some low head systems allow fish to pass through the turbine generally unscathed but various forms of screening (either physical screens or even electrical and ultrasonic) are also used. Fish ladders - a set of small water falls in a channel - are provided to ensure that migrating fish such as salmon can safely bypass the hydroplant" (Fraenkel March 1999).

[27] Source http://europa.eu.int/comm/energy_transport/atlas/htmlu/hydrtdf/html, at 21.02.2002.

It is generally considered that small hydropower technology is technically mature. We prefer a nuanced assessment. Looking from the standpoint of its technological ability of efficiently exploiting all sites of all sizes and location, and from the standpoint of its compatibility for grid-connected and stand alone use, the small hydropower technology is indeed technically mature. However we argue that technical developments so far are not fully satisfactory if we look at small hydropower as complex energy systems dependent on reliable construction works. The small hydropower technology still faces some diffusion obstacles, which could be pushed aside with the help of some technical innovations. The remaining technical challenges can be divided in four categories.

Firstly, experts identified a series of technical options able to reduce technology costs, construction costs or operation costs. Technical improvements were especially needed regarding the economic efficiency of resource exploitation at sites with low water head, below 3 m. This area of development is important as there are currently many sites world-wide that cannot be exploited because the technological options for them are too expensive. Secondly, the research agenda included some technical solutions that could further reduce the environmental impacts of small hydropower installations. Although environmental impacts of small hydropower plants are by far lower, both in number and magnitude, than those of large hydropower plants, local opposition groups often invoke the impacts related to civil works. And thirdly, a series of technical optimisations were signalled necessary in the various components of small hydropower systems. A summary of the most frequently mentioned areas for technical developments is made in Table 4.2.

Table 4.2 *Examples of technical measures that can still help improve the technical, economic and environmental performances of small hydropower technology*[28]

Technical optimisation	Improvement of economic performances	Improvement of environmental performances
- new techniques and turbines for low-head sites (for < 3 m) at acceptable costs; if possible also submersible		- use of stone/brick masonry instead of concrete - new submersible turbines and generators to reduce civil works and visual impacts - siphon structures to improve water oxygenation - innovations in civil design
- automatisation and remote control - simplification of low head designs - improved control systems for stand-alone applications - development of load control equipment and frequency converters for higher power quality from run-of-river turbines - optimise generation as part of integrated water management systems	- head increase techniques; - application of remote control - use of new construction materials (lighter; cheaper) - standardisation in areas of: civil works, electro-mechanical equipment, control systems; - submersible generators and turbines - compact multi-pole generators to avoid the need for speed increasers	

4.3.5 Considerations on hydropower potential and design features for diffusion expansion

The hydropower potential of a river depends on the volume of flowing water per time unit and on the distance between the site of runoff formation and the site where it reaches the ocean

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[28] Sources:" Small Scale Hydro - Future Research and Development" at the EU Energy Directorate website http://europa.eu.int/comm/energy_transport/atlas/htmlu/hydrtdf/html at 21.02.2002.

(Hislop 1992). The theoretical hydropower potential of different regions around the world is difficult to estimate because rainfall and consequently runoff are not evenly distributed. There are seasonal and annual variations in the rainfall volume and geographic distribution, which result in large differences in estimations. Also the energy potential of individual runoffs varies on a seasonal and annual basis, and the reliability of the estimations of the theoretical hydropower potential is limited.

The theoretical potential used to be diminished by technical considerations. But as discussed, innovations in the first part of the century enabled the exploitation of sites with water flows between 0,1 and 500 m^3/s, and with water heads between 0,1 m and 1800 m (Idae[1] 1999: 81). Technical progress has lead to the convergence between the theoretical potential and the technical potential. This means that currently, the theoretical hydropower potential is further diminished by economic, social and environmental considerations. The experience of developed countries indicates that the economic constraints reduce the technical potential of hydropower by 40% to 60% (Johansson et al. 1993). This potential is further reduced when social and environmental limitations are taken into account. These limitations are on the one hand related to competing uses and functions of water resources, both from the standpoint of human needs and of ecological needs. But on the other hand they are also due to social opposition, especially of the local population to hydropower plants, claiming various environmental reasons. The resulting value represents the realistic hydropower potential. In industrialised countries, social environmental opposition can be extremely high, blocking even further diffusion, while in developing countries the economic constraints are obstructing investments in small hydropower even when energy demand is very high. Therefore, the innovation challenge for small hydropower technology is to come up with technical solutions that are able to improve the cost performances of small hydropower plants, and to reduce social opposition based on environmental reasons.

Due to the fact that the small hydropower's economic and environmental performances form the main obstacles for a more forceful diffusion of this technology, we consider that the analysis of technological designs from a diffusion expansion perspective needs to be made from the following perspectives:

- the ability to improve cost performances as compared to conventional technologies, especially the ability to bring improvements in the economic feasibility of exploiting sites with low water head;
- the ability to bring substantial reductions in the environmental impacts of small hydropower plants, especially with regard to impacts created by civil works.

We consider that innovations in these areas are able to improve the chances of small hydropower for a sustainable diffusion. We will consider as diffusion-optimal those technical solutions that are able to bring substantial improvements from these two performance-perspectives[29]. The next section discusses the technical progress, obstacles and technological

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[29] However, the labelling of diffusion-optimal may be a controversial issue. Firstly, as regards improvements in environmental performances: on the one hand, if innovations induce substantially higher rates of social and bureaucratic acceptability, it could be argued that they should be considered as diffusion-optimal - based on the above argumentation related to realistic potential and barriers. On the one hand, having in view that the small hydropower technology has already responded to its ‘main task’ as energy technology - that is its technical ability to harness water energy efficiently from all sizes and shapes of sites, and to be suitable both for smooth grid integration and use of isolated application - one could indeed argue that justice is not done to a technology, in general, when an innovation that brings improvements only in environmental performances is labelled as diffusion-optimal. The ‘referee’ in this case is formed by local populations and bureaucrats who could have very *subjective standards for acceptability*. Besides, environmental *impacts are*

designs of four types of biomass electricity technologies in relation to market adoption and the diffusion expansion potential.

4.4 Biomass electricity technologies

The technological approach of harnessing biomass energy to transform it into electricity assumes the following chain of energy forms: chemical energy stored in biomass is transformed in thermal energy, which then passes into mechanical energy, and results finally in electrical energy. Technical development led to four technological principles for biomass-to-electricity conversion so far: combustion, gasification, pyrolysis and anaerobic fermentation. The difference among them lies in the methods and technologies used to transform the chemical energy of biomass into feedstocks that are suitable for combustion and transformation into thermal energy.

The direct combustion technology is used since the 18th century and assumes the burning of biomass (with little or no processing) to obtain steam (thermal energy). The efficiency of this transformation has been notoriously low, less than 65% (Overend 2000), leading to low overall efficiencies of biomass-to-electricity transformation (5-25%). Therefore, other ways of transforming biomass more efficiently have been searched. The first serious alternative came in the 1970s through the gasification technology. This assumes the transformation of biomass, at high temperatures, into combustible gases and a solid by-product called charcoal. This contributed to biomass-electricity efficiencies above 35%, with 45-50% considered achievable in a near future[30] (Overend 2000). This technology is in demonstration phase in many countries, and some experts consider it very close to market deployment. The second promising alternative came in the 1980s in the form of pyrolysis, that is the transformation of biomass into combustible oil, having as by-products gases and solids - also combustible[31]. This technological principle is, in 2002, at the border between development and demonstration[32], and the efficiency ranges are yet unclear. However, technical studies suggest that there are reasons to have high expectations on efficiency for this technology as well.

Anaerobic fermentation is a method of producing biogas from cellulosic biomass such as animal manure or organic wastes stored in landfills. Biogas contains around 60% methane and 40% carbon dioxide (Rajabapajah et al. 1997). The biogas is then combusted and the thermal

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strongly site-dependent, and so would the perception of an environmental innovation - needed or achieved - be. Secondly, as regards improvements in economic performances of small hydropower, the potential of the technology itself is very limited. As already mentioned, around 50% of investment costs are claimed by complementary costs, given by civil works and engineering which are gain strongly site specific. Here one could argue again that justice to the technology is not done if technical improvements leading to substantial cost reductions in these *'complementary cost components'* are labelled as diffusion-optimal. And again, the innovation might be technically feasible only for *specific sites*. We admit that these are legitimate controversial issues. However, we considered that a technology may be viewed as fully technically mature when there are no remaining obstacles whose answers could lie in the technical sphere - therefore, from technical point of view, market diffusion processes can be sustained. Therefore, we acknowledge that the labelling of diffusion-optimal may be vicious for the case of small hydropower.

[30] The combustion of bio-gases leads to higher efficiency of biomass-to-thermal energy transformation, estimated at around 80-85%. But the overall biomass-to-electricity efficiency depends also on the technology used for the last step of energy transformation, namely mechanical energy to electrical energy transformation. This can take place in engines, steam turbines, gas turbines or integrated gas-steam turbine system. The last are the most efficient.

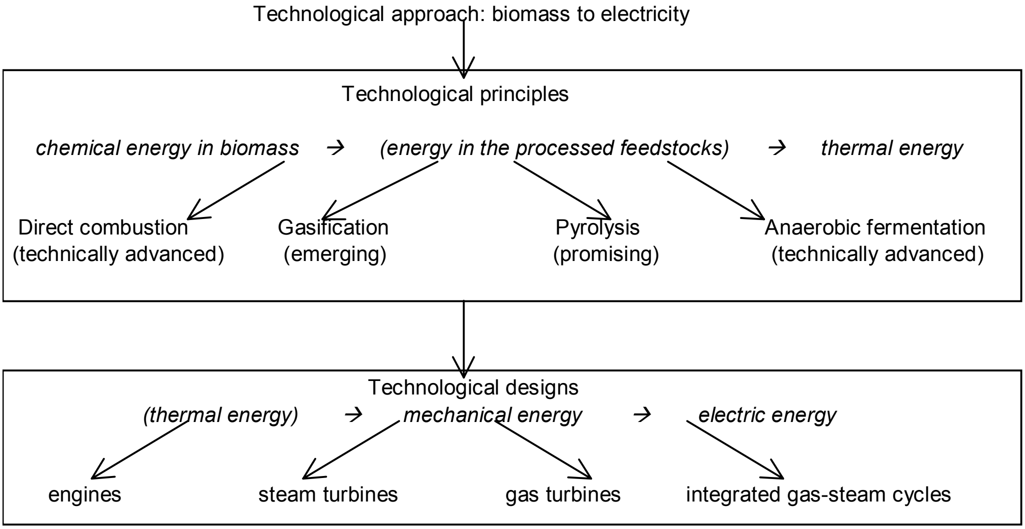
[31] Pyrolysis was used for the production of charcol from coal for centuries (Koukios 2002).

[32] We refer here only to the application of pyrolysis for electricity production and not for transport fuel.

energy drives generally a steam turbine or an engine to produce electricity. The anaerobic fermentation technological principle is also old and considered technically advanced, though there are areas where improvements are considered still possible. This introductory discussion on biomass technological principles is represented in Figure 4.2. The transformation of chemical energy of biomass products or organic wastes into electricity, along the chain of energy forms mentioned above, assumes three groups of technological systems:

- systems for the (cultivation), collection, transport, and first processing of biomass ;
- biomass-to-(advanced)feedstock technologies, with four technological principles; and
- electricity generation technologies, that is the final technological designs mentioned in Figure 4.2.

Figure 4.2 *Technological principles and designs of biomass-to-electricity transformation*[33]



The methods and technologies in the first system depend on the type of biomass resources used. For example for industrial or food processing organic wastes no special collection systems are required. For the collection of landfill gas from waste deposit sites, there are special technical structures needed. But for the collection of animal manure for biogas fermentation the collection and transport system can be quite complex and laborious. The same holds for the collection of clean agricultural and forestry wastes.

The second group consists of the four technologies explained above that transform the available type of biomass into a suitable or more efficient feedstock. In the case of direct combustion, the feedstock is in the form of the biomass initially available, for example straw or wood chips, or organic wastes for paper and wood industry. In the case of gasification the resulting feedstock is a gas, that can have different heating values. In the case of pyrolysis the main feedstock is bio-oil. And finally in the case of anaerobic fermentation, organic wastes are transformed in biogas, fed into the electricity generation system. Electricity generation technologies are the conventional systems used for fossil fuels burning namely engines, steam turbines, gas turbines or integrated gas-steam turbine system. The chain of the three groups of systems used to transform biomass into electricity is shown in Figure 4.3.

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[33] Based on Sims and Gigler (2002) and Koukios (2002).

Figure 4.3 *The systems used to transform biomass into electricity*

biomass supply systems → biomass-to-feedstock technologies → electricity generation technologies

The next sections discus the types of biomass resources and the state-of-the-art in biomass-to-feedstock technologies. As result of this, a qualification will be made regarding which technological designs - new and existing - should be viewed as bringing substantial or modest improvement in the diffusion expansion potential for the four technological principles of biomass-to-feedstock conversion.

4.4.1 Biomass resources and fuel supply systems

In energy terms, biomass refers to “all forms of plant-derived materials” that contain organic matter and can release energy through combustion (Johansson et al. 1993). Biomass includes forest products and wood wastes, agricultural crop residues, animal manure and livestock operation residues, other industrial and household organic wastes, dedicated energy crops and forests, aquatic plants (microalgae) and other living-cell material that can be burned to produce heat energy[34] (Patterson 1994).

Four groups of biomass resources can be differentiated, with several subgroups as shown in Table 4.4. Dedicated energy cultivation presupposes that annual and perennial fast-growing grasses and trees, such as sugarcane, sweet sorghum, miscanthus, willows and poplars, can be cultivated especially for energy production. Forestry wastes are mainly in the form of branches, edgings, tops. Examples of clean woody agricultural wastes are fruit and wine tree pruning and residues. The most used wood and paper industry residues consist mainly of chips, culled logs, sawdust, bark, black and sulphite liquors (Olesen and Bedi 1997). Clean agricultural residues are primarily constituted of straw. After harvesting food crops, such as wheat, rye, oat, maize or barley, the straw is available to be collected and transported to heat energy or electricity production stations. Agro-industrial organic wastes are generally coming from industries such as meat abattoirs, tabacco, alcohol, oil, cereals products and the canning industry. The organic wastes that can be also subjected to anaerobic fermentation for biogas production - for example animal manure, plant and tree residues, municipal and industrial organic wastes (Vintila 1989). Biogas generation from animal manure is more reliable than biogas production from other organic wastes, due to the large continuos availability of manure.

The systems to collect, transport and process resources are in various stages of development. For dedicated energy cultivation improvements are still needed, in 2002, in plant breeding for more productivity, in increasing the diversity of species and their energy potential, and in the area of crop management practices. Next, the collection and processing of forestry wastes relies on conventional technologies from wood industries. But improvements are still needed to increase the density of transported material and reduce transport costs and logistics. The production of biogas from livestock waste by means of anaerobic digestion also needs some improvement in the area of conversion efficiency (Koukios 2002: 9). For the other types of biomass resources mentioned in Table 4.3 experience already exists and the supply systems are considered commercially mature.

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[34] Biomass energy is ultimately a form of solar energy. The basic process that makes biomass a renewable energy resource is photosynthesis. Biomass can be a renewable resource only provided that the rate of consumption does not exceed the rate of biomass formation.

Table 4.3 *Types of biomass energy resources*

Groups of biomass	Subgroup of biomass	Fuel supply system
Dedicated energy cultivation	Energy crops	Rapid developments in the 1990s. Improvements still needed
	Forests-for-energy	
Clean biomass wastes	Forestry wastes	
	Woody agricultural wastes	Commercially mature systems. Experience exists in agriculture
	Grassy agricultural wastes	
Organic industrial and agricultural wastes	Different industries and agricultural sectors	Commercially mature systems. Experience exists in some industries
Biogas	Livestock wastes	Anaerobic digestion: technical improvements needed
	Landfill gas	Commercially mature technology Experience exists
	Sewage gas	

4.4.2 Biomass-to-feedstock conversion - four technological principles

This section discusses the main obstacles with answers in the technical sphere facing the market introduction, respectively diffusion, of the four biomass-to-feedstock conversion technological principles: direct combustion, gasification, pyrolysis and anaerobic fermentation. The technological designs available so far for each of these systems can be observed in Table 4.4.

Table 4.4 *Types of biomass-to-energy conversion technologies (Sims and Gigler 2002)*

Biomass-to-energy conversion technologies			
Combustion	Gasification	Pyrolysis	Biochemical
Underfeed Grate Fluidized bed	Updraft Downdraft Cross-flow Fluidized bed	Fluidized bed	Anaerobic digestion Fermentation Inter-esterification

4.4.2.1 Direct-combustion technologies

By 2002, only combustion technologies were technically and commercially available, but they were still in need for improvements. The pre-combustion operations needed to transform biomass resources into suitable feedstocks are: grinding, drying and compressing. In the direct combustion phase there are currently three technological designs used: underfeed, grate and fluidized bed. Combustion technologies can be integrated only with engines and steam turbines. They had satisfactory performances in some niche markets, but improvements were still needed in three main areas:

- the conversion efficiency,
- the environmental performances in terms of atmospheric emissions (e.g fly ash), and
- reduction of investment costs.

In principle, the economic and efficiency performances of direct-combustion technologies depend strongly on their sizes. Of the three technological designs mentioned in Table 4.4, fluidized bed technologies are more recent and more efficient. But they are only economically attractive for plant sizes above 10 MW (Sims and Gigler 2002). Some studies (Carrasco 1996) suggest that direct-combustion combined with steam turbines as generation technologies can have efficiency performances and incur investment costs as summarised in Table 4.5.

When plant sizes are lower than 1 MW the best option is to use engines instead of steam turbines. Plants with less than 5 MW are still very expensive and can only function with very low efficiency. For projects in the range 10-30 MW the efficiency and cost performances start slowly improving, as the size of the project grows. The most attractive are plants with more than 30 MW installed capacity. The research target for improved efficiency is to bring all these systems, from the current average range of 5-20%, to more than 30% conversion rate[35].

Beside efficiency and cost improvements, the reduction of environmental impacts is also important in accelerating the market diffusion of direct-combustion technologies. Many countries are toughening their air quality standards, and biomass combustion plants have to respond to these, in order to get the environmental license.

Table 4.5 *Efficiency performances of plants of different sizes using direct combustion*

Plant size	Efficiency	Investment costs
< 1 MW engine[36]	higher (20-30%)	lower than steam turbines (1200 €/kW)
1-3 MW steam turbine	very low (can be < 10%)	very expensive (up to 2400 €/kW)
5-8 MW steam turbine	low (~20%)	high (1500 €/kW)
> 30 MW steam turbine	higher (~28 %)	lower (1200 €/kW)

(Source Carrasco 1996)

4.4.2.2 Gasification technology

Biomass-gasification technology converts the organic content of biomass into a gas mixture with higher energy value. This process has been developed since the 1970s, taking as technical reference the coal-gasification principle. Both in direct combustion and in gasification a wide diversity of biomass types can be used. The gasification technology is however more complex than direct combustion because it requires biomass have some specific characteristics in terms of moisture content, ash content particle sizes, etc. Variability in biomass quality has two main consequences. One regards the heating value of resulting gas, and therefore the efficiency of the system. The other one regards the costs to clean the gas (mainly due to tar and ashes) before fuelling it into the electricity generation system (Koukios 2002). Therefore, gasification is more demanding (complex and expensive) than direct combustion of biomass.

In 2002 the commercialization of gasification technologies was still in early stage. There were five main technical challenges facing the speeding up of market diffusion:

- the need to enlarge the types of biomass resources that can be fed in at higher efficiency and lower costs for gas cleaning;
- the need to increase efficiency, especially by means of increasing the heating value of resulting gas;
- the demand to improve the quality of gas (as resulting feedstock) and to reduce the atmospheric emission of these biomass plants (Williams and Larson 1993);
- the reduction of investment and operation costs, especially for small size plants, and
- improvements in the integration of gasifier into the power conversion system.

The first technical challenge is related to the fact that there are differences in the types of biomass for which the four technical designs are suitable. For example the downdraft gasifier can be used only with resources that can be provided within very narrow ranges of moisture and particle sizes. Enlarging these ranges for all technical options would increase the biomass

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[35] When combustion takes place in co-generation facilities conversion efficiencies can be between 50-80%.

[36] Stirling engines assume higher conversion efficiency and lower investment costs compared to steam turbines.

potential that can be harnessed through gasification, contributing to the sustainability of market diffusion processes. But this is also relevant from the standpoint of plant sizes, as not all four technical designs are technically and economically feasible at all sizes. For example the downdraft gasifier is best suited for maximum 1 MW – although multimodular units are possible. Fluidized bed gasifiers are suited for small and medium size projects (Sims and Gigler 2002) but they become more attractive at larger scales.

The highest efficiencies are reached for sizes of 50-100 MW, when combined gas-steam turbine systems are used for electricity generation (Koukios 2002). Progress in this first area of challenge has consequences for the extent to which small developers would also be able to invest in biomass plants, from the perspective of being able to match the desired plant-size, with the feasible technologies, and with the available types of resources. International research networks are studying the technical and economic parameters of biomass-to-energy models using different types of biomass resources for gasification (CBT 1999). But further research and testing on these aspects are still needed.

As regards the general efficiency range for gasification technologies, in 2002 there were already demonstration plants with efficiencies around 35%. The medium term goal was to lift the range to 45% - 50%, and even 60% when fuel cell technology becomes available (Overend 2000). Another challenge is to improve the quality of gas resulting from the gasification process. Good results have already been booked in these directions by forestry and energy experts in Denmark, Sweden, United Kingdom, Finland, the Netherlands and the United States. For example Danish experts developed an updraft gasification system which purifies gas to the level that can be fed in a gas engine, having a fuel-to-electrical efficiency of 32%. Further, gasification needs to reduce its atmospheric emissions of NO_x, NH_4, HCl and alkaline components (Koukios 2002).

The reduction of investment and operation costs is an essential prerequisite for market introduction. For biomass gasification technologies, there is the same relationship between plant size and production costs: the larger the plant size the lower production costs. Table 4.6 shows some differences in efficiency, depending on plant size and technology designs.
The last technical option mentioned was still in demonstration stage at the end of the 1990s (Overend 2000).

Table 4.6 *Efficiency performances of plants of different sizes using gasification*

Plant size	Technical design	Efficiency	Investment costs
< 1 MW	updraft with engines	20-25%	lower (1200 €/kW)
>20 MW	fluidized bed with IGCC[37]	42%	very expensive (2100 €/kW)
30 MW - 100 MW	fluidized bed with gas turbine	35%	high (1600 €/kW)

(Source Carrasco 1996)

In terms of integration between the gasification unit and the electricity generation unit, gasifiers can be directly fired with internal combustion engines, Stirling engines, microturbines, steam turbines and the integrated combined cycle technology (see Figure 4.2). As regards gas turbines, Sims and Gigler (2002) explain that “indirectly fired gas turbines are a mature technology, but (direct) biomass-fired operation would require a specifically designed

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[37] IGCC means Integrated Gasifier Combined Cycle.

heat exchange system which is expensive and still needs extensive research efforts. System efficiencies are in the range of only 20-24%".

The four gasification technical designs mentioned in Table 4.4 have different performances from the perspective of the five technical challenges mentioned above (Koukios 2002; CBT 1999). In the last years of the 1990s the most substantial progress has been achieved for the downdraft technological design. The improved version called two stage downdraft gasification system[38] responds the best to four technical challenges associated with this design: improved efficiency, better gas-feedstock quality, lower air emissions and a larger range of compatible biomass types. But these come at higher costs, leaving the overall production costs still high for the time being. There are improvements also in the other three designs mentioned in Table 4.5, in one or two of the aspects mentioned so far.

For example some later versions of updraft gasification can produce higher quality gas-feedstock with slightly improved efficiency (32%), which adds nicely to the advantage of this design of being compatible with a wide range of biomass resource types. Fluidized-bed has however the best fuel flexibility of all gasification designs. This could make the fluidized-bed design the technology of choice for biomass diffusion, if gas feedstock quality could improve. The problem with this technical challenge however is that the removal of particulate matters and alkali comes at important efficiency and investment costs penalties (Williams and Larson 1997). Besides, it is cost attractive only at larger plant sizes, above 20-30 MW. The cross flow design is a better option at small scale, as it has lower investment costs than the other designs. But it requires substantial pre-processing of the primary biomass resources (Koukios 2002).

Consequently, the four technological designs perform differently from the standpoint of the five technical challenges facing the gasification principle in general. Development and demonstration continues to produce at least one technological design that responds well in all these aspects. So far it seems that the downward flow design is the most promising. But, as already mentioned, the answers to these technical challenges are also explored in the direction of hybridization between the gasification and pyrolysis principles. Based on this analysis, *we propose to regard as diffusion-optimal those technological designs based on gasification systems that manage to bring sufficient improvements in all five areas of technical challenges, so as substantial market diffusion can be induced.*

4.4.2.3 Pyrolysis technology

Pyrolysis is a biomass-to-feedstock conversion technology most indicated for energy crops, agricultural and forestry wastes, as well as solid urban residues. This process can take place at temperatures between 250ºC and 600ºC. The temperature influences the resulting proportions of bio-oil, charcoal (solids) and combustible gases. Fast pyrolysis at moderate temperatures produces bio-oil up to 80% by weight (Kouikos 2002). This is next used in direct combustion systems that pass the energy to engines or steam turbines to produce electricity. The main advantage of this technological principle is that bio-oil production can be separated from power production. This way it can be easily stored and transported. Besides, it offers a high degree of supply flexibility for the power generation plant, making it ideal for stand-alone applications. Fluidized bed systems seem to be the most suitable design for pyrolysis so far (Sims and Gigler 2002).

Currently pyrolysis is considered still in development stage. Demonstration is not recommended until more progress is made in the area of bio-oil upgrading (EU 2000). Bio-oil

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[38] The technology was named two-stage because it combines the gasification and pyrolysis technological principles (CBT 1999). Other hydrid versions are also researched with the view of responding to the technical challenges of both principles (Koukios 2002).

is a feedstock with high-energy value but it has three major ‘unwanted properties’: high viscosity, poor thermal stability, corrosivity (Koukios 2002). The last one is an important technical obstacle for the use of bio-oil with engines[39] and turbines. In addition the technology is currently still expensive. Therefore, *substantial improvements are needed in the areas of bio-oil upgrading and reduction of production costs*. However, even if these occur, market diffusion of biomass-to-electricity systems will be seriously challenged by another major application of bio-oils, that is - transportation fuel for diesel substitution.

4.4.2.4 Biochemical conversion technologies

Biochemical transformations assume the decomposition of organic matter in biomass resources, in the presence of certain naturally occurring bacteria and without oxigen. The resulting biogas contains methane (CH_4 40-70%), carbon dioxide (CO_2), hydrogen (H) and other gases. The rate of conversion is around 30-60% of biomass inputs (Kouikos 2002). Biogas can be burned in direct combustion systems, which can be used in combination with engines or steam turbines. The main types of biomass resources used are organic wastes in landfill lands, sewage wastes, animal manure and organic wastes from industrial or food production industries. The first two dominates world-wide use but its potential is on the decrease in developed countries due to waste management policies. Future market diffusion of this technology is especially expected to come from animal manure use.

Biochemical transformation is considered a technically and commercially mature technology. Conversion efficiencies can currently vary between 27% and 60% (Rajabapajah et al. 1997). However it is assessed that some improvements in the biomass-to-biogas conversion can still take place by manipulating the bacteria that mediate the fermentation process. This would increase the biogas yields per unit of time, and ultimately reduce electricity production costs.

4.4.3 Types of electricity generation systems

Biomass-to-feedstock systems can be integrated with one of the conventional power generation technologies - that is engines, steam turbines, gas turbines, or combined cycle technologies (combining gas and steam turbines). The most efficient alternative is the one using steam-gas combined cycles (Koukios 2002: 17). In practice, due to technical, economic and environmental performances not all biomass-to-energy systems can be integrated to all these power generation technologies. Table 4.7 mentions the combinations currently considered feasible, although in some cases this still faces some technical problems or is strongly dependent on plant size.

Table 4.7 *Currently feasible combinations of biomass-to-feedstock technologies and electricity generation technologies*[40]

Electricity generation	Biomass-to-feedstock technology
internal combustion engines; Stirling engine	direct combustion; gasification; pyrolysis; anaerobic fermentation
steam turbines	
gas turbines	gasification
integrated steam-gas turbines[41]	gasification (in the range 10-100 MW)

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[39] In 2002, the integration of pyrolysis systems with internal combustion engines was under evaluation (Sim and Gigler 2002).

[40] Based on Sims and Gigles (2002), Koukios (2002) and Overend (2000)

4.4.4 Conclusion on biomass technology designs

The transformation of biomass resources into electricity assumes the use of three groups of systems: biomass fuel supply systems, biomass-to-feedstock systems and electricity generation technologies. For certain types of biomass resources the fuel collection and supply systems are commercially mature and large experience already exists. This is the case of organic industrial and agricultural wastes, biogas from landfill sites, biogas from sewage wastes, and clean agricultural wastes - both grassy and woody.

For the rest - dedicated energy cultivation, clean forestry wastes and livestock wastes - improvements at various stages in the fuel supply systems are still needed. Since these types of resources (together with clean agricultural wastes) have the largest potential for the sustainable diffusion of biomass electricity technologies, innovations in their collection and pre-processing methods can be regarded as diffusion-optimal. In the case of dedicated energy cultivation improvement needs go even further to produce higher density and energy value crops. The other resources - secondary organic wastes and biogas from human wastes - have been for a long time exploited in several developed countries. There, the resource potential is approaching exhaustion, due to the limited magnitude of industrial activities and due to wastes management practices. Waste policies are increasingly oriented towards recycling and limitation of organic wastes in landfills. The potential for secondary organic resources remains however important in countries with economies in transition and in developing countries.

Biomass-to-feedstock conversion systems are also in different stages of evolution. Direct-combustion technologies are generally considered in the literature as technically and commercially mature. This contrasts nevertheless with the improvement needs often highlighted. From the standpoint of efficiency, atmospheric emissions and investment costs, direct combustion technologies do not yet perform well. In this context, given their long established use they can be considered as conventional technologies but not yet fully technically and commercially mature. Innovations that would lead to substantial leaps forwards on these three remaining areas of challenge are desirable.

Gasification technologies have two extra areas of technical challenges, namely the quality of the resulting gas-feedstock and the types of biomass resources that can undergo gasification. Modest improvements were already booked in the second half of the 1990s, bringing improvements in one or more areas. If a technological design (diffusion optimal) bringing simultaneous successful performances on all five areas does not occur, it is likely that the overlap of small innovations would lead gasification technology to full technical and commercial maturity in the near term anyway. Substantial progress has been already brought by the two-stage downdraft technological design, which combines pyrolysis with gasification. But so far the gasification technological principle is described by experts as ‘emerging’ (Kouikos 2002).

The pyrolysis principle is characterised as ‘promising’ and ‘under development’ (Kouikos 2002; EU website). Its demonstration has already taken place on few plants. But the first priority is considered the upgrading of bio-oil. New designs in this area can be therefore seen as diffusion optimal as they would enable its testing for electricity generation in engines and turbines. Finally, the bio-chemical conversion principle is the most advanced and due to its long-time use can be described as a conventional technology. Some experts consider however that the design of anaerobic digestion, especially of livestock wastes can be improved to

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[41] At plant sizes above 60 MW these systems can be more profitable than direct combustion through fluidized bed (Overend 2000).

increase efficiency. The analyses regarding the technical performances improvement needed in biomass to feedstock technologies are summarized in Table 4.8.

In spite of substantial differences in terms of technical performances, what the first two mentioned technologies have in common is that plant-size influences strongly the economic performances of plants. The lowest production costs are achieved when plants have less than 1 MW (used with engines) or more than 30 MW. Innovations for costs' reduction will therefore have an important impact on the diffusion of biomass technologies not only from economic perspective but also from social standpoint. The possibility to develop cost-competitive (or lower cost) small and medium size plans would mean that small developers, such as cooperatives, local communities and small and medium size companies - all often located in remote areas with large biomass availability would also be able to invest.

Table 4.8 *The performance improvements needed in the biomass-to-feedstock systems*

Biomass systems	Resources / Technological principle	Diffusion potential / design	Main areas where innovation is needed
Biomass-to-feedstock systems	Direct combustion	small (conventional)	- efficiency; - cost performances; - environmental performances
	Gasification	large (diffusion optimal)	- efficiency - cost performances; - environmental performances - types of biomass suitable - quality of gas-feedstock
	Pyrolysis		quality of bio-oil feedstock
	Biochemical conversion	small (conventional)	still possible to increase efficiency

In this context we propose to operationalise the indicator of project sizes for biomass projects in the following way:

- smaller than 1 MW = very small;
- smaller than 10 MW = small;
- smaller than 30 MW = medium;
- larger than 30 MW = large.

4.5 Summary and conclusions

In this chapter we answered theoretically the fourth research question, for the types of renewable technologies whose diffusion is empirically studied in this book. The aim was to investigate what features of the technological designs so far available for the three selected renewable technologies may have the potential to increase the market expansion of the respective type of renewable resource. But in the same time, we operationalised the indicators of technological design and projects sizes for the analysed technologies, which are two of our indicators for diffusion patterns. We envisaged to specify the technical features that make the difference between conventional technological designs, designs with 'substantial' potential for diffusion expansion and designs with 'modest' potential for diffusion expansion.

In Section 4.1, we focused on wind technology. We started the analysis with an explanation of the technological principles of harnessing wind energy for electricity production. After that, we reviewed the technical obstacles faced by wind technology since its inception and progress so far in addressing them. Based on this we concluded that the analysis

of the diffusion expansion potential of technological designs based on wind energy needs to be made from four performance-perspectives:
- contribution towards grid-friendliness and compatibility for stand-alone application;
- improvements brought in the efficiency of wind energy harnessing at a certain site;
- the ability to function in low wind speeds, below average annual levels of 5 m/s which are the dominant ranges across the globe; and/or
- the ability to close the cost-gap with conventional electricity technologies.

Following this we pointed out that in the case of wind energy, diffusion optimal designs may be defined by different performance perspectives and may have different technical features in different countries and long time. In a country with a wind potential higher than the feasible grid integration ceiling, the required technical features of the diffusion optimal designs will be different than those for a country where the relationship resource availability - grid feasibility is reversed. Finally, we selected the technical features that would define diffusion-optimal designs as follows:
- grid-friendly and stand-alone-compatible application, through pitch control of voltage regulation, variable speed rotor and synchronous generators;
- substantially higher efficiency rates in transforming wind energy resources in electricity than current designs;
- able to function in low wind speeds, below average annual levels of 5 m/s which are the dominant ranges across the globe.

In relation to this it was also specified what should be in our view considered as design with modest diffusion expansion potential and what are the technical performances/features of conventional wind technology designs.

In Section 4.3, the focus was on small hydropower technology. This is an old technology with already large achievements in terms of technical performances. However, so far it did not manage to reach cost competitiveness with conventional fossil-based electricity. We reviewed the types of small hydropower plants in terms of construction works (run-of-the-river and storage plants) and the technological principles of hydropower harnessing. After an examination of the milestones in technical progress, we concluded that at the end of the 1970s, the small hydropower technology was technically-advanced from the following performance-perspectives:
- technological efficiency, through high conversion efficiencies for turbines and generators;
- technical feasibility of exploiting low resource sites - with low flow and head of water;
- compatibility for stand-alone applications and grid-friendliness, through the innovations for power quality and back-up electricity.

The remaining technical challenges for small hydropower diffusion were seen as divided in three groups: technical optimisation needs, improvement of cost performances, and improvement of environmental performances especially with regard to civil works. Due to the fact that the small hydropower's economic and environmental performances form the main obstacles for a more forceful diffusion of this technology, we consider that the analysis of technological design from a diffusion expansion perspective needs to be made from the following perspectives:
- the ability to improve cost performances as compared to conventional technologies, especially the ability to bring improvements in the economic feasibility of exploiting sites with low water head;

- the ability to bring substantial reductions in the environmental impacts of small hydropower plants, especially with regard to impacts created by civil works.

Finally, in Section 4.3 we tackled the issue of technology designs for biomass electricity technologies. Four types of technological principles were differentiated: direct combustion, gasification, pyrolysis, and anaerobic fermentation. Each of these principles has more types of technological designs developed so far. But overall, the designs that have the highest potential for diffusion expansion of biomass electricity are in the category of gasification and pyrolysis principles. The other two are generally considered as having a small remaining technical potential for improvements. Based on updated literature, we identified five main technical challenges facing the speeding up of diffusion of gasification based technological designs:

- the need to enlarge the types of biomass resources that can be fed in at higher efficiency and lower costs for gas cleaning;
- the need to increase efficiency, especially by means of increasing the heating value of resulting gas;
- the demand to improve the quality of gas (as resulting feedstock) and to reduce the atmospheric emission of these biomass plants (Williams and Larson 1993);
- the reduction of investment and operation costs, especially for small size plants, and
- improvements in the integration of gasifier into the power conversion system.

The pyrolysis technological principle is still in development stage. Substantial improvements are needed to in the areas of bio-oil upgrading and reduction of production costs. The complexity of biomass technology and power plants did not allow the specification of technical features, below the performance perspectives above mentioned.

In conclusion, a close analysis of technologies reveals that it is possible to improve the insight into the role of technological designs in diffusion expansion prospects and to specify the technical features and performance perspectives that could lead to improved diffusion expansion potential. The technical performances mentioned above constitute our answer to the fourth research question, for the three renewable energy resources on which we concentrate in the study. In empirical research we will look at the extent to which support systems have stimulated the market adoption of technology designs able to comply to the requirements for these technical performances.

The next chapter explains the research methodology adopted in the project, the selection of case studies, and data collection and analysis. But Chapter 5 serves in the same time as a bridge between the theoretical part of the book, and the empirical parts – Part II and Part III – where we test the theoretical expectations. In its framework, we make a summary of the operationalisation of all variables of the research model and the approach to empirically analyse the more complex variables.

5

The research methodology

5.1 Introduction

This chapter presents the research methodology. Section 5.2 explains the research strategy, case definition and selection of cases. Section 5.3 gives a comprehensive presentation of the operationalisation of the research model's variables. In Section 5.4, data collection processes and the techniques of data analysis are presented. In Section 5.5, we explain how we assess the validity of case studies and the theory. The chapter ends with the presentation of the structure of empirical chapters in Section 5.6.

5.2 The research strategy and data collection

5.2.1 Research strategy

The research strategy chosen to address the central research question is that of multiple case studies. In his landmark book on research design, Yin (1994: 17) suggests a blueprint for selecting the most appropriate research strategy. The selection criteria regard the (1) form of the research question – how, why, what, who, where, how many, how much; (2) whether the research requires control over behavioural events – yes/no; and (3) whether it focuses on contemporary events – yes/no.

Our theory has an exploratory part when searching for its borders, but an explanatory backbone where the relationships among its building blocks are unravelled. The spirit of our central research question is a 'how' question. We aim to understand the impact of support systems' characteristics on the diffusion of renewable electricity technologies, by means of understanding a series of 'how' relationships:

- how do investors behave under different risk profitability contexts created by support systems,
- how does their behaviour affect diffusion patterns, and
- how do diffusion patterns influence the extent of market adoption and the prospects for sustainability of market diffusion processes.

Given the still early stage in the research regarding the impact of governmental support on renewables' diffusion, we felt compelled to address - beside the three above mentioned specific core research questions - also four research questions that were meant to delineate the field of theoretical analysis with regard to the independent variable, the dependent variables and the treatment of the unit of analysis - the renewable electricity technology supported. For these we operated with 'what' type of research questions (2, 3 and 4). There are exploratory questions searching for the borders to which the answers to explanatory questions may apply - to what extent the dependent variable may lend itself affected by the independent variable.

Consequently, having in view the explanatory nature of the core of our theory that rests on a 'how' type of questions, the research design blueprint of Yin (1994) suggests three research strategies: experiment, history and case study. Our research focuses on contemporary research which makes a 'history strategy' not suitable. The experiment strategy requires the study of a control group whose behaviour needs to be contrasted to that of the treatment group. Having in view our empirical interest in investments in renewable power plants at a national level when all types of economic actors are eligible for the support system put in place by central government, a control group cannot be organised. We choose case study as the appropriate research strategy to empirically test the research questions of the study.

Case studies are a suitable strategy because they can be applied in order to identify patterns of constant association between dependent and independent variables, and not to explain variation. Yin (1984: 23) defines a case study as "an empirical inquiry that investigates a contemporary phenomenon within its real life context; when the boundaries between the phenomenon and context are not clearly evident; and in which multiple sources of evidence are used."

Four types of case-study designs are differentiated: single-case holistic (single unit of analysis) designs, single-case embedded (multiple unit of analysis) designs, multiple case holistic design, and multiple case embedded design (Yin 1994: 46). We choose for a multiple case holistic methodology. A holistic design is appropriate because we have one unit of analysis - the investor in renewable electricity technology. He reacts to the support system effectiveness and his reaction determines the extent and prospects of diffusion.

A multiple case design is imperative when a theory, such as ours, includes a large number of variables, and involves conditioning factors, intermingled into complex relationships. Besides, multiple case design has a higher potential to lend robustness to the study, through the replication of hypotheses' testing.

As regards the analytical strategy of case study evidence, three approaches are recommended: pattern-matching, explanation building and time series analysis. We opt for pattern-matching approach which "compares an empirically based pattern with a predicted one (…). If the patterns coincide, the results can help a case study to strengthen its internal validity" (Yin 1994: 107). The format of the theory is such that for each combination of circumstances (independent variables) an expectation can be derived for the outcomes (dependent variables). By first assessing empirically for each case first the value of the independent variables, then deriving the theoretically expected values of the dependent variables, and ultimately assessing these outcomes in empirical reality, the theory can be tested on a case by case basis. Though every (sub)case provides only a partial test, that is tests only the expectations for a singular combination of circumstances, nevertheless by this repeated partial testing also - all in all - the general logic behind the theory is put to the test (cf. Yin 1994). The next sub-section explains the definition and selection of case studies.

5.2.2 The choice of case studies

In the study, we have formulated four hypotheses, for two of which the dependent variables branch off under the influence of selected intermediary variables. This yielded six theoretically predicted situations. By situation we mean the combinations: form of independent variable - form of intermediary variable - form of dependent variable.

The cases have been selected to allow testing of the six sets of theoretical expectations and to provide - to the extent feasible - for the replication of individual situations' testing. After a preliminary exploration of the empirical field we chose eight case studies covering three countries and three types of renewable electricity technologies, for testing our theoretical expectations.

In this book, a case study for empirical research is defined by a situation where in one country the support system addressing the economic and financing barriers of a certain type of renewable technology is stable over a short-medium term period. We consider such a period to be 5 - 10 years, which should be sufficient to allow investors to get accustomed to the support systems and to allow measurable adoption results to be observed.

We had the following main criteria in the selection of case studies:

- enabling the testing of all four hypotheses: the chosen support systems should ensure a balanced spread of the risk-profitability circumstances across the four investment contexts differentiated;
- compliance with our core assumption regarding support systems, namely that the support system - even if it incurs changes - preserves the same risk-profitability profile for a period of 5 to 10 years, so that the classification in one of the four investment contexts does not change;
- compliance with as many as possible assumptions formulated in Section 2.5;
- allowing for technology diversity among case studies so that: to improve the empirical insight into the role that technology characteristic factors can play in investment decisions; and to observe whether these can alter the diffusion patterns and results of the same type of support system;
- avoiding over-researched cases.

In searching cases it appeared that a selection would have eventually to compromise among criteria. We decided not to focus on renewables in Denmark, Germany and California, since an overwhelming part of the currently available empirical literatures concentrates on these countries. Further, we could not find a case study where all the assumptions formulated in Section 2.5 are met. We had difficulties in finding a support system that remained in the political investment context for all types of project developers for at least five years.

After a balance of the degree of fitness with the criteria, we chose to analyse support systems in three countries - the Netherlands[1], Spain and the United Kingdom. The choice for the three countries is mainly related to the diversity in the risk-profitability profiles for the support systems. Besides, in Spain the support system changed in time enabling us to test two hypotheses for each of the three types of technologies selected. The technologies on which we focus are wind, biomass electricity and small hydropower technology. For the case studies in the Netherlands and the United Kingdom we only focus on wind technology. Table 5.1 mentions the empirical case studies we chose and the hypothesis that each of them will test.

Table 5.1 *Case studies for hypotheses testing*

Hypothesis 1	→ wind technology in Spain, 1995-2000 → small hydropower technology in Spain, 1995-2000 → wind technology in the United Kingdom, 1990-2002
Hypothesis 2	→ wind technology in Spain, the 1980s-1994 → small hydropower technology in Spain, the 1980s-1994
Hypothesis 4	→ biomass electricity technologies, Spain, the 1980s-1994
A combination of Hypothesis 1 and 3	→ biomass electricity technologies in Spain, 1996-2001
A combination of Hypotheses 3 and 4[2]	→ wind technology in Netherlands, 1990-1997

We tested Hypothesis 1 in three case studies, Hypothesis 2 in two cases and Hypothesis 4 in one case. For one case study we tested a combination of Hypotheses 3 and 4, while for another one the risk-profitability contexts required the testing of a combination of Hypotheses 1 and 3. This was necessary in the first case because the investment risk induced by the support system was very different for separate groups of project developers. In the second case the

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[1] Although wind diffusion in the Netherlands received attention in much of the Western European policy research, we argue that too much emphasis was put only on one of the components of the support system, that is the Green Label trade system. The working of the support system as a whole has seldom been addressed - mainly just by describing it than understanding the interaction of the support schemes used.

[2] The hypothesis was specified for the mixture of political and minimal investment contexts: Areas 3 and 4.

profitability range expanded widely, covering two of the four investment contexts theoretically differentiated. More details on these two hypotheses are given in Chapter 11, respectively in Chapter 8. The testing of hypotheses for the same technology in the same country took place in the chronological order given by the time of application of the support system to which it refers.

5.3 The operationalisation of the research model's variables

This section summarises how we operationalised the research model's variables and the measurement of variables. The independent variables of the theory are: the aggregated economic-policy risk of the support system, and the profitability of projects enabled by the respective support system. The dependent variables are: diffusion patterns and diffusion results.

Aggregated economic-policy risks

The assessment of economic-policy risks was qualitative. It relied chiefly on our close analysis of the legal texts and policy documents establishing the economic governance structure and policy support mechanisms applicable for the renewable technology. We looked at them both 1) strictly from a legal perspective and 2) at context level analysing the framework in which they were applied. In this process, we were searching for possible sources of uncertainties or, on the contrary reassurance, that the extent of governmental support and time-scale of the guarantees stated in the legal and policy documents were indeed reliable. Investors in RET projects generally require to recover their investment costs over time spans of seven to fifteen years, or more. Hence, the reliability of economic guarantees is crucial for the investment decisions.

In the case-studies for Spain, we were able to include the opinions of developers of renewable projects and market experts regarding economic-policy risks in our analysis. In Spain there was a strong political and business culture influence on the interpretation of the regulatory framework at industry level, which was openly discussed and therefore accessible for our research But this was not repeated in the cases of the Netherlands and United Kingdom because such a situation was not signalled**.**

In terms of analytical process for aggregated risks' assessment, we looked at the economic risks, making qualitative assessments on a scale with four levels: low, moderate, high, very high. Assessments on this scale were made in a first step separately for demand risks, contract risks, and price risks, as resulting from the economic governance structure. In the second step, their interaction was interpreted from the perspective on long-term risks on projects' cash-flows. This resulted in the assessment, on the same four-scale level, of the economic risks. This represented the background on which the consequent assessment of policy risks was projected.

In the third step, policy risks were analysed separately per type of policy support mechanism (see Chapter 2), as well as their interaction. The risks from their interaction were assessed by taking into account the extent of financial support represented by each type of policy support mechanism. The aggregated support system risks resulted from interpreting the interaction between economic risks and policy risks in a similar way.

Profitability of projects

The operationalisation of the profitability characteristic was developed on the basis of expert knowledge taken from interviews with project developers and market analysts, as well as analyses of a rich diversity of empirical material on the issue of renewable energy plants' economics and financing. We operationalised projects' profitability as: low - up to 4%; modest 4-8%; high 8-12%; very high > 12%. In empirical research, profitability was assessed by using one, or whenever possible more, of the following three approaches: 1) direct profitability data from developers, market experts and available empirical material such as governmental documents, journal articles or conference papers; 2) qualitative assessments from developers were used when data were treated as confidential; and/or 3) a rough comparison of production costs and extent of price/financial support, using also information from developers, market experts and empirical material. The last approach can only lead to a qualitative assessment of the research, and is in principle desirable just as back up for the first two approaches.

Diffusion patterns

Five indicators of diffusion patterns were selected: types of project developers, types of financing schemes used, projects' sizes, drivers of developers to invest, and choice for technological design of investors. These indicators were selected because we assumed that with their help one can derive expectations regarding both the rate of installed capacity increase and the prospects for sustainability of market diffusion processes. The typologies for these indicators are mentioned in Table 5.2.

Table 5.2 *Indicators of diffusion patterns*

Diffusion patterns	Forms
types of project developers	1. Large developers: energy utilities / companies, long-established financially-powerful corporations, and publicly-owned companies. 2. Small developers: medium/small-size industrial production companies, small new-entrant firms, cooperatives, communities, associations and individuals.
types of financing schemes	1. External financing: project finance, institutional finance, 2. Internal financing schemes: private finance, participation finance, in-house corporate finance, debt-corporate finance, third-party finance, multi-contribution finance
projects' sizes	On the base of MW very small, small, medium, large, very large
drivers to invest	Commercial, strategic, (partly-)self-generation
technological design	Diffusion-optimal, investor-effective, conventional (see Chapter 4)

Eight types of financing schemes were differentiated that can be grouped in two categories. The first is that of internal financing schemes whereby project developers are in the same time the main financing agents. Six types of financing schemes were placed in this category. The second is that of external financing schemes, when project developers contribute to less than half to the capital structure of the project, and the rest comes either from bank loans or from the stock market.

The types of project developers were considered in the differentiated categories: electricity companies/utilities, long-established financially powerful corporations, medium-size and small-size industrial production companies, publicly-owned companies, small new entrant firms, cooperatives, communities, associations and individuals. The drivers to invest were classified as commercial, strategic, and (partly-)self-generation. Strategic drivers could be quite diverse, ranging from early market positioning, green image, and local business opportunity to ideological reasons. In practice developers base their investment decisions on more considerations, simultaneously. But the typology enables a clearer analysis.

Projects' sizes were labelled and operationalised differently for wind energy systems and for biomass electricity plants. For wind projects the following orientative differentiation was made: very small (<1 MW), small (1-5 MW), medium (5-15 MW), large (15-25 MW) and very large (>25 MW). For biomass projects we took into account the larger economies of scale for costs' reduction and we operationalised project sizes as: very small (<1 MW), small (1-10 MW), medium (10-30 MW), large (30-50 MW) and very large (>50 MW). This division was proposed taking into account the early stage of technology development and diffusion. As technology matures, sizes tend to grow and what is viewed as large in the market introduction period can be seen as small after a longer period of diffusion. But it does not apply for small hydropower technology, as this is politically defined.

Finally, the technological choice of developers was discussed in terms of the potential of the respective designs to contribute to capacity increase of that technology in the long term in the electricity system, improving this way the prospects of sustainable diffusion processes. Several technical characteristics and features were selected that, based on state of the art technical literature, have the potential to directly reduce diffusion obstacles with answers in the technical sphere. This way the market adoption of these technological designs can contribute to the increase in the technically, economically and/or socially feasible diffusion potential of that renewable resource in the electricity system, on a long-term basis. We differentiated between conventional designs, and technological designs with substantial (diffusion-optimal) or modest potential for contribution to diffusion expansion. The indicator of technological choice was operationalised in Chapter 4 for each renewable technology studied in this book.

Diffusion results

The term 'effectiveness of support system' was operationalised as installed capacity increase in short/medium term (5-10 years) and measured in megawatt (MW). The hypotheses formulated in Chapter 3 refer to 'small', 'modest' and 'large' installed capacity increase in short/medium term. The operationalisation of these qualitative assessments is hereby made considering ranges of up to 500 MW increase as *small*, between 500-1000 MW as *modest*, and more than 1000 MW as *large* capacity increase. The numbers were suggested by an overview on the extent of market growth of renewable electricity plants in industrialised countries during the 1990s.

We also took into account the expensiveness of the renewable technologies empirically studied as compared to conventional technologies. Besides, we bear in mind the fact that in industrialised countries the rate of market growth of renewable capacity may be limited by the nationally-sufficient availability of conventional power plants - or even over-capacity. Nevertheless, we suggest the numbers just as orientation for the rate of market growth. More important than the number itself is to check the speed of diffusion and whether the support system is able to sustain or increase that speed.

In the theory, we made the assumption that there would be no barriers affecting the investment interest of developers. This assumption was needed, on the one hand, because the aim was to underpin the diffusion potential of support systems aiming to reduce economic and financing barriers and, on the other hand, because the other types of barriers are often technology specific and nationally specific. Therefore, we only looked at these other barriers empirically.

In order to subtract the effect of such barriers on diffusion and to derive the investment interest on which we actually hypothesised, it appeared necessary to look at the capacity represented by both the installed plants and the projects refused or blocked in the approval process. When data on blocked or refused projects were not available we used empirical information (written or interviews) able to suggest the size of investment interest not reflected in the installed capacity at the end of the period under research. When the impact of such barriers was assessed as small we looked directly at the level of installed capacity.

As regards the second dependent variable, the following indicators for diffusion results were taken into account in the discussion regarding the prospects for the sustainability of market diffusion processes:

- technology-specific costs, expressed as the costs of technology per kW capacity based on factory price [costs/kW];
- cost-performances, measured as costs per kWh generated;
- selected perspectives and indicators for technical performances, which were specified per type of technology in Chapter 4;
- national employment in the industry for the respective renewable technology;
- the degree of ownership involvement at national level by individuals/households in RET plants: investments based on the institutional and participation finance schemes;
- local direct ownership;
- indirect local benefits such as land renting, local taxes; or local economic or social welfare investments;
- number companies offering products/services for renewable plants;
- types of companies involved in industry: looking at the industrial sectors from which the companies forming the emerging manufacturing and service RET industry came;
- the degree of specialisation in renewables, looking at the number of renewable technologies the manufacturing and service companies were covering in the same time, and at the number of other business areas outside the field of renewables; the lower the number of technology areas covered the higher the degree of specialisation in the respective RET.

The next section explains how we collected the data for the operationalised indicators.

5.4 Data collection and analysis

In collecting data, we used three main sources of information: written material, interviews with experts and information posted at the websites of companies and public authorities. A wide variety of written sources was used: book publications, scientific articles and unpublished research reports, articles from journals of the renewables' and wind industry, conference proceedings, press releases, technical studies, the national legislation regarding renewables support and policy documents, country overviews and energy data bases of governmental and European Union bodies, company and organisational internal documents (e.g. overviews of investment activities, project specifications, project evaluations and annual reports, promotion material from manufacturers).

We started by making a general orientation in the empirical field with the help of written material. This offered a point of departure for drawing up the list of institutions and companies to be contacted for interviews, as well as, in many instances the persons to be interviewed. Valuable sources for data collection and the gathering of names of market experts and company representatives were the journals Wind Power Monthly (for all three wind-case countries) and Las Energias Renovales[4] for all renewable technologies in Spain.

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[4] Wind Power Monthly is a journal with information on business news from around the world, market and

We conducted extensive structured interviews in the field, either face to face, by telephone, by e-mail and fax. The question concerning the risk perception of investors regarding the support system was only dealt with in face to face and telephone interviews. The information regarding the five indicators for diffusion patterns and the profitability of projects are seldom available in written material and quite difficult to collect in practice. Due to the dispersion of companies and investors across each country and the company-specificity of the required information, e-mail and fax communication was a rich source of information. In companies, most interviews were carried out with the investment directors/managers or the financial directors. In some cases follow up interviews were made with the same persons in order to collect the answers for all the questions. Face-to-face interviews were mostly carried out during country visits, in Spain and the United Kingdom. But we also used the opportunity offered by our participation at international conferences[5] to make interviews with company representatives attending the events and to check the data collected thus far by means of personal communications with participating market experts and policy analysts[6].

The valuation and assessment of several of the model variables quite often required own calculations of data. For the indicators of projects' profitability, project sizes, types of financing schemes, industrial basis and dynamics, socio-economic benefits, and cost performances we often had to combine multiple sources, as data were available in very scattered form. In each empirical chapter, we make a more detailed account on the sources of data and the methodology of data processing used.

5.5 The assessment of validity

The assessment of the internal validity of each case study was made by means of qualitative criteria specified in Table 5.3. The table explains the meaning of qualitative criteria for the confirmation of theoretical expectations regarding diffusion patterns and results. The testing of internal validity of case studies was done in Chapters 7, 8, 9, 12, 13.

Table 5.4 specifies the qualitative criteria for the assessment of the external validity, i.e. for degree of predictability of (intermediary and dependent) indicator's forms in the empirical research conducted. The testing of the external validity of the theory was done in Chapter 14. The next section presents the structure of empirical chapters.

5.6 The structure of case studies' presentation

The presentation of our case studies in empirical research takes the following structure. The first part of the case study is dedicated to the analysis of the economic-policy support system

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policy analyses and technology progress articles, available for subscribers (with articles archived since 1994) at www.windpower-monthly.com. Las Energias Renovales contains market and policy updates on the Spanish industry of renewables and it is available at www.energias-renovables.com.

[5] We visited the following conferences where such contacts were made: Global Wind Power Conference, Paris 2-5 April 2002; World Renewable Energy Congress VII, Koln 29 June – 5 July 2002; the Annual Summit on Renewables' Financing, Brussels November 2001; The Technology Exhibition of the Wind Renewable Energy Congress V, Brighton June 2000; The European Energy Conference, Technological Progress and Energy Challenges, 30 September - 1 October 1999, Paris.

[6] The list with interviewees from all three countries is presented in the Reference List at the end of the book.

applicable to the respective renewable technology in a country. This analysis ends up with choosing the hypothesi(e)s to be tested for that particular technology.

Table 5.3 *Qualitative criteria for internal validity assessments*

Qualitative labels	Assessments in the empirical research of this study
1. confirmed	All expected forms of the indicator were observed
2. confirmed to a large extent	one or few forms were present to a slightly larger or a slightly smaller extent than predicted
3. partly confirmed	some predicted forms are missing or some forms are present although not unexpected; but there is a basis of at least a 50 % of predicted forms present
4. not confirmed	a substantial part of the predicted forms is missing or unexpected
5. cannot be tested	whenever the forms of the studied indicator are directly and rigidly formulated in the design of the support system; or various factors such as data availability or confidentiality do not allow the observance of the indicator's forms
6. no conclusion	whenever the observed forms are obviously so largely influenced by exogenous factors that a relation with support system characteristics would be meaningless
the addition '*with comment'*	whenever there is special government (or other type of) intervention that influenced one or more of the forms that the studied indicator took in practice

Table 5.4 *Qualitative criteria for external validity assessment*

Qualitative labels	Situations observed regarding the extent of confirmation of the same indicator in more case studies
1. good	(more times confirmed); or (confirmed + confirmed to a large extent)
2. satisfactory	(confirmed + partly confirmed); or (confirmed + confirmed + partly confirmed + not confirmed); or (confirmed + confirmed to large extent + partly confirmed)
3. partly satisfactory	(confirmed to a large extent + partly confirmed); or (confirmed + not confirmed) (confirmed + confirmed + partly confirmed + not confirmed)
4. not satisfactory	(partly confirmed + not confirmed); or (more times not confirmed)
5. no conclusion	partly confirmed + could not be tested, or confirmed + no conclusion

The second part of the case study is dedicated to the testing of the selected hypothesis. When two hypotheses are selected their testing will take place in the chronological order given by the time of application of the support system to which it refers.

Each case study will contain the following key sections:

- a short overview of the context: on the structure and functioning of the electricity industry in which the support system for RET is implemented, the national energy resources basis and potentials;
- a short review of the governmental historical support for the respective RET[7];
- the empirical classification of the national risk/profitability environment and choice of hypothesi(e)s, following these steps:

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[7] In the case of the three technologies studied in Spain - wind, biomass electricity, and small hydropower - this will be done in the introduction of chapters testing the hypotheses, to place the information closer where this aspect of the 'context' are most relevant.

  - empirical analysis of economic governance structure and analysis of economic risks;
  - empirical analysis of policy support schemes and analysis of policy risks;
  - classification of the independent variable 'aggregated economic policy risks';
  - classification of the independent variable 'project profitability';
  - based on the empirical classification, choosing the hypothesi(e)s to be tested for the particular technology;
- testing the hypothesi(e)s on diffusion patterns;
- testing the hypothesi(e)s on diffusion results;
- formulating conclusions on the testing of the theoretical expectations.

For our empirical research covering renewables diffusion in Spain, we concentrated the analysis of support systems for all three technologies studied (wind, biomass electricity and small hydropower) in one chapter, that is Chapter 6. This was motivated by the fact that - while there were differences in the economic-policy risks and profitability of projects - the same legislation and policy applied for all three technologies. This way we avoided repeating the presentation of support schemes. Because of changes in the characteristics of support systems for each of the three renewable technologies in the period studied, 1980-2000, we differentiate between six cases. At the end of Chapter 6 we formulate the hypotheses for these six cases referring to renewables in Spain. Chapter 7 presents the testing of two hypotheses for wind diffusion, Chapter 9 tests the same two hypotheses (Hypotheses 1 and 2) for small hydropower diffusion, while Chapter 8 tests Hypotheses 1, 3 and 4 for biomass electricity diffuison in Spain. The six case studies referring to renewable technologies in Spain form Part II of the book.

Part III of the book is also empirical and tests the theoretical expectations for wind technology diffusion in The Netherlands and the United Kingdom. In the case of The Netherlands, the high number of support schemes used and the complexity of their interaction required an extensive analysis, for which we dedicated the entire Chapter 11. The testing of the hypothesis for the Dutch wind technology diffusion, in the period 1990-1997, is done in Chapter 12. Finally, Chapter 13 takes both steps of hypothesis specification and testing for the case study of wind technology diffusion in the United Kingdom, for the period 1990-2002.

In Part IV we conclude by evaluating the external validity of the theory and the significance of empirical findings of the study.

6

Economic-policy support systems for renewable electricity technologies in Spain

6.1 Introduction

This chapter opens the Part II of the book, where we are concerned with renewable electricity diffusion in Spain. The chapter describes the support systems used in Spain during the 1980s and the 1990s for the market introduction and diffusion of three renewable electricity technologies. The technologies of concern for our empirical research are wind, biomass and small hydropower technologies. The central focus of the chapter is to analyse the economic risks associated with support systems and the extent of financial support they offered for renewable electricity generation.

We start the chapter by means of a general presentation in Section 6.2 of the energy resource and policy context in which the governmental support for renewables emerged and evolved. A close look at the legal framework regulating the trade aspects of renewable electricity reveals that three economic governance structures can be differentiated in the period since 1980: 1980-1994; 1995-1998; and post 1999. Sections 6.3, 6.4, and 6.5 describe the legal frameworks setting these three economic governance structures for renewable electricity. In each section, after the analysis of the type of demand, price design and particularities of contractual relations, a theoretical assessment of the economic risks will be performed first from the sole perspective of a strict analysis of the legal terms. The financial support in terms of price per kWh originating in each of the three economic governance structures will also be specified for each technology studied. In Section 6.6 we summarise our main findings with regard to the economic risks and extent of price support under the three economic governance structures for the three types of technologies that we are concerned with.

In Section 6.7, we discuss the policy support mechanisms for renewable electricity implemented since early 1980s and the policy risks associated with them. Following that, we present the assessment of risks emerging from support systems as they were/are perceived by project developers. This section relies on the interviews we carried out in the field. Finally, in Section 6.9 we select the hypotheses to be tested for each of three renewable electricity technologies. In tracing the hypotheses, we use again information collected during interviews, this time regarding the profitability of projects. As mentioned in the methodology chapter, our theoretical considerations over the economic risks embedded in the legal framework will be combined with opinions of interviewed developers in order to round up the qualitative assessments of the risk/profitability characteristics. Section 6.10 summarises the content of this chapter.

6.2 The context for renewables support in Spain

Spain has been one of the countries with the highest dependency on imported energy resources in the European Union. In 1973, domestically-originating energy resources covered only 28,6% of the total energy demand (Lopez 2000: 155). Towards the end of the 1990s domestic resources served still just 30% of total demand, while the EU average figure was around 50%[1]. In 1975 the share of oil in primary energy consumption was as high as 73% which suggests how hard was Spain hit by the 1973 oil crisis (Idae[1][2] 1999: 38). Under these crisis

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[1] European Commission COM (97) 599, "Energy for the future: renewable energy sources - white paper for a community strategy and action plan".

[2] We will use this reference very often throughout the Part II of the book. This is the reference for the Policy Plan for the Promotion of Renewable Energy drafted by the Spanish agency responsible for renewable energy development, the Institute for Energy Saving and Diversification (Idae).

circumstances, and given the absence of domestic gas resources and poor presence of low quality coal, the Spanish government embarked into a new energy policy for integrated planing of the energy sector. The main energy policy objectives set in mid 1970s were: energy saving, energy efficiency, diversification of primary resources exponentiation of all domestic resources that can be used for energy purposes, reduction of oil dependency, and research for new types of energy resources (Lopez 200: 155).

Beginning with 1975 a series of national energy plans and programs were adopted for the implementation of these new objectives. The attention and extent of support that renewable energy technologies were given in the framework of these policy programs was quite low in the first years but it intensified after the last part of the 1980s, as some explored technologies started to prove their technical feasibility. The 1983 Plan for Energy Conservation and Saving launched some policy support mechanisms in the context of a special R&D Program for Renewable Energy. From mid 1980s up to the end of 2000, four Renewable Energy Plans were adopted, changing every time technology priorities and the extent of support given to each technology based on the different policy support mechanisms deployed.

In 1980, the 82/1980 Energy Conservation Law was adopted placing for the first time renewables' support in a legal framework, and setting the stage for transition from R&D work to demonstration projects. This law launched the first economic governance structure for renewables market introduction. But in the same time, the 82/1980 Energy Conservation Law envisaged a series of policy support mechanisms for demonstration projects that aimed to complement the policy support mechanisms traced in the National Energy Plans and their subordinated Renewable Energy Programs.

The economic governance structure for renewables also changed in time, but only twice. The first time was once in December 1994 - when a new Electricity Law was passed, accompanied by a Royal Decree specifying the legal framework for renewables. The second time was in 1997-1998. In 1997, a new Electricity Law was adopted in order to introduce liberalisation and market principles in the Spanish electricity industry. In the next year, a Royal Decree for renewables was passed by the government, in order to further specify the new protective economic governance structure for renewables in the first decade of liberalised domestic electricity industry. In Spain, the protective economic governance structure was referred to as 'the regime for concerted production', in the 82/1980 Law, and as the 'special regime' in the rest of the pieces of legislation adopted beginning with 1994.

6.2.1 Contribution of primary resources in total consumption and potential of renewables

Table 6.1 shows the structure of electricity generation in Spain, broken down per types of energy resources for the years 1973 and 1998. As it can be observed, in 25 years, renewable resources raised their contribution to electricity production only to a level of 4,5%. However, given the substantial increase in the total electricity consumption, it should be accounted that the 4,5% market introduction of renewables represents quite an impressive level of installed capacity. The 1999 Plan for the Promotion of Renewable Energy (Idae[1] 1999: 43) mentioned that the total installed capacity of renewable electricity plants was as high as 18710 MW, of which around 2500 MW were based among others on small hydropower, wind, and biomass. The last figure includes 1510 MW small hydropower (in plants smaller than 10 MW), 189 MW biomass, and 834 MW wind systems. But at the end of 2000, the installed capacity of wind energy has jumped substantially to around 2500 MW, reshuffling market shares of resources.

Table 6.1 *The evolution of the resource structure for electricity production in Spain*

Year / En. resources	oil	natural gas	coal	nuclear	hydropower >10 MW	renewables & hydropower <10 MW
1973	33,2%	1,0%	18,9%	8,7%	all hydropower 38,2%	0,1% (without hydropower)
1998	9%	8%	32,5%	30,2%	15,8%	4,5%

Based on IEA, 2000 and Idae[1] 1999

Resource availability is quite high for all these types of renewable resources. In terms of wind energy resources, Spain takes the third place in EU, with an estimated net energy potential of 15100 MW left unexplored at the end of 2000 (Idae[1] 1999: 76). For small hydropower the theoretical exploitable potential is as high as 2419 MW. But the estimation of the socio-economically exploitable potential varies among different public bodies and organizations, suggesting figures between 600 MW and 1200 MW (Idae[1] 1999: 89). As regards clean biomass, the national potential is considered extremely high, with a technical-economic potential exploitable by 2010 estimated at the level of 10400 MW clean biomass wastes, and 5700 MW based on energy crops[3] (Idae[1] 1999: 142). Having in view these figures, it cannot be argued that renewables market diffusion was constrained by resource availability. The support systems used by the government played a major role in the diffusion results achieved by the end of 2000, together with the rhythm of technological performance improvement, and the administrative authorisation criteria.

6.2.2 Most important actors

On the governmental side, the main responsibility for energy policy was formerly held by the Ministry of Industry and Energy. In 2000, the conservative party winning elections split the responsibility on energy issues between the Ministry of Science and Technology and the Ministry of Economy (Bustos 2002). The authority on energy policy decisions lies with the Ministry of Economy, which has a State Secretariat for Energy and Small-Medium Size Companies. In 1998, the National Energy Commission was created and attached to the Ministry of Economy. Its main goals are to ensure an effective competition in the energy systems and to protect consumers' interests.

A key actor in renewable energy promotion in Spain has been the Institute for Energy Diversification and Saving (Idae). It was established in 1984 and one of its main tasks is to draft, implement and oversee the governmental policy on renewables. Its ministerial subordination has passed to the Ministry of Science and Technology although Idae has never been a research unit but a governmental arm for political co-decision and policy implementation. The decision has been strongly controversial in governmental and administrative spheres (Bustos 2002). But IDAE remained very committed to renewables promotion. Given its financial autonomy, it played a crucial role in initiating investments in renewable power plants. Beside the traditional investment subsidies and soft-loans, used by most European energy agencies, the renewable energy agency was original and effective through the use of the 'third-party finance' formula, and through its direct capital participation in companies specialised in renewable energy investments. By engaging in this type of support, "Idae tried to find out a replicability effect to speed up private investments to obtain an economically sustainable renewable energy market" (Concha et al. 1996). Further, the

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[3] The potential for biogas is estimated separately for an energy value of 546421 toe (Idae[1] 1999: 149).

governmental agency prepared the 1999 Policy Plan for the Promotion of Renewable Energy setting technology-specific targets for 2010 and the major policy support principle for each renewable resource. For the period up to 2010, one of its main tasks is to design further programs and schemes for funds' allocation, based on the formulated principles.

The regional governments of Autonomous Communities also have a key role to play in renewable technologies diffusion in Spain. Their energy departments have the authority to decide on the administrative approval terms and procedures for renewable power plants, when they are below 50 MW. This way they have a very strong influence on the timetable and extent of renewables market share increase. But beside their legal authorities, the political vision of regional governments was a key success factor for renewables in many Autonomous Communities such as Galicia, Navarra, Castilla y Leon, Castilla la Mancha and Andalucia. Others however, although still politically committed towards renewables' support were more concerned with the aspects of rigorous planning, environmental sensitivity studies and social consensus, which lead to some temporary slow down in installed capacity.

On the other side of the scene, there are the associations representing developers of RES plants. The Association of Renewable Energy Producers (APPA) was formed in 1987 and is currently the largest. In 2000 it had a membership of more than 200 companies. Most of them were active in the field of wind energy and small hydropower, but companies with investments in biomass and solar photovoltaic technologies were also represented. The association played an important role in the gradual improvement of the investment framework for renewable energy, through its constant political lobby and media campaigns.

6.2.3 The governmental support for renewable electricity

A major characteristic of the Spanish approach for renewables support is that, the economic governance structures gave a more protective framework for small hydropower installations, in terms of the legal target group of eligible developers and plant sizes.

Another characteristic is the prioritisation in time of the extent of financial support given to the market diffusion of different technologies. Supporting many or all technologies that were on the policy agenda of the 1980s simultaneously would have posed considerable societal costs. Besides, some technologies were still in need of technical development and were much more expensive than others, such as biomass gasification and solar photovoltaic. For them, a potential for further cost reductions was considered to still exist in the R&D sector, and price support stemming in economic governance structure was seen as too early, while investment subsidies were considered more suitable on a case-by-case basis, being especially focused on demonstration projects.

During the two decades on which the study is focused, only small hydropower and wind technologies were sufficiently supported both in terms of reasonable prices in the economic governance structure and in terms of more constant and consistent financial support in the form of various policy support mechanisms. Biomass projects were rarely profitable, especially when sufficiently high investment subsidies could be mobilised from more sources. Consequently, after two decades of governmental support, only wind technologies and small hydropower plants have managed to be substantially diffused in the market. For biomass technologies only a small extent of market introduction was achieved.

This chapter will explain in detail the individual support schemes used, their interaction and the extent of financial support they were able to bring for the three technologies studied. In Chapters 7, 8 and 9 we will look at how they influenced the investment decisions of project developers and financing agents, the speed of market introduction and the improvements in technical and economic performances.

In the cases of small hydropower and wind technology, Chapters 7 and 9 will explore the diffusion patterns, the emergence of intensive industrial dynamics and the rooting of the new energy activities in the social and economic fabric of the Spanish society and industry. For the case of biomass technologies, Chapter 8 will show how the changes in the last economic governance structure and the policy support mechanisms used have slowly started to increase the interest of developers and financiers to invest, improving the market diffusion rate, with positive signals for the sustainability of the market diffusion processes. In Chapter 7, 8 and 9 we test the hypotheses selected at the end of this chapter for the market introduction and diffusion of the three technologies.

The economic governance structures for renewables support changed in many aspects during the last two decades. The objectives set in the legal framework sharpened in time, the target groups in terms of eligible types of developers and plant sizes were revised, and the provisions regarding price design, price levels and contractual relations were also subjected to change. These attracted considerable changes in the risk investment context, and also some slight changes in the price support per kWh originating in these economic governance structures. The following three sections describe and discuss the objectives, target groups, forms and characteristics of the three economic governance structures put in place to support the introduction and diffusion of renewable technologies in the Spanish electricity system.

6.3 Economic risks under the first economic governance structure for renewables

The first economic governance structure was formed by the legal provisions regarding renewable electricity trade in the 82/1980 Energy Conservation Law. The main objective of this law was to promote energy efficiency and conservation, both at the demand and at the supply side[4]. But as a second objective it also aimed to encourage the use of renewable resources in order to reduce the external dependency on fossil fuels. We discuss in this section the demand risks, contract risks and price risks associated with the first economic governance structure that was operational in the period 1980-1994.

6.3.1 The target group of project developers and demand risks

Independent self-generators of electricity were seen as important potential contributors to the achievement of the law's objectives. In this context, the law was intended to stimulate their involvement in electricity self-production activities using efficient conversion technologies and/or renewable resources, and to regulate the relationships between them and distributing energy companies. Nevertheless, distribution companies were not eligible for the guarantees of the law and price support when investing in small hydropower plants.

A definition of renewable resources or technologies was not given in the law. The law only specified rules for 'hydropower' and 'non-hydropower'. For users of hydropower, there was a limit of 5 MW placed - in contrast to the other types of renewables. Besides, both self-

[4] The 1978 National Energy Plan (PEN) introduced two challenges for the Spanish energy policy that were of relevance for renewables development - energy conservation/saving and "the adequate protection of the ecological framework". Having in view the oil crisis and the high dependency of Spain on foreign primary energy resources, the plan emphasized the need to use national resources of any form and to proceed with an adequate energy conservation plan. This plan was the basis for the adoption of the Energy Conservation Law 82/1980.

generators and commercial generators using hydropower were eligible for legal economic support, with the exception of the projects developed by the distribution companies. Further, the law considered as eligible for governmental support those demonstration projects serving "creation and development of national technology of systems that use renewable energy resources". The economic protection and benefits ensured to RET self-generators, demonstration projects and small-hydropower commercial generators consisted of:

- the right to grid-connection and evacuation of electricity into the grid;
- guaranteed purchase of surplus electricity by the local energy utility[5]; technical constraints were verified by the Spanish Minister of Energy and Industry;
- guaranteed fixed-price for the surplus, determined by Ministry of Industry and Energy;
- several fiscal advantages and advantageous financing terms; and in some cases
- investment subsidies, especially for renewable demonstration projects.

These protective provisions were referred to as 'the regime of concerted production'. Based solely on the interpretation of the law, we consider that the legal target group was defined by self-generation and demonstration projects using renewable non-hydro resources and by all types of small hydropower projects with installed capacity below 5 MW. From here, we imply that demand risks were basically *'very high'* for commercial non-hydro renewable plants, since they were not in the target group. However there were *no* demand risks for small hydropower plants and for (partly) self-generation and R&D non-hydro renewable energy projects. Having in view the types of demand differentiated in Section 2.3.1, the first two guarantees mentioned above place the economic support approach for the eligible target group in the category of 'governmentally guaranteed purchase of unlimited volumes of renewable electricity'. In practice, a series of commercial projects based of non-hydro renewable resources nevertheless, were also developed. Their number increased after 1990, becoming dominant at the end of the first diffusion period in 1994. Interviews with several representatives of public authorities and project developers advanced a series of explanations for these developments. These are presented in Section 6.8 where the perception of developers regarding economic-policy risks is discussed.

6.3.2 Contractual relations and contract risks

Details on the content of trade contracts for (surplus) electricity were not provided for in the 82/1980 Law. Several minimum contractual provisions were traced in Article 3.1. Based on this, project developers investing in small hydro-power projects or renewable R&D and demonstration projects had to conclude a contract with the relevant public authority - Ministry of Industry and Energy - offering certain details such as project description, levels of investments and production, benefits accruing on the public authorities[6] and contract length. For the rest of the self-generation projects with industrial (non-hydro) applications the only provision touching on contractual relations was that the producer and the local distribution-company had to conclude a 'program for concerted production'.

In this program the generator had to estimate the amount of energy he would supply to the grid. In case the amount and patterns of electricity supply the generator declared to make

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[5] The RET generators were however specifically required "to abstain from selling the excess electricity to third-party" as the electricity industry was still organized based on monopoly principles.

[6] No explanations were given as to which would be those benefits, but we assume that law-makers meant the contribution of projects to energy conservation, and the achievement of the law's objectives and of the targets of the national energy policy plans.

available did not match the actually delivered electricity, the law authorised the Ministry of Industry and Energy to impose financial penalties. This came at the strong disadvantage of the highly intermittent resources such as wind, although small hydropower was also affected. In our view, this provision was bringing a contribution to an increased level of price risk, as all the aspects of price design were left to the decision competence of Ministry of Industry and Energy, without any form of minimum protective provisions being set in the law.

As regards the length of the purchase contracts concluded with Ministry of Industry and Energy and/or energy utilities based on the 82/1980 Energy Conservation Law there was no legal provision mentioning this or the criteria for contract re-negotiation. Our empirical research revealed that they varied widely between 2 years[7] and project life-time[8], depending on who were the project developers or equity investors. As it will be explained in Chapter 7, for wind energy most of the grid-connected projects commissioned in this period had the financial involvement of the purchasing energy utilities, the governmental renewables agency Idae and manufacturers. In these cases there were long-term or project life-time contracts.

However, the absence of legal provisions on minimum contract length had the consequence of creating financing obstacles for many developers, especially difficulties or impossibility to have access to ‘project finance’. Contract risks weighted heavy in the risk analysis of financing agents, as lenders pointed out many times during the national workshops for renewables promotion organised during the 1990s with the involvement of the renewable energy agency Idae (Cerro Gonzalez 1996). Only energy utilities and Idae - when they were equity investors - were in the position to hedge themselves from these law-embedded contract risks[9]. Consequently, we assess *contract risks* for the first economic governance structure as ‘*high*’. We base this theoretical assessment on two arguments: first on the absence of a legal guarantee for a minimum contract length; and second, on the absence of a legal provision that contracts can be renewed or, alternatively, a legal provision that the guarantee on output purchase regards the entire life-time of the project.

6.3.3 Price design and price risks

In the theoretical part we chose to describe price design in terms of four characteristics, in order to understand the price risks stemming from the legal support framework: price components, price levels, calculating and updating methodology and decision mechanisms. Their forms in the 82/1980 Energy Conservation Law are presented in Table 6.2. Based on the legal provisions, renewable generators had the right to receive a certain price per kWh for the

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[7] One governmental representative (Ocharan, the Ministry of Industry and Energy, interview August 2001) mentioned that "many contracts were very short, e.g. 1-2 years and had to be re-negotiated when expired, except for the case when the governmental renewables agency Idae was involved in the project. Several project developers interviewed mentioned that they received contracts for 3 to 5 years and if no notification was issued by any part to the contract it was assumed that the contract will continue to run for the next 3 to 5 years (e.g Galvan from the Technological Institute of Renewable Energy, interview August 2001; Marrero Hoeybye, from the wind technology manufacturer Aerogeneradores Canarios, interview August 2001; see also Gish 1999).

[8] Cruz (from Ciemat - the Spanish Energy Technology Research Center, interview August 2001) explained that in the cases when the purchasing utility was an equity investor in the project (especially Endesa, and Union Fenosa who invested in this period already) contracts concluded based on the 82/1980 Law were for the entire economic-life of the project or long-term (15 years).

[9] Combined with the fact that they had sufficient internal financial resources and market-valuable capital to finance RET projects when project finance was not possible, this led to their dominance in the picture of project developers in this first diffusion period. We will discuss the financing and investment aspects in more detail in Chapters 7, 8 and 9.

electricity delivered to the grid. But all aspects of price design were left under the decision authority of the Ministry of Industry and Energy.

There was no consultation mechanism with (potential) project developers regarding the ministerial decision with regard to price design and level, which in our typology in Section 2.3.4.1 assumes a 'directive' type of decision making. This posed in our view high risk on projects' economics because, as we considered in Section 2.3.4.1, decisions at ministerial level may be potentially more politically unstable than decisions at governmental and parliamentary level, especially when tariffs have to be frequently revised[10]. In Spain, the tariff revision in this period was annual. In the period 1983-1989 the price per kWh for wind electricity was mostly a matter of bilateral negotiation between developers and utilities (Cruz 2001), while for small hydropower there were annual orders from the Ministry of Energy and Industry setting the tariff[11]. After 1990 when several Spanish designs of wind technology had been already tested and new developers started showing interest in renewable projects, the payment regime for wind electricity started to be also regulated annually through Ministerial Orders - standardising this way the price for all wind project developers.

The price design in Ministerial Orders was in the form of annually revised tariffs with two components: the electricity component and the hourly-discrimination component. The electricity component was based on the consumers' tariff multiplied by a coefficient reflecting renewables role in achieving energy policy objectives (Cruz 2001). The calculation and updating methodology for purchase prices was therefore based on a formula combining intrinsic and extrinsic variables[12]. The last was given by the final consumer price. But given the monopoly type of organization and functioning of the electricity industry in that time with direct governmental control on prices, the volatility of this extrinsic component can be considered as posing rather modest risks. Therefore, the risks of substantial price change because of the presence of this extrinsic element in the price formula can be assessed as only modest. However, the decision mechanism for the value of the coefficient reflecting renewables role in achieving energy policy objectives was politically set by ministerial order.

Having in view these considerations, we assess price risks as '*very high'*. The 82/1980 Energy Conservation Law did not provide for any guidelines regarding the elements or renewables' particularities that the ministry should take into account when setting prices for renewable electricity. A more precise provision such as extent to which prices need to reflect the energy conservation contribution and the environmental benefits of renewables would have had the consequence of giving developers and external financing agents some confidence that prices would be constantly above the levels of conventional electricity with some clear

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[10] This decision mechanism was also viewed by project developers as posing high risks (Manuel Delas, the President of the Association of Renewable Energy Producers in Spain, "Position paper" 2001 available at the association's website: http://www.appa.es.; and interview with Manuel Bustos, public relations officer of the same association, April 2001.)

[11] Given the stage of technical development, the only technology used in this period for commercial or self-generation purposes was small hydropower. For wind technology, the only project developers were the national renewable energy agency (Idae), manufacturers, and energy utilities. Their purpose was to test new turbine models as they were being developed by Spanish manufacturers. Project profitability and hence the price per kWh for wind technology was less important in investment decisions (Lopez August 2001).

[12] In the theoretical part we discussed that an intrinsic price methodology assumes variables that are internal to the process of renewable electricity production and are directly controllable or at least assessable by the producers. An extrinsic methodology assumes variables that are beyond the direct control of the generator, such as final consumers prices, for market price for fossil fuels. The presence of extrinsic variables in price methodologies lead to the increase of price risks as they are often beyond the control and predictability ability of renewable project developers.

percentages. The Ministry of Industry and Energy was given all competences as to what positive aspects of renewables generation were to be taken into account and to what extent would they be financially valued. The law also did not offer any price floors that developers could take as orientation in making their business plans.

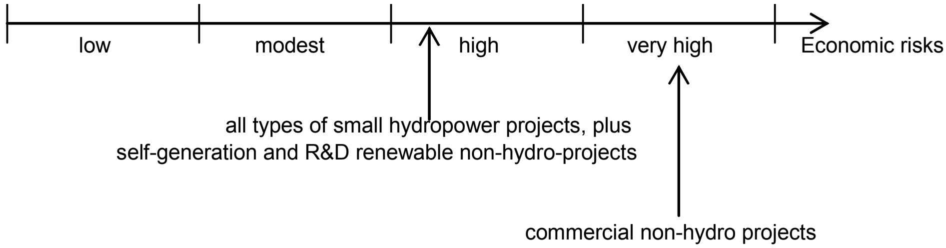
6.3.4 Conclusion regarding the economic risks under the 1980-1994 economic governance structure for renewables

Table 6.2 shows the forms of the three selected elements for the description of the economic governance structure for renewables support put in place through the 82/1980 Energy Conservation Law. In our assessment, this was characterized by some extent of vagueness of economic benefits - especially with regard to contract aspects and price design, substantial transfer of regulatory power to ministerial level, and high complexity of the regulatory framework governing the trade of renewable-based electricity.

Table 6.2 *The 1980-1994 economic governance structure*

The 82/1980 Energy Conservation Law		
Target group: R&D projects for all renewables; self-generation projects; commercial generators with hydropower plants <5 MW (but no distribution companies for hydropower)		
Elements	Characteristics	Forms
Type of demand		Legally guaranteed demand for unlimited volumes
Price design	Price components	Not mentioned in the law (Ministerial Order)
	Price levels	Tariff (Ministerial Order)
	Calculating and updating methodology	Combination of intrinsic-extrinsic [13] formula suggested for self-generators and hydropower users (Ministerial Order)
	Frequency of updating	Not mentioned in the law. In practice annual revision through Ministerial Order
	Decision mechanism	'Directive mechanism' based on Ministerial Order 'Agreement' for wind energy op to 1990 and for biomass during the entire period
Contracts for sale	Contract length	Not mentioned in the law. In practice between 2 years and (many projects) life-time contracts
	Price methodology	Up to 1990: bilateral negotiations for wind and biomass. After 1990 all price aspects set in annual Ministerial Orders for small hydropower and wind energy only.

Figure 6.1 *Theoretical assessment of economic risks in 1980-1994 economic governance structure*



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[13] The intrinsic part referred to the matching between the predicted and realized production delivered to the grid, by the RET generator. The extrinsic part referred to the fact that the tariff has to represent a percentage of the consumer tariff.

Based solely on the analysis of the legal framework, we asses the aggregated economic risks stemming for the 1980-1994 economic governance structure for all types of small hydropower projects, and for self-generation and R&D renewable non-hydro-projects as in the lower range of the *high risk* zone as shown in Figure 6.1. This aggregation comes from the assessed no demand risks for the target group, but high contract risks and very high price risks. However, for commercial generators using renewable non-hydro resources demand risks were very high since they were not specifically mentioned in the target group. In the case when they received purchase contracts from utilities, and the utilities agreed to pay them the price envisaged in the Ministry of Industry and Energy Orders they were still running the same contract and price risks as self-generators. Therefore for commercial renewable projects, we assess the aggregated economic risks for commercial non-hydro renewable projects as in the middle range of *very high risk* zone, as shown in Figure 6.1. In Section 6.8 we will present some explanations of interviewed developers and experts of the energy industry with regard to the presence of commercial projects in the investment picture, and the risk perception of developers at that time.

6.3.5 The extent of price support, 1980-1994

The majority of interviewed developers mentioned that in the period up to 1994 investment subsidies were the main source of price support. They were mainly focused on small hydropower, but wind electricity generation also received such form of support. Biomass projects were mainly subsidised when they generated thermal energy (heat or steam). The number of biomass electricity projects receiving investment subsides was very small. Besides, the price per kWh for biomass electricity was not regulated in Ministerial Orders. During the entire period this remained bilaterally negotiated with energy utilities buying the output. We describe this price decision mechanism as ‘agreement’ in Table 6.2. In Section 6.7, we present the investment subsidies coming from the National Energy Plans. Below we describe the policy support mechanisms rooted in the 82/1980 Law on Energy Conservation and the extent of price support per kWh offered by the same law.

6.3.5.1 Policy support mechanisms rooted in the 82/1980 Law on Energy Conservation

Article 11 of the 82/1980 Energy Conservation Law enumerates several fiscal benefits in the form of exemption of certain corporate taxes and soft-loans. However in practice a series of interviewed developers who had investments in those times[14] and representatives of public authorities (Idae, Ministry of Industry and Energy) mentioned either that they were not aware of these fiscal advantages or that their financial contribution to the profitability of projects was insignificant. A substantial financial contribution was brought however by the investment subsidies enabled by this law for R&D and demonstration projects based on renewables. The subsidy could go up to 30% of eligible costs. The projects needed to be “replicable to other industrial or companies, so as to ensure the diffusion of the results” (Law 82/1980). The other policy support mechanisms used between 1980 and 1994 will be discussed in Section 6.7. The role of all policy support mechanisms in investment risks and project profitability is analysed in Section 6.8.

The 82/1980 Energy Conservation Law was followed by a series of pieces of legislation of different legal-power rank, which aimed to further specify and increase the economic benefits

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[14] Interviewed early developers of wind projects were utilities Endesa, Iberdrola Ingenieria y Consultoria, and Union Fenosa, and wind turbine manufacturers Made and Ecotecnia.

of self-generators using renewable energy resources, as well as regulate their relations with electricity companies. Examples here are the Royal Decree 1217/1981 for promotion of hydropower production in small plants <5 MW, the Royal Decree 907/1982 for the promotion of self-generators of electricity, and the Royal Decree 1544/1982 for the promotion of hydropower plants with installed capacities > 5 MW[15]. A large number of ministerial regulations were focused on specific types of renewable resources or technologies (Idae [1] 1999).

6.3.5.2 The extent of price support per kWh in the 82/1980 Energy Conservation Law

Information regarding the extent of price support under the 82/1980 law for renewable electricity is very scattered, incomplete and sometimes contradictory. Gathering data from a series of sources, it seems that small hydropower electricity was paid, as an average level, with 6,3 €c/kWh. The tariff was annually revised but it seems to have been oscillating around this number. The basis for small hydropower electricity payment was the 1217/1981 Royal Decree (Lopez April 2001). In the case of wind electricity we estimate that prices varied between 6,1 – 7,2 €c/kWh[16]. Given the early stage of technical development, the legal payment for biomass electricity was not regulated in ministerial order until the issue of the 2366/1994 Royal Decree.

In Section 6.9 we discuss the characteristic of project profitability for all types of technologies and all support systems, as part of the specification of the hypotheses to be tested in the study. The next section describes the economic governance structure and the economic risks in the period 1995-1998.

6.4 Economic risk under the second economic governance structure for renewables

A major step in renewables' support was made through the issue of the Law 40/1994 for the Regulation of the National Electrical System and the Royal Decree 2366/1994. They fully abrogated the Royal Decrees mentioned in Section 6.3.5.1, but continued to back up the most

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[15] This decree unifies the economic regime of hydropower plants > 5 MW with the general regime of renewables-based self-generators.

[16] Some ministerial documents mention that depending on the time-of-the-day when electricity was delivered to the grid and the voltage level, the price for renewable electricity could vary around the levels of 6,1 - 6,3 €c/kWh (based on the price methodology specified by the Order of 7 January 1991 of the Ministry of Industry, Commerce, and Tourism setting tariffs for 1991 and the Order of the ministry setting tariffs for 1992). In the reports of Idae regarding the technical and economic aspects of the renewable plants it financed up to 1991 (in Idae 1993) and up to 1996 (Idae 1996) we found different data on tariffs. So it appears clearly stated in the 1993 Idae Report that the price per kWh received by the small hydropower plants in which Idae invested based on third-party finance or multi-contribution finance (see Chapter 3) and commissioned up to 1992 was 6,3 €c/kWh. For the other small hydropower plants, developed later and mentioned in the 1996 report, and for any of the wind-based plants, the tariffs were not mentioned anymore. But we calculated the price/kWh possibly received by developers and it turned out that most of them received 6,3 €c/kWh. Four small hydropower projects seem to have been paid with 6,9 €c/kWh, however, while five wind projects - for which investment plans were negotiated before the entry into force of the 1994 Royal Decree, seem to have been paid with 7,2 €c/kWh (Calculations of price/kWh were made by dividing the annual turnover (in Euro/year) to the annual electricity production (in kWh). All data are provided for in the Idae reports on financing of renewable plants of 1993 and 1996). The Wind Power Monthly Magazine of June 1994 mentioned however that "under Spanish legislation, purchase of wind produced energy is guaranteed by law at 6,6 €c/kWh, that is 1,8 €c/kWh more than the price paid for electricity from conventional power plant". Further Cruz (CIEMAT, August 2001) estimates that “in average renewable generators were paid around 7 €c/kWh between 1990 and 1994”.

important incentives to invest in renewable plants that were nailed in the Law 82/1980[17] - grid connection, guaranteed purchase and guaranteed fixed price. One of the reasons invoked by the decree for the change in the special regime was “the inadequacy of the current economic regime to the actual reality” surrounding investments in RETs and the need for a “adequate profitability of projects”. This statement gives direct evidence of the governmental assessment of insufficiently attractive price support per kWh for renewable electricity production in the 1980-1994 economic governance structure.

In addition, the need for new regulations was motivated by the increasing complexity of the techno-economic relations between RET generators and grid companies, as a result of the continuous issue of royal decrees and ministerial orders, complementing and at times abrogating each other provisions[18]. Our interpretation of the motivations for a new decree mentioned in the introduction is that the price design and characteristics of contractual relations of the economic governance structure originating in the 1980 Energy Conservation Law needed to be reconsidered. The 1980-1994 economic governance structure proved to be inadequate in terms of addressing the economic difficulties of RETs, having in view their economic performances at that time.

6.4.1 Target group - technologies and economic actors - and demand risks

The Law 40/1994 did not include a definition of renewable resources and technologies that can enjoy the economic benefits of the special regime. But this was given in Art. 2 of the 2366/1994 Decree, which separated RETs in three groups[19]:

- installations using only “non-hydro renewable energy such as solar, wind, ocean power, geothermal, and others similar” (Group A in the Decree),
- “plants that use as main fuels urban wastes, industrial wastes, biomass and others similar”, where the main fuel should be in proportion of at least 90% (Group B), and
- hydropower plants with capacity below 10 MW (Group F).

The target group of renewables-based generators under the 1994 pieces of regulation was clearly formed by self-generators. Only hydropower plants were eligible both in the form of self-generation and commercial projects and the capacity limit was raised to 10 MW, compared to the 1980 Law. The eligibility of R&D projects using renewables was not mentioned at all. However, based on the compared analysis of the provisions of the 1980 Law

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[17] It is important to note that the roots of the 2366/1994 Royal Decree is in the Law 82/1980 and not in the Law 40/1994. As mentioned in article 1, the 1994 Royal Decree "has as an objective the regulatory development of Chapter II Title I of the Law 82/1980 (…) with regard to the conditions and procedures for qualification under special regime, the condition for payment for the energy, and the economic regime". The Law 40/1994 - beside re-regulating the organization and functioning of the national electricity system - only comes to strengthen the provisions of the 1994 Royal Decree through a higher-rank piece of legislation - a law. But in the same time it states that all the provisions of the law 82/1980 that come in contradiction with the terms of the new electricity law are abrogated. This rooting of an essential piece of legislation for renewables support in a law that is declared partly abrogated through another law promoted in the same month with the Royal Decree signals the regulatory mis-coordination among the Spanish public and political authorities at that time, as Lopez (2000: 229) also observes.

[18] As the introduction of the Royal Decree 2366/1994 mentions, its intention was to systematize and "develop a framework that clarifies the future of this type of production in the context of the criteria and priorities of the energy plan, fixing an adequate price for the surplus electricity, which allows that the development of this production takes place in a coordinated fashion with the rest of the electrical system".

[19] The decree distinguishes actually between 6 technological groups, but we will refer here only to those that reflect to our definition of renewable energy.

and of the 1994 Royal Decree we concluded that R&D projects were actually legally eligible for economic protection.

Art. 1 of the 1994 Royal Decree stated that its objective was "the regulatory development of Chapter II of Title I of the Law 82/1980". But most importantly, there was no provision at all, neither in the 1994 Royal Decree nor in the 1994 Law, which abrogated Chapter I of Title I of the 1980 Law. This Chapter was the one that defined the target group of the 1980 Law, which included R&D/demonstration projects based on RETs, as well as hydropower commercial generators below 5 MW. Therefore, indirectly, renewable R&D and demonstration projects were eligible under the 1995-1998 economic governance structure. However, commercial non-hydro renewable projects remained literally outside the target group of both the 1994 Electricity Law and the 1994 Royal Decree. Before describing the forms of the 1995-1998 economic governance structure it is necessary to shed some light on the basic regimes for electricity trade, and on the general organization and functioning of the Spanish electricity industry based on the Electricity Law 40/1994. The interaction of the Law's provisions with the terms of the 2366/1994 Royal Decree will also be discussed. Consequently, in our assessment, in terms of types of demand the situation is similar to that created under 1980-1994 economic governance structure:

- *no demand risks* for all types of small hydropower projects, and for self-generation and R&D renewable non-hydro-projects, and
- *very high demand risks* for commercial renewable non-hydro-projects.

Given the fact that the 40/1994 law introduced the first concepts for the liberalisation and re-structuring of the electricity industry, before we discuss the issues of contract risks and price risks, we consider necessary to make a brief description of the industrial structure of the electricity sector in the period 1995-1998.

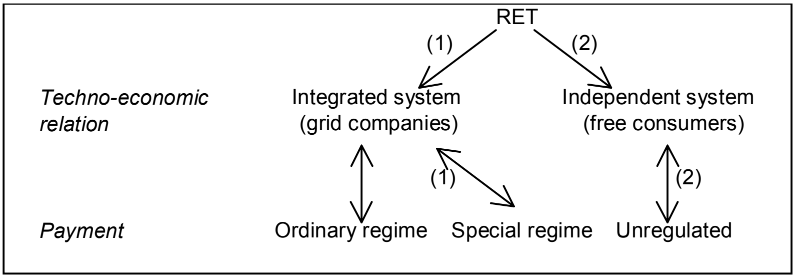
6.4.2 The main characteristics of the industrial structure of the electricity sector 1995-1998

The Electricity Law 40/1994 attempted to open up the national electricity industry to new players and allowed for the functioning in parallel of two systems of electricity production and trading. The first was the 'integrated system' whereby all generators had to comply to 'the governmental principles of joint planning, integrated exploitation, economic integration of (electricity) production, integrated tariff system, and compulsory supply all (captive) consumers, given the public service nature of this system' (Lopez 2000: 227). The payment for the generators included in the integrated system was separately regulated and denominated as 'ordinary regime'.

In parallel to this, the Electricity Law 40/1994 allowed for the functioning of a second trading system, referred to as the 'independent system'. The authorization to generate electricity and to trade under this system was still to be issued by the national authorities based on central energy planning considerations. But contractual parameters and the exchange price could be freely agreed between buyers and sellers. The output of the independent system could be sold to third parties or could be traded internationally. But, under certain circumstances, it could also be sold to the integrated system, under the ordinary regime of payment.

Renewable-based and co-generation plants were placed in a separate protective regime for payment, authorization and exploitation, denominated as the 'special regime'. According to Art. 26.1 the (surplus) electricity output had to be ceded to the integrated system in order to enjoy the special regime status. In this case the payment method had to be regulated in a specific document (see Art.16.3 of the law), that is in the Royal Decree 2366/1994[20]. The special regime is represented in Figure 6.2 by the sequence (1) of arrows. Renewable plants could also be commissioned under the independent system. This possibility was offered under Art.26.3 of the same law. But in this case the price for the generated renewable electricity had to be agreed between buyers and sellers bilaterally. And being a trade system based on price-competition, this was just a theoretical option for the expensive renewables. This is represented in Figure 6.2 by the sequence (2) of trade.

Figure 6.2 *Electricity trading systems and payment regimes under 40/1994 Electricity Law*



6.4.3 Project sizes eligible for guaranteed demand and contracts

The 1994 regulations included in the special regime all eligible types of resources and technologies used in plants with capacities below 100 MW. For them, guarantees were offered for grid-connection and for the purchase of output by energy utilities, except for temporary technical constraints. Further, the 1994 Royal Decree regulated in Article 11 that the lengths of contracts had to be of minimum five years for these plants, and it had to cover both the technical and the economic aspects of electricity delivery. The installations using eligible types of resources and technologies but with installed capacities above 100 MW were only guaranteed grid-connection rights. This way, they were supposed to be submitted to the demand, contract and price rules of the integrated regime described above, and to the ordinary regime of payment. Therefore, they were actually not part of the special regime.

6.4.4 Price design and eligible plant sizes

The 1994 Electricity Law set some general principles based on which the price for renewable electricity was to be further designed and calculated in the Royal Decree. This way Article 16.7 of the law stated that "the retribution of the surplus energy defined in Article 29.2, ceded by the producers under the special regime will be determined by the government, applying criteria that reflect the benefits for the integrated system that this form of electricity is offering, and taking into account its contribution to the diversification of the base of energy resources and generation technologies, energy efficiency, the environmental protection and the development of renewable energy". We view these provisions as contributing to the reduction in price risks, as compared to the 1980 Law. Further, the fact that the price per kWh was to be

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[20] As it will be explained in the next paragraphs, the 40/1994 Law only traced the basic principles for price design. But the Royal Decree 2366/1994 specified in full detail the methodologies of price calculation, and set the fixed price for each technology type, for projects having certain installed capacities.

set directly by the government through a Royal Decree type of instrument further lowers price risks, compared to the previous period when it was a matter of Ministerial competence.

The 2366/1994 Royal Decree re-stated the right of generators using eligible resources and technologies in plants below 100 MW to receive a certain guaranteed price per kWh, and introduced two price methodologies, depending on the sizes of eligible plants. However, uncertainty emerged with regard to which would be the ‘border’ plant-size, below or above which the price methodology would change. This piece of information was very important, because the resulting tariffs calculated in the decree differed by a factor of ~2,7 between the two methodologies.

The first price methodology was set in Art. 12 of the 1994 Royal Decree which stated that for the renewable plants with installed capacity smaller than 25 MW and for those with capacities between 25 MW and 100 MW which had received special authorization from national authorities[21] the price for the surplus electricity delivered to the grid of public service will take into account the *long-term avoided costs*[22], and will take as a reference the average of electricity tariffs for all consumers. In addition to this, a special coefficient had to be added, in which various positive externalities of renewables had to be taken into account. This coefficient had to reflect “the contribution to the energy policy”[23] brought by the respective type of technology in terms of diversification, use of renewables, and reduction of environmental impacts. Finally, a second coefficient had to be added, reflecting the avoided costs and tariffs. The role of it was to further improve RET plants’ economics through an amortisation scheme, and it assumed differentiated values for three renewable technology bands mentioned in Section 6.4.1.

Article 14 set the exact tariffs for each technology group, meant to be applicable during the five years following the entry into force of the decree. These tariffs were supposed however to be revised by Ministerial Order if changes occurred in the average final price for all consumers. The tariffs set in the 1994 Decree based on the first price methodology are presented in Table 6.3. The Unique Final Disposition of the decree regulated that after the five years of guaranteed purchase, contract and price - i.e. in 2000, prices can be recalculated if “substantial variations have been produced in the cost structure of the electrical system or in the tariffs system”. In practice, the price levels governed by this decree changed in the beginning of 1997, on the basis of the 2657/1996 Royal Decree for electrical tariffs, Annex IV.2. As a result of this, the technologies in Group A and F had their price lowered to 6,8 €c/kWh, and those in Group B to 5,98 €c/kWh compared to the numbers shown in Table 6.3.

The installations with capacities lower than 100 MW, but which had been considered by national authorities to come in contradiction to the national energy planning requirements, were subjected to the second price methodology. They could only benefit of a price calculated as short-term avoided costs, that is the *variable avoided costs*, equivalent to the average variable cost that served as a basis for the methodologies to modify tariffs and which was to be published in Ministerial Orders. The exact price level was specified in a later decree - the 2657/1996 Royal Decree which established the tariffs for 1997. This new decree regulated that “the basic price for surplus electricity of installations larger than 25 MW and that do not

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[21] The approval had to certify that the commissioning of a plant with such a size was complying with the national energy planning considerations.

[22] The long-term avoided costs assumed four price components: a capacity (kW) component, an energy (kWh) component, an hourly discrimination component, and a reactive energy component.

[23] This was the highest for the "renewables group" of Art.2.a: "wind, solar, geothermal, ocean power and others" (1.09), followed by small hydropower smaller than 10 MW (1.08), and by biomass wastes (placed in the same category with urban and industrial wastes: 1.07).

comply with the energy planning criteria will be 2,4 €c/kWh, which coincides with the variable avoided costs".

Table 6.3 *Price design for plants smaller than 100 MW and complying with the central planning criteria of the national energy plan, and price levels for the year 1995*

Components included in price design, according to Royal Decree 2366/1994	Price levels for different technology bands
- "long-term avoided costs of the electric sector for generation, transmission and distribution" - a coefficient reflecting positive externalities - a coefficient of "not avoided costs and tariffs"	Group A (wind, solar, geothermal ocean power, etc): 6,9 €c/kWh Group B (biomass wastes): 6 €c/kWh Group F (hydropower): 6,9 €c/kWh, plants <10 MW

The problem facing interested project developers was, therefore, that the maximum size of renewable plants that could be eligible for the high fixed-price system of the special regime was not clear and was expected to change in time. As Art. 3 of the 1994 Royal Decree mentioned, the upper level of installed capacity and characteristics of the plants complying with the provisions of the national energy plans were to be determined and published periodically by means of Royal Decrees.

Consequently, a project developer commissioning a RET plant with a capacity higher than 25 MW that had been considered eligible for the high-tariff methodology under special regime at the moment of investment could have later been placed into the second category, receiving only variable avoided costs. No provision on the Royal Decree stated explicitly that projects already approved under the long-term avoided costs methodology could not be transferred to the variable avoided cost system of the same regime. This uncertainty on the sizes of plants qualifying for the high-fixed price method could be the main explanatory factor for the dominant presence of plants below 25 MW in the 1995-1998 diffusion period, with only six exceptions. The issue of plant sizes will be further expanded in Chapters 7 and 8 for wind and biomass technologies.

6.4.5 Contract risks and price risks

The protection in terms of contracts for renewable electricity sale to grid companies improved after 1994, by guaranteeing a minimum length of five years. Many interviewees stated that this played a crucial role in renewables' market diffusion as it had substantially improved the attitude of banks towards renewable energy projects[24]. In more and more cases, given that resource availability was good - especially for small hydropower and wind systems, it became possible to recover (most of) the total investment costs within the five-year time-span of the contract with the utility. This was especially the case when investment subsidies were available, but it was also helped by the new higher levels of tariffs set in the 1994 Decree. When financing agents analysed the business plans - for wind projects in particular - under the new economic-policy support system, approvals of loans based on the project finance scheme increased, and better financing terms could finally be obtained.

In practice energy utilities seldom issued contracts longer than exactly five years as they were obliged, except for the cases when they or the governmental renewables agency Idae or the manufacturers had shares in projects[25]. But still, in time, project finance started to be more

[24] E.g. Cruz (Ciemat interview 2001), Castillo (Union Fenosa Energias Especiales utility, interview 2001).
[25] Ocharan (Ministry of Economy), Cruz (Ciemat energy research institute) interviews August 2001.

and more used, even when investment costs could only be recovered partially during the five-year contract period. In such situations, banks asked however for larger contributions of equity by developers in the capital structure of projects and sometimes they also required higher interest rates for the risks taken that contracts might not be renewed. Indeed, the fact that minimum five-year contracts were guaranteed did contribute substantially to contract risk reduction, in the assessment of both developers and financing agents. But this did not induce the total removal of contract risks.

The 1994 Decree did not explicitly mention what would happen after the first contract of a renewable generator expires. Does he have the right to ask for automatic contract renewal? Would the next contract be also valid for at least five years? The theoretical possibility existed, in our opinion, that the government argued that new developers would need to be supported too, in order to increase the renewable capacity in the national system, and that the unlimited support in time of all developers would pose too high social costs. The introduction of the 1994 Decree re-states the target of the National Energy Plan 1991-2000 that aims to achieve a contribution of self-generation projects based on co-generation and renewables of 10% in energy consumption by 2000. But it also mentions further that it is important that “the economic regime contemplates the needed equilibrium between an adequate project profitability and a cost for the electricity system that does not attract a too much increase in (consumers’) tariffs”. The aggregation by the government of the target for co-generation with that for renewables promotions, together with the concern that the achievement of this target would pose burdens on consumers’ bills can be seen as sources of uncertainty over the particular commitment for renewables support. Consequently, given these arguments we assess that the *contract risks* of the 1994 regulations were ‘modest’, but rather in the *upper part of the ‘modest’ range*.

As regards price risks, they also decreased substantially compared to the 1980-1994 economic governance structure. The first source of risk lowering is associated with the fact that the 1994 Law provided for some basic principles that the government had to account for in designing the tariffs for renewables, which was not the case in the 1980 Law. This way prices were supposed to reflect the benefits of renewables for system security, resources diversity, fossil fuels conservation and environmental benefits. Secondly, the further design of price components, calculation and updating methodologies, and final levels was a matter of governmental decision though Royal Decree, which assumed lower risks of unfriendly tariffs than in the case of decision by Ministerial Order (Bustos 2001). Thirdly, the new tariffs set in the 1994 decree were scheduled for a five year period, with an eventual revision only when the final average price for all consumers changed. Consequently, we assessed that the 1994 changes in price design resulted in overall modest *price risks*, and here rather in the *middle of the ‘modest’ range*.

This assessment suggests that some residual price risks persisted and we consider that these risks stem from the absence of a more elaborated price design in the 1994 Law, especially a more specific methodology for the calculation of the renewables benefits and/or the placement of some form of price floors for the payment of renewable electricity. In contrast these were provided for in the next electricity law, adopted in 1997, inducing a large positive impact on developers and financiers’ investment behaviour, as we discuss in subsequent chapters.

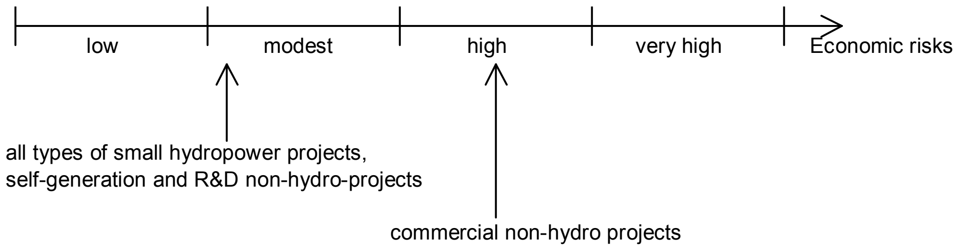
6.4.6 Conclusion regarding the economic risks under the 1995-1998 economic governance structure for renewables

Table 6.4 shows the forms of the three selected elements for the description of the economic governance structure for renewables support put in place through the 40/1994 Electricity Law and 2366/1994 Royal Decree.

Table 6.4 *Forms of the 1995-1998 economic governance structure*

the 2366/1994 Royal Decree and 40/1994 Electricity Law			
Target group: self-generators < 100 MW, but for hydropower < 10 MW; commercial generators with hydropower <10 MW; and R&D projects for renewables (for plants > 100 MW only guaranteed grid-connection, but no special regime)			
Elements	Characteristics	Forms	
Type of demand		Legally guaranteed demand (unlimited guarantee industry level)	
Price design	Method 1 (<25 MW or ?)		Method 2 (>25 MW or ?)
	Price components	Long-term avoided costs Coefficient positive externality Coefficient better econ. perform	Short-term avoided costs
	Price levels	(high) Tariffs	(low) Tariffs
	Calculating and updating methodology	Calculating: intrinsic & extrinsic. Updating extrinsic	Extrinsic (both)
	Frequency of updating	After 5 years revision by Royal Decree government	Annually by Ministry of Industry and Energy Order
	Decision mechanism	Directive, Royal Decree	Directive, Ministry of Industry and Energy Order
Contractual provisions	Contract length	Minimum 5 years	Minimum 5 years
	Price methodology	Not applicable. Tariffs used	Not applicable. Tariffs used

Figure 6.3 *Theoretical assessment of economic risks in 1995-1998 economic governance structure*



The second economic governance structure represents a substantial improvement in the price and contract risk for renewable projects. It kept however demand risks for commercial non-hydro renewables such as wind and biomass electricity at very high levels, by continuing to refer to the target group of developers as 'self-generators'. The introduction of the limit on project sizes eligible for the high price methodology contributed to the increase of the regulatory complexity as compared to the previous economic governance structure. The price design for both groups of project sizes was complex and uncertain in terms of plant eligibility.

In conclusion, on the basis of a close scrutiny of the legal texts of the forms of the 1995-1998 economic governance structure, summarised in Table 6.3, the *economic risk* for commercial small hydropower generators, self-generators and developers of R&D renewable non-hydro projects can be assessed as somewhere at the *border between modest and low* *ranges*, as represented in Figure 6.3. This comes from the mixture of middle-range-modest price risks and upper-range-modest contract risks, which however could be projected on the background of no demand risks, drawing the aggregated risks of the economic governance structure down. But how much downwards is more challenging to specify exactly. Contract risks are more important than price risks, since when the contract bringing above market price revenues is not renewed at all, the owner has to suffice with market price level income. This is a more substantial reduction to project's cash flow than under a scenario when the guaranteed contract price lowers more than expected, while remaining though above the average market price.

If the regulatory framework did not make any reference to the unlimited guaranteed purchase of renewable electricity for eligible plants, demand risks would have been the same with contract risks. But as the legal frame guaranteed both unlimited demand but only five year contracts to sell for the 'special regime' price, the risks on cash-flow posed by the interruption of renewable electricity purchase after 5 years depends on the economics of the projects. When projects have a high margin of profitability and can recover investment costs in the first five years, contract risks could be seen as low. But if more time is need after the first five years of operation to recover all investment costs, the level of perceived risks would be proportional to the time necessary to recover those costs if only market prices can be secured in continuation. The legal formulation does not exclude however neither renewal nor new shorter contracts. Therefore, under this approach to the regulation of the right to sell renewable electricity at special regime prices, we assess the economic risks as being at the border between the low/moderate risk ranges.

Commercial generators of renewable non-hydro projects were not in the target group of the 1994 regulations and therefore they operated in a context of very high demand risks. When, on a case-by-case basis, developers were given purchase contract by utilities who agreed to further pay commercial developers based on the same tariffs as the 1994 Decree imposed for self-generators, it can be considered that commercial developers were actually operating in an investment environment characterised by *high* aggregated economic risks, and in this case in *the middle part of the high risks range*.

The next section presents the economic governance structure emerging on the basis of the 1997/1998 regulatory framework and which started to affect investment decisions since 1999, when all its details became clear.

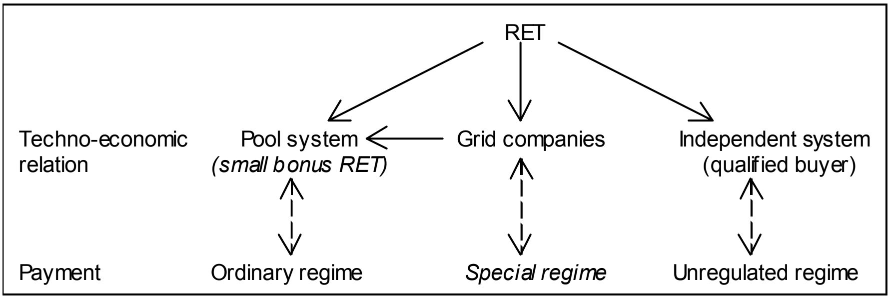
6.5 Economic risk under the third economic governance structure for renewables

The main goal of the 54/1997 Electricity Law was to harmonize the organization and functioning of the Spanish electricity system with the principles set in the European Union Directive 92/1996 for the liberalization of national electricity industries and creation of an integrated electricity market. In this context, the policy for the support of renewable electricity was redefined and sharpened, while the characteristics of the economic governance structure were altered to ensure the achievement of the fresh ambitious goals, in the new competition-based system. The 16th transitory disposition of the 54/1997 Law established a target for the contribution of renewables to Spanish electricity demand of 12% by 2010. The inclusion of this target in the law was a strong signal of commitment from the part of Spanish political authorities, with significant positive consequences for the investment strategies of developers and financing agents. Before discussing the characteristics of the new economic governance structure for renewables, we present the main organisational features of the electricity industry based on the 54/1997 Electricity Law.

6.5.1 The main characteristics of the new industrial structure

The 54/1997 Law introduced competition and free entry at the generation and supply levels. Market entry can take place based in the administrative license procedure. Three systems for electricity trade and payment regimes emerged which are shown in Figure 6.4. Generators, including those using renewable resources, are offered with three choices for the selling of their output. One is through the pool system in which all domestic generators with plants above 50 MW are obliged to subscribe[26]. The payment for participants in the pool system takes place under the 'ordinary regime'. This assumes the trade of electricity by matching supply and demand on an hourly basis and results in the market price. A generator using eligible renewable resources qualifies as well for the receipt of a small bonus, when their plants have a capacity higher than 50 MW. This price support is rooted in Article 30.5 of the 54/1997 Law, and it is further regulated in Article 31 of the 2818/1998 Royal Decree, which sets a bonus of 0,6 €c/kWh for plants using among others wind energy, agricultural wastes and primary[27] biomass energy (but not for hydropower).

Figure 6.4 *The trade systems and payment regimes under the 54/1997 Electricity Law*



For the domestic generators with plants below 50 MW, foreign generators and self-generators supplying their own consumption site at distance, a second trade option is made available under the 'independent system'. Renewable generators are also eligible to participate in this trading system, but this does not offer them any guarantee on demand, contracts, and price protection.

The third trade system is applicable to renewables, cogeneration, waste-incineration, and plants for wastes' reduction and treatment. Grid companies are obliged to conclude standard physical bilateral contracts with generators using these technologies and resources, provided that they satisfy the conditions for access to the 'special regime'. Project sizes form the major precondition for access to the special regime, but there are different size-levels for the various resource/technology categories, which we discussed below. The special regime offers the same

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[26] But the option is also opened for generators with plants below 50 MW, including renewable generators if they wish so - and foreign companies exporting to Spain.

[27] Primary biomass is defined as purpose-grown plants or natural plant resources younger than one year that can be used for energy production either directly or through a transformation process (Art. 2.b.6, of Royal Decree 2818/1998).

three main guarantees ensured in the 1994 economic governance structure: grid-connection and evacuation of renewable electricity, purchase contracts by grid-companies, and a certain revisable price per kWh.

6.5.2 The target group and eligibility of project sizes

As a general observation, the 54/1997 Electricity Law and the 2818/1998 Royal Decree for renewables miss a good legislative technique in linking articles and integrating them into a coherent set of rules with regard to types of projects eligible for special regime. The provisions of the 1997 law are very confusing and induce high uncertainty regarding the eligibility of commercial projects for the protective economic governance structure. The 1998 Royal Decree brings important clarifications however and removes many eligibility risks but not those with regard to biomass electricity plants. But because a law has a higher legal rank than a decree, it is theoretically possible that the government reverses to the legal provisions of the 1997 law and cancels the right of commercial projects to sell their entire output to the grid energy company from that decision-moment on.

In the 1997 law, reference to the target group using renewable resources is made in the Art. 27.1(b), Art. 29, and Art. 30.2(e). The first one states that eligibility under the special regime takes place when plants below 50 MW "use as primary energy one of the non-exhaustible, renewable forms, biomass or any type of biofuel, and always when its owner does not develop activities of production in the ordinary regime". Therefore, companies participating in the power pool system are not eligible to have their renewable plants protected by the special regime, even when these plants comply with the capacity and resource preconditions[28]. Art. 29 is concerned with the destination of the energy produced under special regime, and clearly refers to it as 'excess energy', suggesting that only self-generators are eligible for guaranteed purchase by utilities[29].

But Article 30.2(a) finally opens the possibility for commercial projects to become eligible under the special regime stating that "Exceptionally, the government will be able to authorize that the installations under special regime that use renewables as primary energy are allowed to incorporate in the system the totality of the energy produced by them". However, the government reserves the right to cancel - for a determined period - this guarantee on purchase for commercial plants[30]. The reasons for this uptake limitation will have to be related to "the conditions of electricity supply".

Article 30.2(a) introduces therefore the possibility for commercial projects to be eligible for special regime, but inserts in the same time some contract risks. We would not classify this as a demand risk because it is mentioned that the limitation of output uptake will be restricted in time[31]. The 1998 Royal Decree enumerates in Art. 2 the installations that can enjoy the three

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[28] But, as it will be shown in Chapters 7, 8, 9 this constraint was shortcut in practice by creating separate companies for renewable energy investments, and by creating joint ventures with economic actors not involved in the ordinary regime.

[29] Self-generators are defined in Article 9 of the 1997 Law (Title II - Regulation of supply) as "those physical or legal persons who generate electricity fundamentally for their own use (…) meaning that he consumes at least 30% of the electricity produced by him, in case his installed capacity is lower than 25MW, and at least 50% if his installed capacity is equal or higher than 25 MW". This implies very large self-generation plants.

[30] The 1998 Royal Decree sets another exceptionality clause when it regulates in Art. 21.3 that the competent regional authorities could limit the volume of renewable capacity accepted for special regime in island and peninsular regions to certain percentages of the total energy demand.

[31] But it can be interpreted as a contract for which the amount and timing of purchase is uncertain. If temporary refusal of uptake happens, this will affect the cash flow of the project and the recovery of

main guarantees of the special regime, mentioning both their sizes and the resource composition for each technological band. The definition of renewable energy and separation in technological bands can be observed in Table 6.5.

Table 6.5 *The renewable technology bands in the 2818/1998 Royal Decree*

Band	Types of energy resources and technologies
b1	only solar energy
b2	only wind energy
b3	geothermal, wave, tidal, hot dry rocks
b4	hydropower < 10 MW
b5	hydropower between 10-50 MW
b6	minimum 90% primary biomass: naturally occurring or purpose-grown plants younger than 1 years that can be used directly or through a transformation process
b7	minimum 90% secondary biomass: wastes from a primary use of biomass - manure, sludge from residual water treatment, forestry and agricultural wastes, biofuels and biogas.
b8	plants using the b6 and/or b7 resources in a proportion of at least 50%, together with conventional fuels (for the contribution of which only the market price is paid)
b9	plants mixing any of the b1 to b8 groups

The 1998 Royal Decree contains three articles referring directly or indirectly to the eligible target group: Art. 18.2, Art. 19.3 and Art. 21.1. The first suggests that both self-generators and commercial generators can enjoy the special regime as long as their installations belong to one of the technological bands mentioned in Art.2. They have the right to deliver their *production or surplus* to grid companies and receive the special price specified by the decree. But no link is made with Art. 21.1 which clearly states that only certain technological bands are eligible to have their entire production output purchased by the grid energy company, while the others can only be accepted under the special regime if they are self-generation projects[32]. This way solar-only, wind-only, geothermal-only, tidal-only, wave-only, hot-dry-rocks-only, and hydropower of any size up to 50 MW can be used for commercial projects. As regards primary and secondary biomass resources, as well as technologies mixing biomass with conventional or any of the b1-to-b8 technology bands, they can only be admitted under the special regime if they are self-generation projects.

Analyzing the reaction of economic actors to the new law Lopez (2000: 278) mentions that “The publication of the Law of the Electricity Sector did not contribute to the alleviation of the uncertainties existing among economic operators, but, on the contrary it brought about major confusion”. The applications for new projects have suddenly stopped after its publication, especially due to the “exceptionality clause” in the Art. 30.2(a), which stated that only exceptionally can the government decide to include commercial plants also in the special regime. But the government has eventually chosen to make good use of this provision, if the achievement of the 12% target of renewables by 2010 had to be given a chance. This has been highly appreciated by developers and Lopez (2000: 278), taking their ‘pulse’, considers that “with the publication of this Royal Decree, the majority, if not all the uncertainties have been cleared up”. The National Commission for the Electricity System has also given a positive

investment costs, respectively the period of loan reimbursement. The economic performances of the project can be shaken but it can still remain viable, though needing a longer time-span for recovery of investment costs. The risk can be considered however serious by institutional investors, who are generally looking for high profits and early exit from RET projects so as they can recycle their profits faster.

[32] In the 1997-1998 regulations self-generators are more sharply defined in terms of minimum percentage of produced electricity they need to consume in order to be qualified under this category.

evaluation of the decree declaring that "having in view the limitations imposed by the Law 54/1997, the proposal establishes a reasonable development of the law, for which it deserves a positive global evaluation"[33].

Risks are still present in this third economic governance structure, but their level has decreased compared to those harbored in the previous one, while in the same time market and financing players have learned to navigate among them, or live with them. Consequently, in spite of the awkwardness of target group formulation, and having in view the discouraging wording in certain articles of the law, it can be considered that the acceptance of commercial projects through the 2818/1998 Royal Decree, and the range of resources eligible for them, represent a large step forward in the stimulation of RET market diffusion. But as long as biomass - which could have a very high technical and economic resource potential in Spain - is not given direct unmistakable legal protection, this step would hardly mean just half-way to the 2010 target.

6.5.3 Economic risks - demand, contract and price risks

The economic risks associated with this third economic governance structure have been considered by all interviewed developers as very low. Many articles and analysis papers published in the last years in Spain praise the establishment of a low-risk legal investment framework after 1997. The legal provisions most frequently invoked by interviewees were those made in the introduction of the 2818/1998 Royal Decree. A first statement made there was that "for the installations based on renewable energy and residues the established incentives will not have temporal limits because of the fact that it is necessary to internalize their environmental benefits" and because their current technological status and higher costs does not allow them to compete in the free market.

This statement suggests that a long term protective economic governance structure for renewables will be maintained and that developers and financing agents should not fear the withdrawal of government support. The legal guarantee that RET generators can connect their plants to the grid and sell their output to utilities, the placement of a clear target directly in the law that renewables have to cover at least 12% of energy demand in Spain by 2010, together with this introductory statement of the Royal Decree support the assessment that *demand risks are not present* for all types of projects, excluding biomass commercial projects this time. Hence, *biomass commercial projects* remain, as in the previous economic governance structure, under *high demand risks*.

As we pointed out above, Art 30.2(a) of the 1997 Law places some contract risks by enabling the government to halt the uptake of renewable electricity from commercial plants for limited periods of time. Based on the Royal Decree, the contracts for electricity sale with distribution companies have to be standardized by the Ministry of Industry and Energy, and they must have a minimum length of 5 years, as in the case of the 1995-1998 economic governance structure[34]. But given the above explanations and the encouraging text of the 1998

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[33] The National Commission for the Electricity System, "Informe de la propuesta de Real Decreto sobre production de energia por instalaciones abastecidas por recursos o fuentes de energia renovable, residuos y cogeneration" 14.07.1998.

[34] The main techno-economic aspects to be included in the contract have basically remained the same as under the 1994 Decree. The distribution company is obliged to subscribe to such a contract, and pay the generator monthly a contractual price that is decided in the last applicable Royal Decree. In the case of self-generators, the bonus is paid only for the amounts of electricity delivered to the grid-company. However, the conclusion of the sale contract is conditioned by the separate agreement between the RET generator and

decree's introduction, we assess *contract risks* as lower than in the case of the second economic governance structure. The presence of several regulatory provisions able to increase the confidence in the level of political support in long term leads us to assess contract risks as in the *upper part of the 'low' risk range*.

A second introductory statement made of the 1998 Decree is that "the incentives being established for renewable energy will have such a level that will enable the contribution of renewables to the energy demand of Spain of at least 12% by 2010" as the 1997 Law requires. We interpret this statement as suggesting that even if prices are exposed to some risks in the new economic governance structure, that need to realize a certain extent of convergence with market principles, and even if the extent of price support might decrease in time, attention will be paid that renewable energy projects remain profitable, continuing to attract new investments. Since the goal is to enable capacity increase, an important concern of the Spanish government is to prevent capacity shut-down and to keep the activity of renewable electricity generation attractive for developers and financiers. We discuss below how price was designed in the 1997 and 1998 regulations in order to make a complete assessment of price risks.

6.5.3.1 Price design

For eligible renewable technologies and plants below 50 MW capacity, the 2818/1998 Royal Decree offers two payment methods, at the choice of generators. The first is a 'market-based option', and the second is a 'revisable tariffs option'. Generators who were already under the payment system of the 1994 Decree when the 1997-1998 regulations entered into force have the right to request the shift to one of the two 1998 methods. But, at their choice, they can also remain under the 1994 economic governance structure and continue receiving the tariffs calculated based on the methodology set in that decree. The shift to one of the 1998 price methodologies is not reversible however. We describe here the two price designs of the 1998 Decree.

The market-based option for plants below 50 MW capacity is traced in the Art. 30.4 of the 1997 law, which sets two main price components: the market price and a bonus. As regards the bonus, the 1997 law regulates that this will be received for plants using renewable non-hydro energy, biomass, and small hydropower below 10 MW. The bonus is to be set by the government and published through Royal Decrees. In terms of methodology, the Law mentioned that the bonus should be calculated by taking into account the voltage level at which delivery to the grid takes place, the contribution to the improvement of the environmental performances of the energy system, fuel saving and energy efficiency. But, in addition, the bonus level has to reflect also "the investment costs incurred with the purpose of achieving some reasonable rates of profitability, with reference to the financing costs in the capital markets". With this specification, the 1997 Law is a unique example of political concern for the financing difficulties encountered by renewables as innovative technologies. But in the same time it is also a unique example of 'legally-reflected' political awareness for the need to enable reasonable profits, in order to attract the substantial investments at which the law aims through the 12% target by 2010.

In terms of consistency of support, the law indicates that the bonus should have such a level so as the final price received per kWh to be situated within the band of 80-90% of the average electricity price. This average price is, in its turn, calculated by dividing all revenues

the grid company regarding the technical aspects of grid-connection. As it will be shown in a following chapter, this agreement has became an obstacle or reason of delay for many projects, especially in the case of new and/or smaller market entrants.

for the supply of electricity for all consumers, to the total amount of electricity supplied. The revenues have to be computed without including the Value Added Tax or any other applicable taxes. Consequently, the law designs the guaranteed economic governance structure price/kWh as a price derived based on an extrinsic formula that has to observe both a certain floor and a ceiling level.

The 1998 Royal Decree complements the law's provisions by specifying that - for certain selected technologies - the bonus level will be annually updated so as the reflect the expected changes in the average annual market price, and in the total amount of electricity that will be supplied in the following year. However, the problem is that this method assumes an ex-ante calculation. In case real developments do not follow the governmental scenarios for price and demand evolution, no compensation is given to renewable generators. Moreover, the representatives of the Association of Renewable Energy Producers argue that the way the government builds these scenarios is not transparent (Bustos, interview 2001). The technological bands for which this updating methodology is valid are wind, geothermal, tidal, wave, hot-dry-rocks, hydropower, primary biomass and secondary biomass.

For all types of RET plants eligible for special regime both under the 1998 Decree and under the 1994 Decree, the levels of bonus and, respectively, tariffs will be revised every four years, in additional to the annual updating. Three principles are mentioned for the four-year revisions: evolution of market price for electricity, participation of RET installations in the coverage of total demand, and the impact of these installations on the technical management of the system. These result in quite high price risks, because - beside the market price risks expected to increase as liberalization is expanded to all consumers and the European markets are becoming more integrated - the more renewable installed capacity will be, the lower support prices can be expected to fall. Besides, the technical management of grids can be expected to become more challenging especially in the context of fast market diffusion of intermittent technologies such as wind-based systems. All these pricing principles announce a possible fall in governmental financial support. This can be considered to pose a moderate price risk to investors in the short-medium term, but a serious risk in the long-term, as the market share of RET increases[35]. However as plants commissioned at a later time are expected to benefit of lower design costs, technology and service costs, it may be possible that investors enjoy similar levels of project profitability along time.

In updating the price methodology, the government consults in practice with the interest groups - developers and manufacturers. However, the process of consultation is not rooted in the legal framework and disagreements may not prevent a unilateral decision by the government to be taken. This leads to a 'directive' type of decision mechanism for the bonus component in the price design.

Based on these considerations, we assess that the price risks associated with this market-based option are in the upper part of the 'high' range, having in view that both components are considerably volatile. Pool prices proved their expected volatility in the first three years of pool operation (1998-2000), taking values in the large range of 2,4 – 4,8 €c/kWh (Ministry of Industry and Energy statistics). Beside fossil fuel prices, one important source of price volatility in the Spanish pool is the 16% contribution of large hydropower[36]. The second

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[35] Not accounting under this scenario for a possible increase of the 12% target, as long as this is not placed even at the level of the European Union. At the time of writing the EU target is indeed only 12% renewable energy in total energy consumption.

[36] In dry years, like 2000 was, pool prices can go up considerably, improving the cash flow of renewable generators. But still market risks remain high. (As less rain falls, the hydropower supply on the power pool

component, the bonus, is linked to elements that are also extrinsic to the activities of renewable electricity generation - average price of final consumers, and total demand level in the system. Being quite unpredictable under the new conditions of liberalised generation and trade of electricity, these linking components pose high risks for bonus levels too.

In this context, the second introductory statement of the 1998 Decree, mentioned above, regarding the governmental concern that incentives for RET projects will remain sufficiently appealing in order to reach the 12% target was an essential step in ensuring the investment community that the possibly high price risks will be compensated by attractive levels profitability. Besides, the fact that the right to a bonus is specified for the first time in the law, and that the law further describes the bonus calculation methodology and offers an orientative range for the final price it in the form of 80%-90% of average final consumer prices, come to lower price risks, in contrast with a sole consideration of market price volatility and bonus vulnerability. Overall, we assess that the price risks associated with the market-based option are in the upper part of the high range of risks.

The second type of price design set in the 1998 Decree is the ‘revisable tariffs option’. The updating of the 1998 tariffs takes place based on the same methodology as that applicable for the bonus levels, and the tariffs have to be approved based on a Royal Decree type of instrument. In contrast, the 1994 tariffs had to be approved by means of Ministerial Order. Theoretically, this would mean that the 1994-decree-based tariffs are exposed to higher price risks than the 1998-decree-based tariffs. However, both are linked to the average annual price for all types of consumers. Therefore, it is less likely to observe that one type of tariffs will be lowered more strongly than the other one.

However, if we compare price risks for tariffs during the second economic governance structure and during the third economic governance structure, we need to take into account that the 1997 law introduced the power pool system for the trade of electricity generation and a gradual liberalization of trade at consumers’ level which leads to expectations of higher volatility of consumers prices during the third economic governance structure than during the previous. Hence, we assess price risks associated with the revisable-tariffs option of the 1998 Decree as still ‘modest’ but slightly higher than the price risks under the second economic governance structure, in the upper part of the modest range.

With regard to tariff levels, the 1998 tariffs are lower than 1994 tariffs for wind and small hydropower technologies. Therefore, if an eligible generator using this types of RETs wishes to move away from the 1994 tariff, he will do so by choosing the ‘market-based option’ of the 1998 Decree. But eligible generators installing renewable energy systems after January 1999 may only choose between the two 1998 price options.

In addition of the above-described price options, the 1997 Law enables the government to give a bonus also for certain renewables-based installations that are actually not eligible for the special regime, because they have installed capacities higher than 50 MW[37]. Installations qualify if they use non-exhaustible and non-hydro renewables, biomass, biofuels, agricultural and other organic wastes. Based on this legal provision, the 1998 Decree sets the bonus at the level of 0,6 €c/kWh, and the updating methodology is the same as for the bonus corresponding to the plants eligible for special regime. Hydropower plants with installed capacities between 10 MW and 50 MW have a different treatment. They are eligible for the three guarantees of the special regime - grid-connection, minimum five-year purchase contract and bonus - but

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lowers; if demand remains high, the market prices go up, increasing the price support for renewables, according to the applicable price design for the market-price option).

[37] Therefore they will not enjoy the other privileges of the special regime - guaranteed grid connection, guaranteed demand and five-year contracts.

bonus level is determined by the government on the basis on a different methodology than for the rest of RETs. The legal text does not make any specification with regard to the principles or the formula for deriving this bonus, and neither does the 1998 Decree. The decree provides for the same annual updating methodology as for the other technologies.

The levels of bonuses and tariffs rooted in the 1998 Royal Decree are presented in Table 6.6. It is important to take note of yet another statement made in the introduction of the 1998 Decree implying that financial support will be differentiated according to the efficiency that each technology can contribute to the achievement of the 12% target. This assumes better revenues for closest-to-market technologies, which creates a vicious circle for the market introduction of the technologies that are not sufficiently cost-attractive.

Table 6.6 *Bonuses/tariffs based on 1998 and 1994 Royal Decrees and updated levels*

Type of RET / €c/kWh	Capacity	Bonus in 1999	Updated bonus in 2001	Tariff in 1999	Updated tariffs in 2001
Wind	P<50 MW	3,2	2,9	6,6	6,3
Hydropower	P<10 MW	3,3	3	6,7	6,4
Primary biomass	P<50 MW	3	2,8	6,5	6,2
Secondary biomass	P<50 MW	2,8	2,6	6,3	

6.5.4 Conclusion regarding the economic risks under the 1999-2002 economic governance structure for renewables

Table 6.7 summarises the forms of the elements selected for the analysis of economic governance structures, as they were applicable in the period 1999-2002 (when our empirical study ends). The contractual price methodology was the same to the price design established in the Royal Decree on the basis of the pricing principles set by the 1997 law.

Table 6.7 *The forms of 1999-2002 economic governance structure*

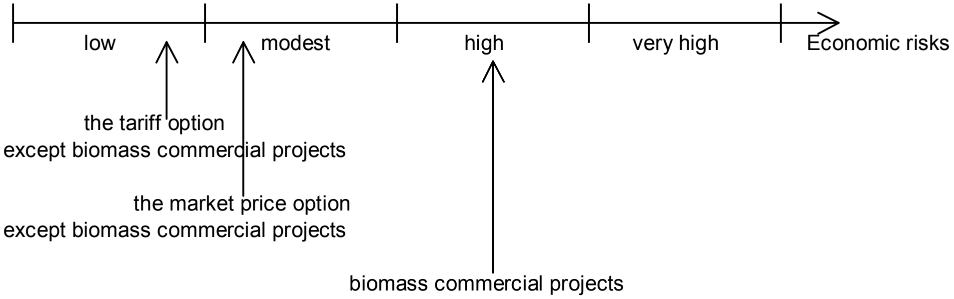
<table>
<tr><td colspan="4">the 2818/1998 Royal Decree and 54/1997 Electricity Law</td></tr>
<tr><td colspan="4">Target group: non-biomass projects smaller than 50 MW; but for hydropower smaller than 10 MW</td></tr>
<tr><td>Elements</td><td>Characteristics</td><td colspan="2">Forms</td></tr>
<tr><td colspan="2">Type of demand</td><td colspan="2">Legally guaranteed demand - unlimited at industry level</td></tr>
<tr><td rowspan="2">Contracts</td><td>Contract length</td><td colspan="2">5 years (minimum)</td></tr>
<tr><td>Contract price method</td><td colspan="2">prescribed in price design of Royal Decree</td></tr>
<tr><td rowspan="7">Price design</td><td></td><td>Method 1 (market option)</td><td>Method 2 (tariff option)</td></tr>
<tr><td>Price components</td><td>market price + bonus</td><td>not specified</td></tr>
<tr><td>Price levels</td><td>variable monthly (indirectly subject to floor and ceiling)</td><td>tariffs</td></tr>
<tr><td>Calculating and updating methodology</td><td colspan="2">Both extrinsic and intrinsic for 1998 levels.
Extrinsic for annual and 4-years updatings</td></tr>
<tr><td>Frequency of updating</td><td colspan="2">Annual + revision every 4 years</td></tr>
<tr><td>Decision mechanism</td><td>Market price + Directive (Royal Decree)</td><td>Directive (Royal Decree)</td></tr>
</table>

As in the case of the previous two economic governance structures, there are two groups of projects in terms of demand risks: no demand risk projects and very high demand risk projects. In the second group are the commercial biomass projects. The first group includes all types of wind and small hydropower projects (in terms of the differentiated drivers to invest), as well as partly-self-generation and demonstration biomass projects.

For project developers who obtain a contract for the sale of renewable electricity to the grid at the special above-market price, the risks that contracts would not be renewed are ‘low’.

As regards price risks, they are either in the upper part of ‘modest’ range when the tariff option is chosen, or in the upper part of ‘high’ range when the market-based price option is chosen. Overall for non-commercial-biomass projects the economic risks for this economic governance structure can be theoretically assessed as ‘low’ when the tariff price option is chosen, or slightly ‘modest’ when the market price option is selected by developers, as represented in Figure 6.5. For commercial-biomass projects, we assess the economic risks as in the middle part of the *high risks range.* As considered in the previous two cases, when developers receive purchase contracts from grid companies, and the grid companies agree to pay them the price envisaged in the Royal Decree they are still running the same contract and price risks as the owners of other type of resource-projects.

Figure 6.5 *Theoretical assessment of economic risks in the third economic governance structure*



6.6 Conclusion: risks under the economic governance structures for renewable electricity during the 1980s and the 1990s in Spain

Sections 6.3, 6.4, and 6.5 described and analysed the forms of the economic governance structures put in place in Spain for the support of renewables market diffusion during the 1980s and the 1990s, and the economic risks embedded in them.

Looking at the legal framework, during the first two economic governance structures (1980-1994 and 1995-1998) the economic risks were different for commercial non-hydro projects (hence including wind and biomass) than for the rest of renewable power projects. For the post 1999 economic governance structure, the economic risks are different for commercial biomass projects than for the rest of renewable power projects types/resource. The results of our assessment of economic risks are summarised in Figure 6.6.

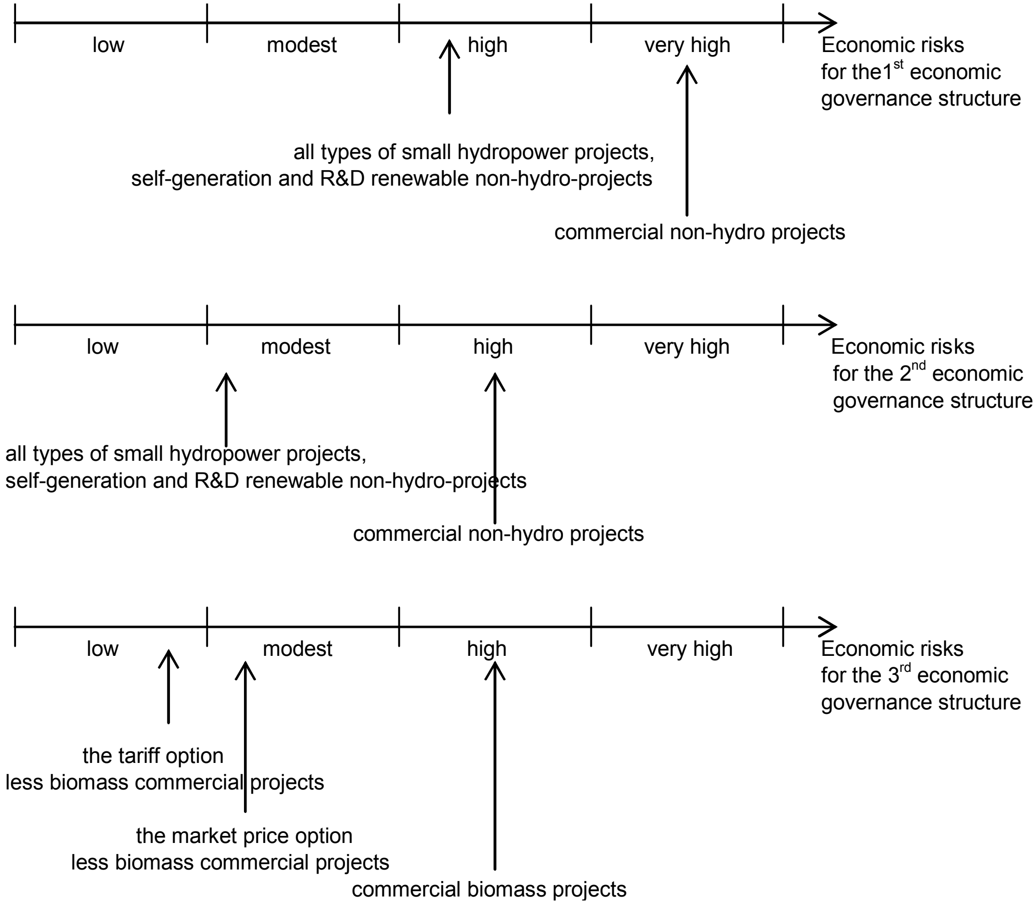
For wind power projects, the economic risks changed as follows:
- for commercial projects: *very high* during 1980-1994, *high* during 1995-1998 and *low/modest* since 1999 - depending on developers choice for the price design;
- for partly-self-generation and demonstration projects: *high* during 1980-1994 and *low/modest* since 1995 - depending on developers choice for the price design;

For biomass power projects, the economic risks changed as follows:
- for commercial projects: *very high* during 1980-1994, and *high* since 1995;
- for partly-self-generation and demonstration projects: *high* during 1980-1994 and *low/modest* since 1995 - depending on developers choice for the price design

For small hydropower projects of all types, the economic risks changed as follows:
- *high* during 1980-1994, and *low/modest* since 1995 - depending on developers choice for the price design.

Beside differences in economic risks for the three technologies, there were also differences in terms of the extent of price support from the economic governance structure. In the first period, 1980-1994 the price per kWh was annually set by means of Ministry of Industry and Energy Order only for small hydropower installations and since 1991 also for wind power. After the adoption of the 2366/1994 Royal Decree biomass systems were also specified a certain price per kWh, but these prices were very small compared to the cost performances of biomass technologies at that time. In order to enable however their market introduction, investment subsidies were used bringing sometimes substantial contributions to the investment costs of individual projects. But the number of projects supported was much lower than in the case of the other two technologies. In order to assess the levels of project profitability enabled in time by the support system for the three technologies and the overall investment risks emerging from the support system, it is necessary to review what types of policy support mechanisms were used in the last two decades. The next section presents the types of policy support mechanisms used in Spain during the 1980s and in 1990s. The section is focused on the policy risks, as risks of losses on the expected cash flows of projects. But we also present the extent of financial support offered for each of the three technologies.

Figure 6.6 *Summary of qualitative assessment of aggregated economic risks*



6.7 The policy support mechanisms

In terms of the financial sources, three groups of policy support mechanisms can be differentiated: mechanisms emerging from national energy policy plans programs, investment subsides from the European Communities, and support mechanisms developed and financed by the regional governments of the Autonomous Communities[38]. Their significance for the three renewable resources was different in terms of the extent of financial support received. European Community investment subsidies supported substantially projects using small hydropower, but for wind projects only few developers received subsidies for demonstration projects. Section 6.7.1 presents shortly first the programs for renewables support in Spain from the European Community.

The regional governments of the Autonomous Communities that opened programs for renewables offered financial support mainly for wind (especially small scale) and biomass projects. We do not discuss the policy risks associated with the regional schemes because the number of projects benefiting of each regional support program was small compared to diffusion at national level. In Appendix 6.1, we list the regional programs, the extent of financial support offered and their target group. At national level a prioritisation of the extent of financial support could be observed with small hydropower getting much more funding since early 1980s, wind power plants receiving more subsidies since early 1990s, while biomass energy was still being promised more financial support in early 2000.

Section 6.7.2 looks at the policy support mechanisms from the national energy policies and programs in terms of policy risks and the extent of financial support offered.

6.7.1 Investment subsidies from European Community programs

In the period 1980-1994, the Valoren Program brought a substantial contribution to the diffusion of small hydropower technology in Spain, while to a smaller extent it also supported wind power projects (Cruz 2001). But since 1995 the support mechanisms originating at EU level did not play an important role for the diffusion of renewables in Spain anymore.

The Valoren Program was financed based on European Regional Development Fund that aimed to support economic development in less-favored regions. For wind technology, given the state of technical development, most subsidized projects were for demonstration purposes. But for small hydropower all types of projects were subsidized, including commercial projects for new construction, rehabilitation, automatization and grid connection costs. In the period 1986-1991, a total number of 210 small hydropower plants benefited of Valoren investment subsidies[39], representing a total installed capacity of 289 MW (Idae 1992: 93). This means that

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[38] The 1978 Spanish Constitution started a process of decentralization that led to the creation of 17 Autonomous Communities. They represent an "intermediate level of government between the State and the Local Corporations". The current state organization resembles federal models, but "the national sovereignty resides over the whole Spanish population". The competencies recognized to the Autonomous Communities are more limited than in federal states. "The Autonomous Communities cannot benefit from a law that gives themselves their own Constitutions. They will have Statutes that are not passed by their own regional Parliaments, but which follow a special procedure (which requires a majority of 3/5 at the Parliament), and follow Organic Laws" (Sodean and Idae 1999).

[39] The subsidy level differed more across regions than according to project types. In Spain 27 regions were classified as "type 1", for which subsidies could be up to 50%. The division in these regions differs from the division in the 17 Autonomous Communities. Only 6 regions were considered as "type 2" and developers there could get up to 40% investment subsidies, 5 regions were classified as "type 3" and were eligible for

the overwhelming small hydropower capacity installed in this period in Spain benefited of Valoren subsidies, since Idae data show that in the same years the total number of projects commissioned was 237, with a capacity of 276,6 MW[40]. The subsidies allocated at industry level for small hydropower amounted to 12% of the total investment costs associated with these projects (Idae 1992: 93).

Between 1990-1994, some investment subsidies originated also in the Thermie Program of the EU. Demonstration projects could be subsidized with up to 40% of eligible investment costs, while projects for technology diffusion could benefit of up to 35% subsidy. But plants had to have a maximum size of 5 MW to be eligible (Idae 1992: 90). Very precise empirical data on the number of MW installed with help from this program could not be found. However, this program supported far less projects and total capacity than the Valoren Program.

The 1993-1997 Alterner Program of the EU endorsed only 13 Spanish projects with investment subsidies for renewable energy projects totalling 11,40 M€ (Idae and Miner Sept. 1999). Further, the Joule-Thermie Program of the Fourth EU Framework Program, spanning between 1994 and 1998, financed 10 projects using one of the three technologies of interest for us. The main target-group was formed by projects using technologies that has passed the initial R&D stage but needed support for demonstration and commercialisation[41]. The maximum subsidy contribution per project was 40% (Idae[2] 1999: 37). The application of European investment subsides did not pose policy risks on the cash-flows of projects, since they were in the ex-ante form of support. They did however contribute substantially to make many projects economically feasible to improve their profitability as compared to the support from national investment subsidies and price support from the economic governance structure.

6.7.2 Policy support mechanisms at national level - policy risks and financial support

The Spanish government initiated beginning with 1983 a series of special Programs for Renewable Energy in the framework of National Energy Plans. The most frequently used types of policy support mechanisms for market introduction and diffusion were investment subsidies and direct financing of renewable projects by means of third-party financing schemes and direct equity participation. To these, another stream of investment subsidies was added between 1980 and 1994, based on the 82/1980 Law on Energy Conservation. Since 1998, another type of policy support mechanisms was introduced at national level in the form of soft loans with governmentally subsidized interest rates. Two soft-loan schemes were implemented aiming to encourage small developers and small-size projects, especially partly-self-generation installations, which have been difficult to finance under the requirements of the traditional financing community.

There have been four major National Energy Plans between the 1973 oil crisis and the turn of the century. In 1997, for the first time a law - the 54/1997 Electricity Law - set a target for RET contribution in the national electricity system, and has specifically required the drawing-up of a policy plan for the achievement of this target. The Plan for Renewable Energy Stimulation was adopted in December 1998, covering the period up to 2010. The sequence of

maximum 30% of subsidies, while only 4 regions were regarded as “type 4”, for which only a 20% investment subsidy was given to developers (Idae 1992: 91).

[40] Statistics on small hydropower projects and capacities are presented in Idae, 1998, “Renewable energy in Spain: balance and perspectives 2000”.

[41] All these projects were, admittedly, un-economic projects, developed for one or more strategic reasons. Many of these projects received in parallel also investment grants from national or regional/local governments.

National Energy Plans and their branching programs for renewable energy is shown in Figure 6.7. The following three sections discuss the extent of financial support and the policy risks associated with each of the three types of national policy support mechanisms implemented on the basis of the energy policy plans and programs mentioned in Figure 6.7

Figure 6.7 *The sequence of national energy plans and of the programs for renewables in Spain*

1975 Energy Policy Plan → (at the basis of the adoption of) the 82/1980 Energy Conservation Law
1978 Energy Policy Plan → updated as 1981 Energy Policy Plan
1983 Energy Policy Plan → Plan for Energy Saving Conservation and Substitution
→ R&D Program for renewable energy
→ 1986 Renewable Energy Plan
→ 1989 Renewable Energy Plan; but change of National Energy Plan =>
1991 National Energy Plan → 1991 Plan for Energy Saving and Efficiency (PAEE) 1991-2000
1997 Electricity Law → (basis of the adoption of) 1998 Plan for Renewable Energy Stimulation 1999-2010

6.7.2.1 Investment subsidies

The level of investment subsidies allocated per technology in the frame of each policy plans are summarised in Table 6.8 which also presents in parallel the extent of price support per kWh offered in the economic governance structure in each period.

The 1983 Plan for Energy Saving Conservation and Substitution included an investment subsidy scheme that could cover up to 25% of a project's investment costs for technologies perceived by potential developers and financing agents as still risky, in spite of having passed the demonstration phase[42].

The 1986 Renewable Energy Plan established more detailed criteria on investment subsidies. For small hydropower installations the policy was to encourage economic agents and individuals to set up commercial projects and make small hydropower electricity generation a new industrial-business activity (Lopez 2000: 173). The subsidy could cover at most 25% of investment costs, based on the assessment of this technology as 'already operational' in this Program. The market introduction of wind energy was intended to take place based on nationally developed small-capacity wind turbines. But due to the lack of domestic skills and knowledge at that time, foreign technologies were also considered eligible for investment subsidies for medium-capacity turbines, as long as they could generate employment and "allow national technological participation" (Lopez 2000: 173).

The subsidies for grid-connected wind systems could go as high as 60% of the total investment costs of the park, while for stand-alone systems the maximum was 30%. Stand-alone wind plants were however in need of more technological development in order to become reliable energy systems, which explains the low interest in such projects in this period. High-capacity wind turbines were not on the priority list, but their financial support was not excluded as long as they had good chances of replication and commercialization.

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[42] In addition the plan envisaged the implementation of information and communication schemes that can improve knowledge by potential investors regarding project opportunities and the financial support schemes available. The political perception in 1983 Program for Renewable Energy, regarding the development stages and the supply potential of these technologies at that time, was that: small capacity wind turbines and small hydropower, were "operative technologies" in 1983; while medium and high capacity wind turbines, were "operative on a medium-large term" (Lopez 2000).

Table 6.8 *Investment subsidies and economic governance structures' price support during the 1980s and the 1990s*

Small hydropower			
Investment subsidies		economic governance structure price/kWh	
Law 82/80	30%	1st economic governance structure	Tariffs: 6,1-6,3 €c/kWh
1983 Plan	25%		
1986 Plan	25%		
EU Valoren Plan	up to 50%		
1991 Plan (for 1991-1994)	maxim 50%		
1991 Plan (for 1995-1997)	10%or 20%	2nd economic governance structure	Tariffs: 7 - 5,8 €c/kWh
1991 Plan (for 1998-1999)	5% or 15%	3rd economic governance structure	Bonus: 3,3 - 3 €c/kWh Tariff: 6,7 - 6,4 €c/kWh
Wind			
Investment subsidies		economic governance structure price/kWh	
Law 82/80	30%	1st economic governance structure	Tariffs: 6,3 - 7,2 €c/kWh
1983 Plan	25%		
1986 Plan	60% or 30%		
1991 Plan (for 1991-1994)	maxim 50%		
1991 Plan (for 1995-1997)	30%	2nd economic governance structure	Tariffs: 7 - 5,8 €c / kWh
1991 Plan (for 1998-1999)	< 5 MW 30% or 40%	3rd economic governance structure	Bonus: 3,2 - 2,9 €c/kWh Tariff: 6,6 - 6,3 €c/kWh
Biomass			
Investment subsidies		economic governance structure price / kWh	
Law 82/80	30%	1st economic governance structure	not available / applicable
1983 Plan	25%		
1986 Plan	-		
1991 Plan (for 1991-1994)	maxim 50%		
1991 Plan (for 1995-1997)	15%	2nd economic governance structure	6,1 - 5,2 €c/kWh
1991 Plan (for 1998-1999)	30% or 40%	3rd economic governance structure	Bonus: 3 - 2,6 €c/kWh Tariffs: 6,5 - 6,2 €c/kWh

It is important to note the major "action principles" launched in the 1986 Program. The plan explicitly acknowledged the importance of energy policies for the achievement of the general objective of political economy, that is creation of employment, technological development and international competitiveness of Spanish industries. For this, the governmental financial support for renewable technologies - both for R&D studies and for market introduction projects - had to give priority to commercial considerations and to the promotion of national technologies. Therefore, as Lopez (2000: 171) mentions, only "investments with a perspective of economic and commercial viability within a determined period, and stimulating the development of national companies" were to be supported. These support principles remained the red line of Spanish policy for renewables.

The 1991 Plan for Energy Saving and Efficiency adopted on the basis of the 1991 National Energy Plan had four programs, of which one was exclusively dedicated to renewable energy. This aimed at the market introduction of small hydropower (defined as smaller than 5 MW), biomass, and wind energy - among others - which were considered sufficiently close-to-the-market technologies. The 1991 National Energy Plan aimed to realize the targeted renewable capacity based on self-generation projects that were expected to generate 10% of the electricity generated in Spain by 2000, compared to their 4,5% contribution in 1990. Technology-specific targets were also set. This way the target for wind energy amounted to 168 MW, for solar PV was of 2,5 MW, and for small hydro 779 MW, all expressing the targets for capacity increase by 2000, as compared to 1990[43].

Three approaches can be differentiated in the application of investment subsidies based on the 1991 plan. In the first period, 1991-1994, investment subsidies were given mostly on a cases-by-case basis, depending on the needs and particularities of the projects for which applications were made. Subsidies could cover at maximum 50% of total eligible investment costs[44]. During 1994-1997, the investment subsidies were distributed through calls for applications at national level, under Ministerial Order. But gradually regional authorities (Autonomous Communities) took over responsibilities of subsidies' allocation, moving the scheme towards regional management. This was institutionalized through the 615/1998 Royal Decree for subsidies' territorialization (Etsu 1996). Therefore, in 1998-1999 subsidies' allocation was decentralized through Autonomous Communities.

The criteria for subsidies' allocation in the years 1995-1997, set through Ministerial Orders of March and December 1995, were as follows (Etsu 1996). For wind projects developers could obtain up to 30% investment subsidies in the case of location difficult to access, or high grid connection costs, or low wind speeds. For all projects the size had to be less than 20 MW. In addition, stand-alone wind systems could also benefit of the same subsidies. Small hydropower generators could obtain up to 20% subsidies only in stand-alone electricity projects or small independent networks, or only up to 10% investment subsidies in the case of water supplies' exploitation.

After 1998 the subsidy program changed more substantially. As a major characteristic, the new subsidy approach aimed to support mainly small and medium size companies. This type of developers had been disadvantaged up to that time because of the preference of banks to finance large-size projects and work with traditional clients formed by energy utilities and large companies from various industrial and construction sectors. The eligibility criteria for 1998 and 1999, issued on the basis of the Royal Decree 615/1998 were the following[45]. When developers of wind projects were small and medium size companies with plants smaller than 5 MW in location with difficult access, investment subsidies could be maximum 40%. For other types of developers, the level of subsidy was only 30%. In addition investment subsidies of the same size were given for wind projects larger than 500 kW that included at least two innovative turbine designs, as well as for installations for desalinisation and water pumps. Besides small and medium size companies could get 15% investment subsidies for small hydropower plants and 40% for biomass/biogas projects. For the other types of project developers, investment subsidies were 15% and 5% respectively.

In the new policy plan for renewables stimulation of 1998, small hydropower is considered a mature technology that does not necessitate financial support anymore. In the same time the investment subsidy support for wind projects is drawing to a close (Idae[4] 1999). In the

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[43] These targets were calculated based on the scenario that energy demand will increase during the 1990s and the installed capacity able to meet that demand had to increase from 43.000 MW in 1990 to 51.000 MW in 2000. The government was committed to contribute with 21% public aid to the achievement of targets (Idae [1] 1999). Representatives of public authorities are of the opinion that the 1986 and 1989 plans for renewables succeeded to introduce renewable technologies into the market, while the 1991 Energy Plan managed to initiate a real market diffusion of renewables (Idae[3] Nov. 1999).

[44] The role of Idae was to study applications for subsidy and make recommendations to a Special Committee of Ministry of Industry and Energy taking final decisions. The applicants were required to have all necessary permits, licenses and environmental impact assessment already approved.

[45] These criteria were published at www.jrc.es/cfapp/eneriure/exe/consulta.cfm, at 28 August 2001.

following ten years investment subsidy support would be focused on solar PV, biomass electricity and other technologies that were also less supported so far.

The investment subsidy schemes in all the programs mentioned were designed to be allocated to developers before or immediately after the entry into operation of the renewable power plants, which means that the schemes did not pose risks for the cash-flow of projects during project economic operation life.

6.7.2.2 Financing involvement of the government renewable agency

An innovative support schemes was introduced in mid 1980s and assumed direct equity participation by the governmental renewable agency Idae in the capital structure of projects. Initially such projects were financed together with other interested economic actors based on the *multi-contribution finance* schemes. The equity contribution was meant to help economic actors with the problem of technology risk perception or to complement the financial resources of interested investors, when banks loans were not available. After 1994, it became possible to obtain non-recourse loans from banks although it was not the same easy for all types of project developers. The new renewable power plants were then based on equity contribution in the frame of *project finance* schemes. The equity contribution of Idae based on project finance schemes was most frequently used for wind energy. The presence of the renewables agency helped developers to obtain non-recourse loans or sometimes to obtain more advantageous financing terms.

Since late 1980s, another form of financing involvement to stimulate diffusion was introduced by means of *third party financing*. This was aimed at economic actors who either perceived the renewable technologies too risky and for those who would have liked to invest but lacked access to financial resources. Starting with 1998, the third-party financing efforts of the agency have been mobilized to support investments in small and medium-size wind plants by small industrial companies, individuals and associations still experiencing difficulties in using the project finance scheme for their investment plans. This support scheme was also made available for investments by town halls and public institutions in ownership of land[46]. The objective is to support self-generation and commercial projects with installed capacities between 0,3 and 5 MW. In 1998 and 1999, thirty one projects were financed based on third-party financing. On average equity provided by the agency per project was 86,5%. Biomass electricity plants have so far not been considered a priority for support under this scheme[47].

The use of these types of policy support mechanisms aims to address the financing obstacles of renewables. In some cases to small extent they may also help them with the economic obstacle, when the agency's participation leads to lower interest rates required by loan financing agents. The idea of third-party financing is actually precisely to protect the would-be owner from risks during the period of project operation when investment costs need to be recovered. When equity is offered for the finance of a project, the equity supplier - in this case Idae - is co-owner of the plant and is directly interested in good cash flows of the project. Besides, equity is the first financial resource to be consumed when a project is executed. When a co-owner of a project wishes to withdraw his shares, he can sell them to another interested

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[46] The preference of the Spanish banks, when convinced that RET projects, especially wind systems, can be an attractive business opportunity, has been to invest in large parks. Some banks even had some floor levels for their loan contribution - e.g. 25 M€, or for the plant sizes in which they wish to become involved - e.g. around 30-40 MW (ETSU 1996: 113).

[47] Based on the agency's documentation, we counted only two biomass projects that were financed based on third-party financing since 1998.

investor or some of the other co-owners. Consequently, there are no policy risks associated to these forms of support, for the projects' cash flow during their economic life-time.

6.7.2.3 Soft loans

The 1983 Plan for Energy Saving Conservation and Substitution involved beside investment subsidies also a special soft-loan public credit line and the subsidization of interest rates required by private financing institutions (also soft-loan type). There are however no publicly available data on how many projects benefited of such schemes and what types of renewables they used. The scheme for soft-loan on private financing was more likely not used since non-recourse loans were not yet available in those years[48].

In 1998 the national policy support mechanisms package was enriched with a new component. A support scheme for small and medium-size companies has been adopted as part of the 1995-1999 Feder[49]-Idae global subsidy framework. This scheme offers both technical and financial support and it is meant to support small industrial companies to reduce their energy expenses and improve competitiveness by becoming self-generators using renewable resources or using energy efficient/saving technologies. The energy savings of the applicant-company, through the proposed project, have to be at least 20% in order to be supported. The scheme offers soft loans with interest rates that are 3% lower than the average rate on the market, Mibor[50]. The loans could have a contribution in the capital structure of projects of up to 100% of project investment costs. The average debt maturity for these loans is eight years, based on project finance terms.

Since June 1999, a new policy support mechanism has been put in place through the agreement between Idae and the Official Credit Institute for the financing under soft loan terms of renewable and energy efficiency projects of certain type and size[51]. The entire credit line to be made available by Official Credit Institute amounts to 150,26 M€. Idae will make available a special budget, from which it will pay directly to Official Credit Institute the subsidized parts of the interest rates of the developers financed with loans from this credit line. Depending on the type and location of the project, the loan subsidy can be between 1% and 5% of interest rates. This means that the resulting interest rate can be as low as 4% below the average market rate Euribor[52]. These loans can account for maximum 70% of the capital structure of the project. The renewable energy systems that qualify for this line are: biomass for electricity production and for co-generation systems; wind plants with <4 MW installed capacity for self-generation; small hydropower smaller than 1 MW and biogas based plants. Applicants can be either physical or legal persons, in the last case both public and private entities being eligible. The maximum amount that can be lent per project is 6,1 Million €. The debt maturity periods can be five, seven, or ten years with two years of pardon. The credit risks are analysed by looking at the private assets of the applicants: mortgages, personal goods,

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[48] See chapters 7, 8, and 9 on diffusion patterns.

[49] Feder is the Spanish abbreviation for European Regional Development Fund. This program aims to promote social and economic cohesion in the European Union and its financial assistance is targeted at supporting small and medium sized enterprises, promoting productive investment, improving infrastructure and furthering local development. The ultimate goal is to create jobs by fostering competitive and sustainable development. (More information is available at http://europa.eu.int.)

[50] Mibor is the reference interest rate set by the Bank of Madrid. This was the reference rate used in Spain before the unification of the financial policy of EU Member States.

[51] Information regarding this scheme was available at ICO website, www.ico.es/idae.htm, August 2001.

[52] Euribor is the abbreviation of the EU inter-bank interest rate. For a subsidy of 5 points of the interest rate the remaining interest to be paid is considered (Euribor - 4) because under normal circumstances, on average, the interest rate would amount to (Euribor + 1) for these types of projects.

community/association assets and guarantors or jointly responsible actors, as well as eventual assets of the companies for reciprocal guarantee of which the applicant is part. This means that only internal financing schemes can be used under this credit line - either private finance or debt-corporate finance.

Soft-loans pose some policy risks, theoretically, as this policy support mechanism has a time dimension that spreads during more years of project operation. The government might decide to withdraw its support prematurely, leaving the developer pay the entire interest rate required by the bank. In case project profitability is already low, this negative impact on projects’ cash-flow can even make projects un-economic. And the higher the subsidization of interest rates is, the stronger the negative impact on projects’ cash flow can be as a result of support withdrawal. However, it can be argued that in Spain policy risks associated with soft-loans were very low.

The soft-loan scheme adopted in 1998 for the support of energy saving investments by small and medium size companies was designed in the framework of the 1995-1998 Feder-Idae global subsidy framework. This program uses subsidies from the European Union and aims at the improvement of the international competitiveness of small and medium size companies in regions with lower economic development - called also ‘Objective 1 areas’. The subsidy scheme envisages the achievement of this aim by means of lowering the energy costs these companies are facing. Together with energy saving technologies, renewables are also viewed as means of reducing companies' energy costs. In this context, it can be considered that the soft-loans these types of developers have been receiving since 1998 have very low policy risks. The fact that the financial support for this scheme has been substantially coming from EU funds, and that the final goal of the Idae-Feder agreement is to make small Spanish firms more internationally competitive, give confidence that the scheme will not be withdrawn, leaving developers in financial troubles.

The most recent soft-loan scheme is that administered with the help of the Official Credit Institute since 1999. The target group is formed by small developers investments in small-size plants and the reduction in interest rates can be between 1% and 5%. In this case we argue that policy risks are very low for developers because of the way this scheme has been implemented. The agreement for interest rate subsidization was concluded not between Idae and individual developers, which might have posed indeed some policy risks, but between Idae and the Official Credit Institute. The renewable energy agency committed itself to make available for the Official Credit Institute a special budget from which the bank will take the necessary money to compensate for the difference in interest rates that developers are exempted of. Therefore, since this scheme does not function in the form of reimbursement of interest rates expenses to developers, and it assumes a direct agreement with an important financial institution, we consider that this support scheme poses also only very low policy risks for the developers at which it is targeted.

6.7.2.4 Fiscal incentives

In addition to the support schemes used in the framework of all these policy plans, some attempts were made to introduce also several fiscal incentives. As discussed in Section 6.3, some tax reductions were offered in the framework of the 82/1980 Energy Conservation Law, but the extent of financial support they represented was insignificant. In addition two other national tax incentives have been adopted in the 1990s - the Law 18/1991 on personal income tax and the Law 43/1995 on corporate income tax. The first offers some levels of tax reimbursement for individuals making investments in energy systems using renewables and energy saving technologies. The second offers a 10% reduction on corporate tax - which normally is 35%, for investments in environmentally-friendly fixed assess. Interviews with developers and representatives of public authorities revealed a lack of knowledge among developers regarding this tax incentives (Idae and Sodean 1999). Very few developers seem to have applied for the advantages of these fiscal schemes.

6.7.2.5 Conclusions regarding policy risks and extent of financial support from policy support mechanisms

In conclusion the most frequently types of policy support mechanisms used by the Spanish government have been investment subsidies and various schemes for the improvement of the financing conditions. Fiscal instruments played no role. The support mechanisms used had three types of effects over the investment framework:

- offer financial support, to cover the cost-gap as compared to the technology costs of conventional power systems and to improve the levels of project profitability,
- remove the financing obstacles and technology-risk perception of potential developers and traditional financing agents during the early stages of market diffusion, and
- enable diversity in the types of developers and projects sizes, by removing the financing obstacles met by small developers and for investments in small-size plants.

Table 6.9 summarises the risk effect and the extent of financial support offered by each policy support mechanism discussed in this section. Since only the two soft loan scheme may be seen as associated with very low risks, we consider that the aggregated economic-policy risks of the support system in all three periods distinguished are defined only by the risks in the economic governance structures.

Table 6.9 *Qualitative assessment of risk-profitability contributions by policy support mechanisms*

Type policy support mechanisms		Risk effect	Contribution to project feasibility / profitability		
			small hydropower	wind	biomass
invest subsidy	national	risk neutral	initially large, but very small after 1998		initially small; increasing after 1998
	European Union		initially large (and numerous) but decreasing		-
third party financing		risk neutral	-	-	-
equity contribution		risk neutral	-	indirect; small	
soft-loans		very low risk	modest (for small projects and developers after 1998)		

The next section presents the assessment of economic-policy risks and profitability of projects for all three types of renewables by project developers, based on interviews carried out in Spain. Following that we select the hypotheses to be tested for the diffusion of the three types of renewable technologies in Spain during the 1980s and the 1990s.

6.8 Assessment of support systems' risks by energy market experts in Spain

In the previous section we concluded that the risks stemming from economic governance structures were in the same time representative for the entire economic-policy investment frameworks. The economic-policy risks can be therefore represented as in Figure 6.6. The problem that remains is related to the target group at which the economic governance structures were aimed, since for the first and the second economic governance structure, the only legally protected developers were self-generators and demonstration projects. In practice, however, the overwhelming majority of wind projects, but also many biomass plants, were developed as commercial projects.

This section discusses first some explanations with regard to the difference in commercial non-hydro projects and commercial non-biomass projects as compared to the rest of the types of renewable electricity projects. After that, it presents the opinion of interviewed project developers and market experts with regard to the risks associated with the support systems in the three periods distinguished.

6.8.1 Commercial and non-commercial renewable electricity projects

We interviewed two energy experts in order to understand how was it possible for so many wind commercial projects to emerge in a context were the economic risks were so high for this type of projects[53]. Five explanatory lines emerged that reinforce each other, leading to the conclusion that in practice commercial projects were allowed to benefit of the same legal protection and guarantees as self-generation and R&D projects.

The first explanation has a technological nature and refers to the qualification of the wind projects as R&D projects up to 1994. Lopez (August 2001) argues that the commercial stage of wind projects started in Spain only in 1994. There was no problem to consider any wind-based project as an R&D or demonstration project since the technology was not considered as mature yet. Further Ocharan (August 2001) argues that sometimes wind turbines produced by foreign manufacturers, which were actually already tested and market-ready designs, were considered as demonstration projects because they were used for the first time in Spain. These arguments converge with our interpretation of the legal texts in Section 6.4 where we argued that the 1994 Royal Decree did not abrogate Chapter II of the 82/1980 Law, leaving this way the door open for the eligibility of R&D and demonstration projects for the guarantees of the second economic governance structure.

The second explanation has a combined policy and strategic business nature, and relates to the governmental vision regarding the way renewables can contribute to the Spanish energy supply and to the vision of energy utilities towards their role in renewables development. The political commitment for the market diffusion of renewables was very strong, especially since mid 1980s. The vision of the government was to achieve a higher contribution of renewable resources to the Spanish energy resource-base by encouraging consumers of any type to invest in renewables and become self-generators. The 1991-2000 Plan for Energy Saving and Efficiency set targets of 168 MW wind capacity by 2000, and 779 MW new small hydropower plants - among other technologies, and expected their achievement solely though self-generation projects. That is why the 82/1980 Law and the 1994 regulations were also targeted at self-generators' support. But because the interest in self-generation projects proved very low, commercial projects started to be accepted under the protective special regime, in order to reach the policy targets (Ocharan 2001).

Energy utilities understood that the political commitment for renewables was strong and long-term, and decided that if renewables are to play an important role in the future energy-base of Spain, they will play an active role in renewables' development. This way some large utilities, especially Endesa, and Union Fenosa, started investing both in demonstration and commercial projects in the first half of 1994. Later Iberdrola and Hidrocantabria created

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[53] Ocharan de la Camara is technical consultant for the General Sub-Direction for Energy Planning, Ministry of Industry and Energy (currently the Ministry of Economy); Cristobal Lopez is engineer in wind power at Iberdrola Ingineria y Consultoria (subsidiary of the second largest energy utility in Spain).

special subsidiaries for renewable investments[54]. This created an environment of acceptance for commercial projects based on non-hydro resources commissioned by other developers, although utilities had no legal obligation to purchase 100% of the output of commercial plants, from a legal perspective. The governmental vision that self-generation projects would be sufficient to increase the contribution of renewables to the energy-resource base proved to be too optimistic.

The third explanation has a political nature. In Ocharan's opinion, the focus on self-generators in the legal support system was advantageous from the standpoint of "the simplification of the law". It would have been more difficult to introduce commercial projects in the special regime from the very first years of support. Later, in early 1990s, when the cooperation of utilities was obtained, it was considered politically easier to keep the legal special regime only for self-generators, with the assumption that societal dialog and political statements of commitment for renewables would lead to the development of commercial projects. The Spanish renewable energy agency Idae initiated a series of national workshops where energy utilities and financial agents such as banks, insurance companies and specialized investment companies were key participants. This substantially contributed to the improvement of the perception of the energy utilities that were still not involved in renewables investments at that stage. But it also contributed to the improvement of the perception by traditional financing community that the economic and policy investment environment is favorable and stable for the development of commercial renewable energy projects.

A fourth interesting explanation relates to the Spanish business culture and is linked to the third. Ocharan (August 2001) explains that in Spain when all involved actors agree and if there are no other parties that can be injured by (or opposing to) an act, it is easy to modify a certain legal criteria or to apply the law differently. Therefore, whenever energy utilities did not oppose, commercial projects could also be developed.

Finally there is a fifth explanation that has a technical nature. Lopez (August 2001) explains that the 2366/1994 Royal Decree referred literally indeed only to self-generators, but actually commercial plants were also understood as eligible. He argued that it was just a matter of style in language: even in a wind farm electricity is consumed for the auxiliary systems, or when wind turbines stop, or when operation and maintenance operations need to be done. Any generation plant consumes electricity as well. Even if self-consumption accounts only for 1-2%, or maybe sometimes up to 5% of total wind production, and the rest is sold for profits - this was still considered a case of self-generation. As he explains, in Spain there were no cases where banks or developers perceived the provisions of the 1994 Royal Decree as risky in terms of demand for output (or qualification for the special regime). Therefore, it seems that in the perception of commercial project developers and bankers there were no economic risks associated with the focus of the legal target group for both the first and second economic governance structure on self-generators.

Based on these explanations we will consider, for the purpose of selecting the hypotheses to be tested, that in practice the economic-policy risks were the same for developers of all types of projects - R&D, self-generation and commercial. This way, for all three types of technologies we will consider that economic risks were in the lower part of the 'high' range during the first economic governance structure 1980-1994, and they decreased to slightly the lower part of the 'modest' range during the second economic governance structure between 1995-1998. The third economic governance structure has led to two options of very similar risk levels. Because of the choice on price design offered to developers, two formulas

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[54] In 2001 Endesa was the largest energy utility, followed by Iberdrola, Union Fenosa and Hidrocantabrico.

emerged: for those who choose the tariff option the aggregated economic-policy risks will be considered as 'low', while for those who choose the market price option risks as slightly 'modest'.

6.8.2 Interviewees' assessments of economic risks

The opinions of interviewed developers and energy experts regarding the risks embedded in the three economic governance structures are quite similar to each other, and do not vary much from the theoretical assessments we made in Sections 6.3 to 6.5 from a legal perspective. The only important difference in risk interpretation is that no interviewee raised doubts over the eligibility of non-hydro renewables-based commercial projects to the special regime created by the first and the second economic governance structure. Similarly, nobody doubted the right to special regime protection and guarantees of commercial biomass projects based on the third economic governance structure, while we pointed out in Section 6.5 that based on the 2818/1998 Decree strict legal interpretation, only self-generation biomass projects would be eligible.

Fewer interviewees made assessments over the economic risks during the 1980-1994 economic governance structure since it is not easy to identify individual developers who were involved in wind renewable projects during the 1980s when these technologies' were emerging, even when companies are still there. Some interviewees explained that the 82/1980 Conservation Law was mainly targeted at co-generation, small hydropower and renewable R&D installations, and that the law was not drafted with commercial renewable plants in mind because they were technically not ready for market introduction (Ocharan, Cruz, Lopez 2001).

However investments in several commercial wind plants still took place after 1990 and, assessing the economic framework for investments, many respondents[55] argued that there was not a real stable legal framework, before the adoption of the 1994 Royal Decree. This was mainly because there was no legal guarantee on a minimum contract length and a minimum price, or at least a clear methodology for price calculation[56]. Too many economic and financial aspects of renewable plants functioning were left at the decision discretion of the Ministry of Industry and Energy and at the arbitrary decision of utilities, which had to issue grid-connection approvals. Unless potential developers could build a direct bilateral trust relationship with public authorities and energy utilities, the economic risk framework was not very encouraging, especially for new entrants in the energy industry. Hence, while the legal right for grid connection and guaranteed purchase were not doubted, risks were perceived in relation to contracts' length and renewal, and in relation to contractual prices. The most direct evidence of this was the fact that, with few exceptions, it was very difficult to obtain loans for renewable non-hydro plants.

The second economic governance structure lowered the economic risks, in the view of all interviewed developers, and brought new developers and investors in the market[57]. However,

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[55] Cruz I., Castillo, Prats J., Lopez C, Galvan G., Bustos M., interviews 2001; de Delas (APPA 2001).

[56] In this context Prats (Ecotecnia April, 2001) mentions that (wind) installations were difficult to finance up to 1994 because there was no clear frame for the price of the electricity output. There were also a lot of barriers from the grid interconnection point of view. Utilities made problems to connect wind turbines to the grid, in spite of some regulations. After 1995 financing of wind projects became easier because regulations changed in 1994. Lopez (Iberdrola IyC, April 2001) also confirms the idea of high price uncertainty highlighting that in the period up to 1994 there was no price guaranteed. The legal support was mainly for R&D in wind technology. The guaranteed surplus price appeared only in 1994.

[57] Castillo, Lopez, Bustos, de Rojas Barcina, Arrieta, Prats, Cruz, April 2001.

although economic investment risks were lowered, some uncertainties still remained with regard to contract length and availability of guaranteed price. As Alberto de Rojas Barcina points out (2001), "under the 1994 regulations it was not clear whether the guaranteed price will extend beyond the 5 years of minimum guaranteed contracts". Besides, the fact that clarity on guaranteed contract lengths was given only for the first five years of plant functioning, represented a risk for external financing agents who preferred to finance plants that could recover investment costs, or at least the value of the loan, during the first five years of plant operation, unless Idae was involved in the financing of the plant (Cruz August 2001).

The third economic governance structure was assessed by many interviewees as a political-legal framework with 'no risk' or 'very low risks'. Some uncertainties are only hovering over the levels of extra prices. The risks associated with the market-price option of the 1998 Decree, whereby developers receive the pool price added to an annually approved bonus, were assessed by all developers as high. But all developers with projects under this payment method argued that they are confident that even if the bonus level lowers, there will continue to be a bonus for a long time.

Similarly there is confidence that the special tariffs for renewables will also exist as an alternative option. As Arrieta (EHN April 2001) explains, the ideology in Spain is that the premium/tariff currently received is not a 'subsidy' but an internalization of the environmental benefits and system benefits of renewable plants. This has also been stated in the 54/1997 Law and 2818/1998 Royal Decree. This approach to price support was reinforced in the last years of the 1990s by EU authorities and contributed substantially to the way developers and financing agents assess price risks.

The time horizon, to which the confidence of interviewed developers expands, with regard to the existence of the special regime, differs however slightly. Some developers argued that the bonus/tariff will be available at least until 2005, when the EU plans to decide on harmonized support systems for renewables. At that moment other countries and EU authorities would realize that the price support system used in Spain, Germany and Denmark has been the most successful for the market development of renewables and would continue to back it up. Even if after 2005 a special bonus or tariff will not be available anymore, there is very high confidence that there will be a similarly attractive system to continue stimulating renewables market diffusion (Lopez and Arrieta 2001).

Others assume that the current special regime support will last at least until 2007, when the liberalization of the entire segment of consumers is scheduled in Spain. Currently all expenses related that the guaranteed bonuses and high-tariffs for renewables are falling on the electricity bills of captive consumers (Utrillio, Lopez, Castillo 2001). And others expand the time horizon of their expectation for special regime protection to at least the year 2010 when the 12% target of renewables contribution to Spanish energy consumption should be reached (de Rojas Barcina, Fernandez, Bustos 2001).

The prolongment of one or another form of governmental support for renewable is actually expected by most developers beyond these suggested years for reasons related to security of supply and resource diversification needs, lowering social tolerance over the environmental and health impacts of fossil and nuclear energy technologies, and expected increasing evidence of climatic changes (del Pozo, Arrieta, Mendilluce 2001).

As regards contract risks, the situation is different than under the second economic governance structure. The minimum guaranteed contract length is also five years. But, in contrast to the 1994 regulations, the inclusion of the 12% target for renewables by 2010 and the policy statements made in the context of the 54/1997 electricity law and especially the introduction of the 1998 Decree have substantially contributed to the increase in confidence towards the political commitment of the government to support renewables.

In addition, the latest developments in the EU policy towards renewables, especially that the extra prices some countries are paying for renewables should not be seen as a subsidy but as a recognition of benefits, as well as the discussions regarding the need to internalize the environmental costs of fossil fuels, have also strengthened the perception of continuity of direct economic and financial support for renewables. These developments overshadowed the aspects of contractual lengths. As Santo ([CESA] August 2001) explains, developers and financing agents do not see anymore risks associated with the five-year contracts: “Banks have no problem with issuing ‘project finance’ types of loans because there are sufficient guarantees in the new 1997/1998 legal framework assuring financiers that the output of plants will be bought for a long time and that the target needs to be reached”. Lopez mentions that, according to Idae information, after the five year period expires purchase contacts are annually renewed.

We would not equate the investment enthusiasm since 1998 with ‘zero contract risks’. As we explained in Section 6.5 in the short period between 1997 and 1998 great confusion was created among developers and financiers, after the publication of the 1997 Electricity Law. Among others, the confusion was also inserted by the Article 30(a) of the law, which introduced some contract risks by allowing the government to limit the uptake of renewable electricity for some periods of time. This would affect the cash flow of projects and the period of loan repayment and investment costs recovery. For this reason we would argue for the maintenance of a ‘low’ risk in the description of the contract risks associated with the third economic governance structure.

In conclusion, the interviews with Spanish energy experts regarding the attractiveness and risks of the economic framework for renewables’ investments brought about new and interesting perspectives. The main deviations as compared to our theoretical assessments regard the eligibility of commercial developers as target group under first and second economic governance structures and the weak concern with contract risks, especially under the third economic governance structure.

In the analysis of the following sections, we will represent the economic-policy risks on the vertical axis of the graphs suggesting the risk-profitability investment frameworks, with the qualitative values of :

- lower part of high risks range during the first support system, 1980-1994;
- lower part of modest risks range during the second support system, 1995-1998; and
- low/modest risks during the third support system active, since 1999.

The next section discusses the profitability of wind projects, small hydropower projects and biomass electricity projects during the three support systems. After the ranges of projects’ profitability have been traced, we specify the hypotheses to be tested for each technology for the three support systems.

6.9 Assessment of project profitability for the three renewable technologies. Selecting the hypotheses to be tested.

The profitability characteristic was operationalised as follows: low - up to 4%; modest 4 - 8%; high 8 - 12%; very high > 12%. In Chapter 5 we mentioned three approaches for assessing profitability ranges: 1) direct profitability data from developers, market experts and available empirical material such as governmental documents, journal articles or conference papers; 2) qualitative assessments from developers, used when data are treated as confidential; and/or 3) a rough comparison of production costs and the extent of price/financial support, using also information from developers, market experts and empirical material.

In the framework of empirical research in Spain, most interviewed preferred to discuss about the profitability of their projects in qualitative terms. Few of them mentioned however numbers with regard to their business criteria, the renewable energy projects developed and the ranges generally applicable in Spain based on their knowledge.

Hence, we used mainly the second approach, complemented with some direct data on profitability of projects. In addition, we also made some rough comparisons between the ranges of production costs per technology and the extent of financial support from the support systems, on the basis of the data summarised in Table 6.8.

As general observation, from discussions with project developers it appeared that in Spain the preferences of large developers and electricity companies with regard to the profitability of commercial projects is that investments are able to generate profitability above 8% - 9%[58]. But financing agents require higher project profitability levels in order to approve loans exclusively based on non-recourse guarantee. An investor specialised in commercial renewable projects explains that if the internal rate of return of the project is 20% or higher, the project can be financed by means of the project financing scheme. But if the profitability of the project is only around 8% - 12%, banks ask to support the project finance with the balance sheet of the project developer(s) as secondary recourse, or even shift to corporate finance. But this also depends on how experienced is the developer in energy projects. These suggest a likely location of support systems with diffusion results in the entrepreneurial and/or optimal investment contexts, having in view the considerations on economic risks and our operationalisation of profitability characteristic.

6.9.1 Profitability ranges and the hypotheses to be tested for wind technology diffusion

6.9.1.1 Profitability of wind energy projects under the 1980-1994 support system

During the 1980s, the only project developers were the national renewable energy agency (Idae), manufacturers, and energy utilities. Their purpose was to test new turbine models as they were being developed by Spanish manufacturers. In the period 1991-1994 the types of project developers started to diversify slowly. However, an expert in wind energy of the central energy research institute Ciemat (Cruz August 2001) warned that it is difficult to estimate the profitability of wind projects during before 1994 because companies did not publish information over these projects in annual reports. However, some inferences can be made, backed by few empirical data.

For example one experienced interviewee[59] (Prats April 2001) explained that mainly wind projects with profitability of 20 - 21% could secure banks loans before 1994. Other interviewees explained that before 1994, very high profitability levels were possible because at that time very good sites with high wind speed and large availability in terms of hours per year were still easy to find. Very high profits were also made possible by the easy accessibility of more investment subsidy sources.

Investment subsidies were available from three sources to the extent needed by the project at hand: the EU Valoren Program, the national (renewable) energy policy plans (see Table

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[58] For example 8% is the threshold for the (subsidiaries of the) second largest electricity Iberdola, but preferably this should be 12-13% (Mendiluce 2001). For the renewables subsidiary of the fourth largest electricity company (Sinae) an at least 8% profitability is also considered sufficient to invest (Fernandez April 2001). The renewable energy subsidiary of the largest electricity company (Endesa Cogeneration y Renovables) uses often a threshold of 12% or even 15% for project profitability (del Pozo 2001).

[59] Josep Prats is one of the founder members of the wind technology designer and manufacturing company Ecotecnia, with experience in the Spanish wind energy industry and market since early 1980s.

6.8), and the regional governments where the wind project was to be located[60]. Interviewees mentioned that projects generally had between 50-90% investment subsidies, such as the demonstration projects of wind technology manufacture subsidiary of energy utility Endesa, while occasionally they could reach 100%[61]. Besides, the setting of the price support per kWh was also flexible as it was based on agreements between the developer, the energy utility buying the wind electricity and the renewables agency Idae.

An important aspect is that, in the first period of market introduction, the renewable energy agency had agreements with energy utilities and Spanish wind turbine manufacturers to invest the profits from wind projects back into innovation efforts and new demonstration parks during the 1980s (Cruz August 2001). But the wind projects had to book good profitability levels in order to support the build-up of a good track record for economic actors and financing agents watching the emerging market. The governmental renewable agency was itself operating on commercial terms in the field of wind power. According to Idae experts, the involvement of the agency in the financing of wind projects during the 1990s was based on several (re-defined) criteria, among which there was also that of "participation on commercial wind parks, based on certain criteria of project profitability and connected to the grid" (Ayuste et al. 1996).

For the period after 1995 more detailed information could be obtained regarding the profitability of projects from developers and market experts (see Section below). The profitability numbers they mention are in the range of 8% to 15%, and sometimes even 25%. But it is widely argued that current profitability levels are decreasing compared to what was possible in early 1990s to gain. An 8% profitability is the lower border of the profitability range described by interviewees for 2000-2001, while we operationalised this as the start of the 'high' profitability range.

Taking into account all these considerations, we conclude that while statements on the profitability of projects during the 1980s are more difficult to make, for the period 1990-1994 the available empirical information suggests that the majority of projects must have been developed with levels of profitability higher than 8%, that is in the 'high' range. Taking into account also the conclusion reached in Section 6.8.1 that for all three types of technologies we will consider that economic risks were in the lower part of the 'high' range during 1980-1994, we select to test Hypothesis 2 for the market introduction of wind technology during the first support system (see Figure 6.8).

6.9.1.2 Profitability of wind energy projects since 1995

The interviewees answering the question of project profitability for wind power plants since 1995 can be divided into two groups. Several were of the opinion that the profitability was very good. They referred to levels between 12% - 15% and mentioned that sometimes even 25% profitability was possible[62]. For example Prats (April 2001) explained that for a project with an equity contribution of 20% and the rest with a project finance loan with an interest rate of 6% - 6,5%, the profitability of the project could around 15% in 2001. Lopez (April 2001) further explained that large companies are able to develop in good resource locations wind

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[60] Beside the subsidies rooted in national policy plan, as shown in Table 6.8, developers also received subsidies from regional governments were developments took place first, e.g. Andalusia, Canary Islands, Galicia and later also Catalonia and other regions. The levels of regional subsidies differed They were usually up to 10% and were not issued based on an organized framework or special criteria.

[61] Interviews del Pozo 2001 (April 2001) and Cruz (August 2001).

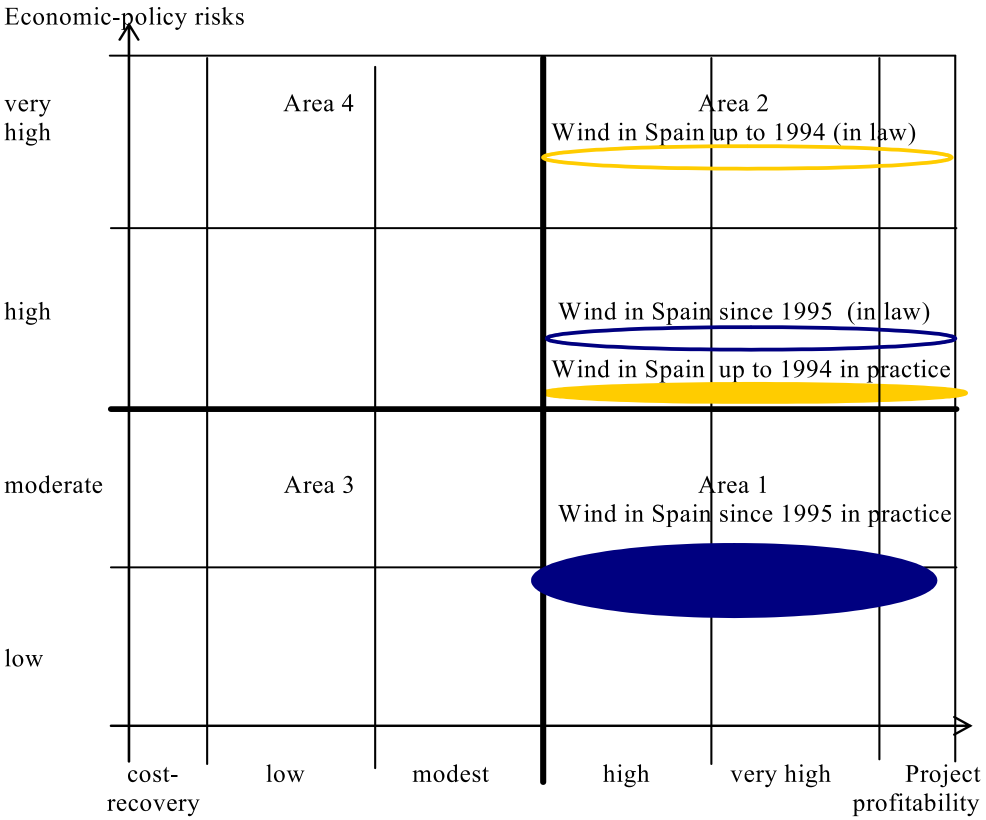
[62] Interviews in April 2001 with Utrillio (DeWind); Lopez (Iberdrola Ingenieria y Consultario); Prats (Ecotecnia); de Rojas Barcina (Elecnor); del Pozo (Endesa Cogeneracion y Renovables).

power plants where the average production costs are around 4,2 – 4,3 €c/kWh after taxes. Given the price support in the Royal Decrees (see Table 6.8) a net profit of around 1,8 €c/kWh is possible which is seen as a very good profit.

Another group of interviewees argued that in Spain wind projects developed since the end of 1990s have in general a profitability 8% - 10% (after paying tax) during 15 years, while some wind plants can still reach 15% profitability[63]. But there are also companies that develop projects with lower profitability. Few interviewees made qualitative assessments, referring to profitability as 'good'[64].

In December 2002, a study was completed by the Association of Renewable Energy Producers APPA for the Ministry of Economy with regard to the profitability of wind projects in Spain and cost performances of wind power plants. This study mentions that by 2002 the profitability of a typical wind project of 25 MW based on project finance with 25% debt lowered to 8,6%[65]. A series of causes for profitability decrease were mentioned, among which also the decrease in the price support due to the annual revisions of the government.

Figure 6.8 *The risk-profitability investment contexts for wind technology in Spain*



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[63] Interviews in April 2001 with Fernandez (Sinae); Mendiluce (IberRenova); Cruz (Ciemat August 2001), del Pozo (April 2001).

[64] Interviews April 2001 with Bustos (Appa); Castillo (Union Fenosa Energias Especiales); Arrieta (Energia Hidraulica Navarra), and Betscheider.

Taking into account our operationalisation of the profitability characteristic it appears that the majority of projects developed since 1995 until 2001 were in the high and very high ranges of project profitability. In Section 6.8.1 we concluded that for all types of wind projects we will consider economic risks as in the lower part of the 'modest' range during the second economic governance structure between 1995-1998. For the third economic governance structure economic risks were assessed as low for those who choose the tariff option for price design and modest for those who choose the market price option for price design. Consequently, we select to test Hypothesis 1 for the diffusion of wind technology in Span in the period 1995-2001. In Figure 6.8, the risk-profitability investment contexts for which we test the two selected hypotheses were represented in the form of full ellipses. For contrast, we also represented by means of empty ellipses the risk levels in the support systems applicable before 1994 and in the period 1995-1998, as it emerged based solely on legal analysis.

6.9.2 Profitability ranges and the hypotheses to be tested for biomass technology diffusion

In contrast to wind energy, the profitability of biomass electricity plants is strongly influenced by the price of biomass resources. In Table 4.4 of Chapter 4, we enumerated the types of biomass resources that can be used for electricity generation. Although in national contexts there may be cost differences, in principle, dedicated energy cultivation resources are the most expensive resources, followed by clean biomass wastes. Organic industrial and agricultural wastes come usually at considerably lower costs, while biogas may even come at negative costs when the owner of biogas generating wastes incurs higher costs to eliminate those wastes by an alternative measure.

Beside the types of resources used, the production costs assumed by biomass electricity plants may vary widely also depending on:

- the types of technologies used for the biomass-to-feedstock technologies and the electricity generation units;
- sizes of plants constructed.

The economics of biomass electricity plants show that the production costs per kWh are often higher than for other technologies and they have a lower elasticity to plant size up to a certain level. In the case of direct-combustion and gasification technologies, costs start to lower only after sizes larger than 30 MW (see Section 4.3). Low-cost biomass projects can only be developed using engines with capacities below 1 MW (Carrasco 1996). In Spain, the designers of the support systems did not take into account the impact of these aspects on the economic feasibility and profitability of biomass electricity projects, with important consequences for the diffusion patterns and rate of this technology.

6.9.2.1 Profitability of biomass electricity projects under the 1980-1994 support system

In the period up to mid 1990s biomass electricity projects were seldom supported by means of investment subsidies. The priority of the governmental renewable agency was to support the cheaper biomass thermal technologies for heat and hot water production. Besides, the price per kWh for biomass electricity was not regulated in Ministerial Orders. Biomass electricity technologies were considered yet too expensive to lead to any substantial levels of

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[65] The findings of the APPA report are summarised in the newsletter APPA Info No. 9 of December 2002, Barcelona downloadable at http://www.appa.es.

investments. During the entire period the price per kWh guaranteed by the 82/1980 Energy Conservation Law remained bilaterally negotiated with energy utilities buying the output. Due to the reason that we could not identify individuals (in companies developing projects in that period) with knowledge regarding the extent of financial support and type of financing scheme per project, we cannot use the first and the third methods of data collection on the profitability characteristic mentioned in the beginning of Section 6.9.

Interviewees from companies developing projects after 1994 and the governmental experts interviewed had similar opinions regarding the profitability of projects before 1995. The general argument was that biomass electricity technologies was not yet perceived as commercially viable at governmental level, which led to low interest in putting in place a financial support framework for them. More demonstration and research was needed before financial support for market introduction was justified. When some economic actors were interested to use the organic wastes of their company to generate electricity or combined heat and power (cogeneration technologies) for their own consumption, investment subsidies were sometimes made available to justify the investment economically, as compared to the alternative of buying electricity from the energy utility. When the developers also would have liked to sell the surplus electricity to the energy utility, the price per kWh was bilaterally agreed. But the extent of financial support was mainly focused on the cost recovery of investments while occasionally projects could overall result in low/modest profitability.

In Section 6.6 we concluded that for biomass power projects, the economic risks during the 1980-1994 were ‘very high’ for commercial projects and ‘high’ for partly-self-generation and demonstration projects. In conclusion, the risk-profitability investment contexts created by the 1980-1994 support system for biomass electricity technologies can be represented approximately as in Figure 6.9. We select Hypothesis 4 for the testing of theoretical expectations regarding market introduction of biomass electricity technologies in Spain, in the period 1980-1994.

6.9.2.2 Profitability of biomass electricity projects since 1995

The 2366/1994 Royal Decree categorised biomass resources in the same technology group with industrial and urban wastes, giving projects the same low level of price support/kWh. Not taking into account that biomass resources may be costly, the support system restricted the chances for profitable projects only to biogas and to organic wastes from agricultural and industrial applications. The interviewed market experts and representatives of companies developing biomass projects indicated that there was a niche market of profitable projects since 1995 when the extent of price support per kWh became clearer. However, due to the lowering of investment subsidies to only 15% in these years (see Table 6.8), the profitability of projects was mostly in the range of ‘low’/‘modest’. The use of clean biomass wastes and dedicated energy cultivation was not able, however, to yield profitable projects, unless more sources of investment subsidies could be secured by the developers, for example from European Union Funds or regional/local governments. The biogas plants could reach high levels more often (Anegon, Escobar April 2001).

The third support system brough about a slight improvement in the profitability range. Both the level of national investment subsidies and the price support per kWh from the 2818/1998 Royal Decree increased, as shown in Table 6.8. According to the president of the biomass energy section of the Association of Renewable Energy Producers (Vitales 2001) projects could reach profitability of 10-12% and qualify for project finance loans when they used low-cost organic wastes, generally below 1,2 €c/kg from industrial/ agricultural applications.

But, according to the same interviewees, power plants based on clean biomass wastes and dedicated energy cultivation (such as energy crops and dedicatd forest resources) were in 2001 still not economically feasible or assumed 'low'/'modest' profitability. The 2818/1998 Royal Decree made again a resource classification with negative impacts on diffusion when it categorised clean biomass wastes (such as forest residues and unused agricultural remainings) in the same group with organic matter from industrial and agricultural applications. The dedicated cultivation resources were placed in a separate group but they were given low price support as compared to their production costs range.

Menendez (1997: 139; 128) mentions that the cost for clean forest wastes supply is between 3-4,8 €c/kg. For clean agricultural wastes prices have an even much larger variation. For example for straw they can vary between 1,2-9 €c/kg. For woody agricultural wastes costs are above 3 €c/kg. Biomass-electricity plants can only be profitable - under the financial support available after 1998 - if biomass resources are available at maximum 1,8 €c/kg. Interested developers (Vitales 2001) estimate that only a price increase of at least 1,8 €c/kWh for electricity sold to the grid (compared to the 2001 tariffs) can make plants using clean biomass resources profitable.

Empirical information suggests that since 1999 it became possible to build projects with 8% - 12% profitability, when the following combinations were used[66]:

- secondary biomass resources: biogas, and organic wastes from industrial and food production applications; these often came at zero costs or below 1,2 €c/kg, while price support made projects possibly profitable when biomass costs were below 1,8 €c/kg
- direct-combustion technologies; and
- larger size plants (Vitales 2001).

When higher investment subsidies were occasionally available, the niche market of high profitability projects extended to the three categories of clean resources as well - agricultural wastes, forestry wastes and energy crops. Consequently, the range of project profitability for the period after 1999 can be represented as spreading from the 'low'/'modest' ranges towards 'high' profits in niche conditions.

In Section 6.6 we concluded that in our assessment the commercial biomass projects were exposed during the second and the third economic governance structures to 'high' economic risks, while partly-self-generation and demonstration projects were more protected, being under low/modest economic risks (see Figure 6.9). Nevertheless, given the general perception that we encountered during empirical research in Spain, that biomass commercial projects are eligible to all legal and financial benefits applicable to partly-self-generation and demonstration projects (see Section 6.8.1), we will consider for the purpose of selecting the hypothesis to be tested that since 1995 economic risks are in the low/modest ranges for all types of biomass projects. Having in view the assessment of:

1) low/modest profitability ranges during 1995-1998 and;
2) a concentration of the new projects in the 'high profitability zone' since 1999;

we select to test a hypothesis that is specified for a combination of optimal and political investment contexts. In this case study, diffusion patterns are expected to take:

- the forms expected under political investment contexts in the period 1995-1998; and

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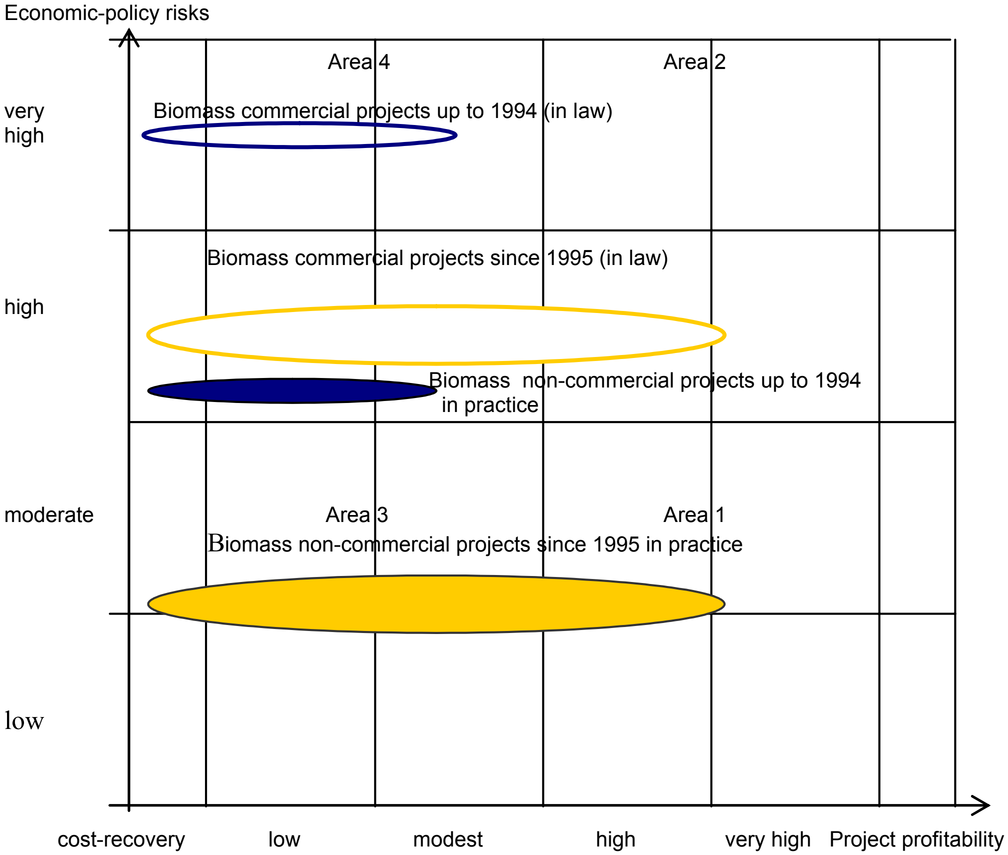
[66] An expert in biomass power plants of the national research institute Ciemat (Carrasco 2002) explained that most commercial plants that are being developed and proposed are in the range of 18-25 MW. Due to the economics of biomass plants and having in view the level of financial support, only these sizes, and larger are really profitable. If cheap resources are available, they can reach project profitability of 10-12%.

- a transition towards the forms of diffuison patterns expected under optimal investment contexts (according to Hypothesis 1), after 1999.

As regards the potential for installed capacity increase, this is more likely to be ‘modest’ in short-medium term of diffusion based on this type of support system, because of the limited opportunities to build high profitability projects under the available price support. Given the context of limited potential of resources economically feasible with the available price support we consider that in this case the features of the social-economic-industrial context of diffusion would rather have the characteristics expected under political (Area 3) investment contexts. The prospects of diffusion continuity are strongly dependent on the availability of biomass resources at costs that would still enable projects with high or at least modest profitability.

In Figure 6.9, the risk-profitability investment contexts for which we test the two selected hypotheses were represented in the form of full ellipses. For contrast, we also represented by means of empty ellipses the risk levels in the support systems applicable before 1994 and in the period 1995-1998 as we assessed them theoretically looking from the perspective of legal guarantees.

Figure 6.9 *The risk-profitability investment contexts for biomass electricity technologies in Spain*



6.9.3 Profitability ranges and the hypotheses to be tested for small hydropower technology

6.9.3.1 Profitability of small hydropower projects under the 1980-1994 support system

Some interviewed developers with investments in small hydropower plants assessed the project profitability during the first economic governance structure as 'good'[67]. Others considered that both the first and the second economic governance structures offered small hydropower developers 'lots of profits' (Lopez September 2001) or 'high profitability' (Bustos April 2001; Arrieta October 2001). Castillo and Fernandez mentioned that in the beginning of the 1980s there were many applications for small hydropower. Because of the very high interest in new plants, local and regional authorities stopped the approval process due to social and environmental concerns over the impact of so many projects. Likewise, Bustos (APPA) explains that "the 1980 Law, and the subsidy schemes the government put in place, helped to achieve a big increase in the number of small hydropower put on line". These statements suggest that the financial attractiveness of small hydropower plants was very high in the period 1980-1994.

A rough comparison between the average production costs and the extent of financial support in the support system suggests the assessment of high profitability - or even expanding in the very high range - as credible. On average, production costs in early 1990s were around 6 - 6,6 €c/kWh, while at the end of 2000 they lowered only very slightly, to 5,4 €c/kWh (Velez[68] 2000). The IEA considers small hydropower technology as a production system with 'constant' investment costs of electricity production in the period 1987-1997, given the breakdown of investment costs and the very strong influence of technology complementary costs that are site specific and non-malleable cost variables[69].

The financial support for small hydropower was the most substantial in the period up to 1994, in line with the governmental policy to give special stimuli for the diffusion of this technology. In Table 6.8, we summarized the prices per kWh received by hydropower generators based on the three economic governance structures and the investment subsidies generators could use in each period. The price support varied between 6,1 and 6,3 €c/kWh during 1980 to 1994. But that was also the time span when substantial investment subsidies were used both from national and EU programs.

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[67] Bustos April 2001; Gonzalez Velez (January 2002); Castillo (UFES, April 2001); Franco del Pozo (ECYR April 2001), Fernandez M. (SINAE, April 2001; Hidrowat 2001; Sofoensa October 2001.

[68] Maria Jose Gonzales Velez is the president of the Small Hydropower Section of the Association of Renewable Energy Producers.

[69] Source website http://www.europa.eu.int/en/comm/dg17/atlas/htmlu/adtech.html. The final production costs of small hydropower plants are strongly influenced by a series of non-technology factors. Examples of such factors are terrain topography, the percentage of public versus private land, the difficulty of access to the site in the process of construction works, the head of water (see Chapter 4). In the total investment costs of a small hydropower plant, the turbine-generator installation represents only 25% - 30% of total costs. The costs for the engineering and construction of civil works reach 50% of total costs, while the remaining 20-25% of costs are assumed by electrical equipment and regulation control devices (Idae 1992: 64; Idae[1] 1999: 83). This division of costs suggests that, given a certain type of small hydropower technology, even considering the improvements in the technical and cost performances of the turbine and generator in the last two decades, the overall costs of electricity production per kWh most probably have not changed too substantially. The run-of-the river systems are generally more expensive than storage systems (see Chapter 4). Besides, costs can be higher when the site is located high in the mountains with difficult access or when special electrical devices and regulation-control installations are needed. But also, costs increase quite steep as the size of the plants decreases below 2 MW.

The 1983 and 1986 Renewable Energy Programs were offering investment subsidies for individual projects of 25%, while the 82/1980 Conservation Law could also give up to 30% subsidy for individual projects. The sources of subsidies could be combined. In the period 1991-1994 the average figure for the 1991 Plan for Energy Conservation and Saving financial support was 9,6% of total investment costs at industry level. Individual project subsidies based on 1991 Policy Plan could go up to 50% of eligible project costs. Besides, the EU Valoren Program subsidized 210 plants of the total 237 small hydropower projects developed between 1986 and 1991, with an amount representing 12% of total investment costs at industry level. At the level of individual projects, Valoren subsidies could vary between 20% - 50% of investment costs depending on plant regional location.

Comparing this financial support with the average production costs it appears that even when projects were exceptionally expensive there were sufficiently many and generous sources of financial support in the support systems so as to enable the majority of projects to have profits in the high/very high ranges. Having in view the conclusion reached in Section 6.3 that investments in small hydropower projects of all types - commercial, partly self-generation or R&D - were exposed to high economic risks, the 1980-1994 support system appears to be located in our terminology in the entrepreneurial investment context, as shown in Figure 6.10. For this type of investment context, we developed in Chapter 3 Hypothesis 2. In the first part of Chapter 9 we will test the theoretical expectations of Hypothesis 2 regarding market diffusion patterns and results for the case study of small hydropower in Spain in the period 1980-1994.

6.9.3.2 Profitability of small hydropower projects since 1995

Interviewed developers[70] assessed the levels of project profitability as ‘good’, ‘reasonable’ and ‘sufficient’ for the entire period after January 1995, when the 2366/1994 Decree came into force. These labels suggest a slight narrowing of the profitability range towards lower levels as compared to the previous period, when the same interviewees used a different language to describe profitability. The president of the Small Hydropower Section of the Association of Renewable Energy Producers actually mentioned that there was a trend in the decrease of the ranges of project profitability towards the end of the 1990s (Velez January 2002). Franco del Pozo (April, 2001) indicated that in Spain the average level of project profitability for small hydropower projects was around 8% - 10%, but sometimes levels of 15% were possible as well. In a qualitative assessment, we consider the range of project profitability associated with the second and third support systems for small hydropower plants, as mainly in the range of ‘high’ with an extension to the range of ‘very high’ for a smaller number of projects, as represented in Figure 6.10.

Looking from the perspective of production costs and financial support this assessment appears realistic. The average production costs in the second half of the 1990s were in the range of 5,4 - 6,6 €c/kWh (Gonzales Velez 2000 and 2002). The contribution of investment subsidies to the market diffusion of small hydropower systems decreased in this period. The investment subsidies based on the 82/1980 Energy Conservation Law disappeared. The EU Valoren Program subsidies were phased out in a short period of time. The average of national investment subsidy contribution from the 1991 Plan for Energy Conservation and Saving lowered to 6,42% of total investment costs (Idae 1998). Table 6.8 shows the decrease of national investment subsidies for individual projects. Project profitability has started to owe

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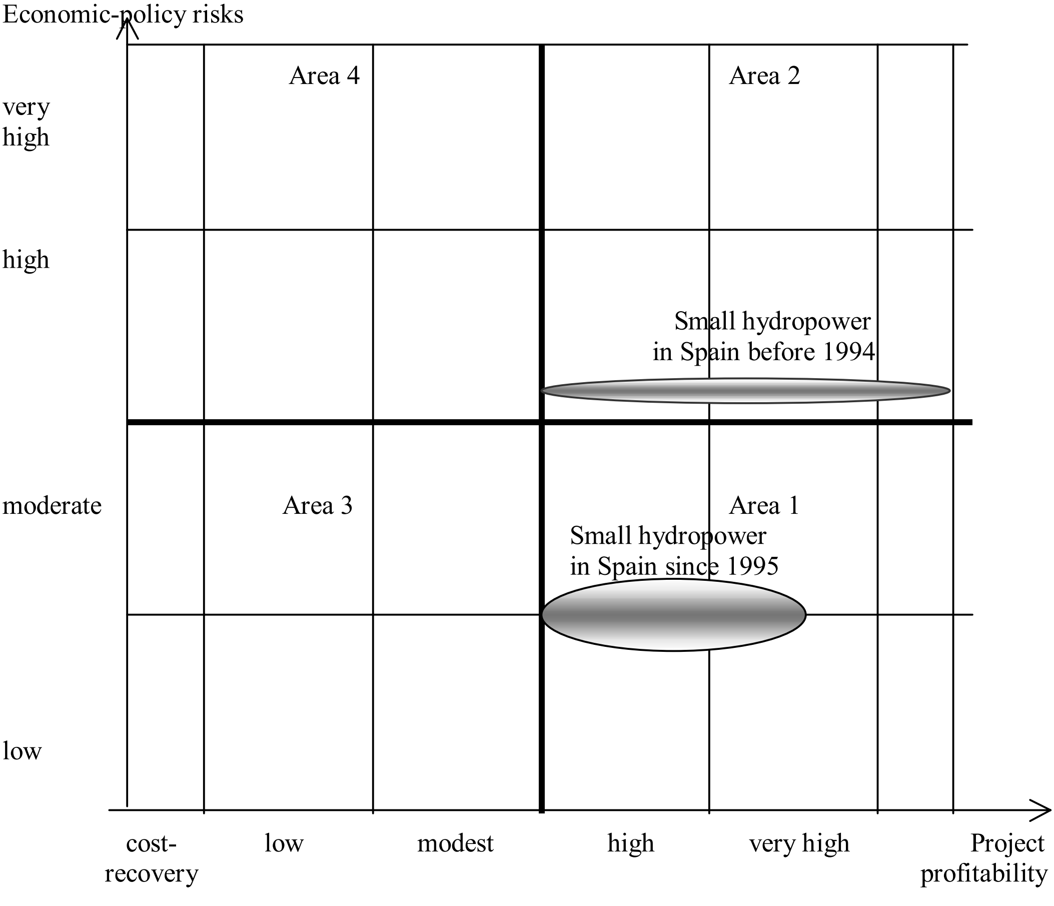
[70] Fernandez, Lopez, Castillo, Arrieta, Anegon (April 2001). Gonzalez Velez (January 2002).

more to the price support from the economic governance structures which first increased to 7 €c/kWh and later lowered to 5,8 €c/kWh.

On the basis of the interviewees assessment and these considerations on production costs and financial support, we assess the profitability of small hydropower projects after 1995 as mainly in the 'high' range with a decrease in the number of projects able to reach 'very high' profitability. Having in view that for both support systems since 1995 we assessed economic risks as in the range of low/modest, and that the two systems also had similar ranges of project profitability, we select Hypothesis 1 for the testing of theoretical expectations (see Figure 6.10). The next section makes a summary of the content of this chapter and its main empirical research findings and conclusions.

Figure 6.10 *The risk-profitability investment contexts for small hydro-power technology in Spain*



6.10 Summary and conclusions

This chapter opened the Part II of the book, where we are concerned with renewable electricity diffusion in Spain. We described and analysed the support systems put in place to enable the market introduction and diffusion of renewable resource technologies during the 1980s and the 1990s. The aim was to select the hypotheses to be tested for the diffusion of wind technology, biomass electricity technologies and small hydropower technology. In order to do so, it was necessary to specify the investment risks embedded in the support system, and the ranges of profitability that support systems enabled. We took the following steps in order to get there.

Firstly, we looked at the economic risks associated with the economic governance structures for renewable electricity. During the 1980s and the 1990s there were three legal frameworks containing provisions regarding the trade of electricity from renewable resources. All of them referred to the three renewable technologies we are interested in. The first economic governance structure was constituted by the 82/1980 Law on Energy Conservation. This changed in 1994 when the second economic governance structure was defined by the general provisions of the 40/1994 Electricity Law and the more specific provisions of the 2366/1994 Royal Decree. But the liberalisation of the electricity industry brought about a new electricity law. This needed an updated approach for renewables support. In addition, a cumulation of political concerns for security of supply and climate change, required a stronger support for renewable energy. A third economic governance structure emerged then through the 54/1997 Electricity Law and 2818/1998 Royal Decree.

We closely analysed the risks for the economic feasibility and profitability of investments in renewable power plants from a strict legal perspective, for each of these economic governance structures. In doing so, we looked at the target group for support in terms of eligible project developers, types of renewable technologies, and projects sizes. Then we analysed the demand risks, the risks related to contracts for renewable electricity sale to the local grid companies, and the risks associated to the design of prices. These are the three elements based on which we chose in Chapter 2 to describe and analyse economic governance structures. By aggregating the demand risks, contract risks and price risks, we made assessments with regard to the economic risks embedded in each of the three economic governance structures.

One general observation regarding economic risks is that for all three technologies they decreased in time, as the economic governance structures changed. Another general observation is that there were different levels of risks for different types of projects: commercial, self-generation and R&D projects. Besides, there were limits on project sizes that also changed from one economic governance structure to another.

1) For wind power projects, the economic risks changed as follows:
- for commercial projects: *very high* during 1980-1994, *high* during 1995-1998 and *low/modest* since 1999 - depending on developers choice for price design;
- for partly-self-generation and demonstration projects: *high* during 1980-1994 and *low/modest* since 1995 - depending on developers choice for price design;

2) For biomass power projects, the economic risks changed as follows:
- for commercial projects: *very high* during 1980-1994, and *high* since 1995;
- for partly-self-generation and demonstration projects: *high* during 1980-1994 and *low/modest* since 1995 - depending on developers choice for price design

3) For small hydropower projects of all types, the economic risks changed as follows:
- *high* during 1980-1994, and *low/modest* since 1995 - depending on developers choice for price design.

The first economic governance structures defined small hydropower as projects smaller than 5 MW. The second economic governance structure posed a limit of 10 MW for small hydropower and 25 MW for the other types of renewables. The third economic governance structures raised the limit for other renewable resources to 50 MW.

In the second step of support system risks analysis we described and analysed the policy risks emerging from the application of policy support mechanisms. In terms of the financial sources, three groups of policy support mechanisms were differentiated: investment subsides from the European Communities, mechanisms emerging from national energy policy plans programs, and support mechanisms developed and financed by the regional governments of the Autonomous Communities. The role of the first mentioned group was significant only for the diffusion of small hydropower. The regional financial support had a more noticeable impact on the first stages of wind technology diffusion and on biomass technologies.

Concentrating on policy risks associated with the national support mechanisms we observed that the most frequently used types of policy support mechanisms were investment subsidies and various schemes for the improvement of the financing conditions. Fiscal instruments played no role. Only two soft loan schemes that were used may be seen as associated with very low risks. Therefore, we concluded that the aggregated economic-policy risks of support systems - for all three periods distinguished and for all three technologies - may be defined only by the risks in the economic governance structures.

In the third step of support system risks analysis, we examined the opinion of interviewed market experts, project developers and representatives of governmental (renewable) energy authorities and agencies regarding the risks in the economic governance structures. The conclusion of this section was that the main deviations as compared to our theoretical assessments from legal perspective regard the eligibility of commercial developers as target group under first and second economic governance structures and the weak concern with contract risks, especially under the third economic governance structure. Then, it was decided to represent economic-policy risks for all three technologies with qualitative values as follows:

- lower part of ‘high’ risks range during the first support system, 1980-1994;
- lower part of ‘modest’ risks range during the second support system, 1995-1998; and
- ‘low/modest’ risks during the third support system active, since 1999.

With the analysis of support system risks, we arrived half way to the specification of hypothesis to be tested. Further, we had to look at the ranges of profitability for projects that the three support systems enabled. In Chapter 5 we mentioned three approaches for assessing profitability ranges: 1) direct profitability data from developers, market experts and available empirical material such as governmental documents, journal articles or conference papers; 2) qualitative assessments from developers, when data are treated as confidential; and/or 3) a rough comparison of production costs and extent of price/financial support, using also information from developers, market experts and empirical material. Due to the fact that not all interviewees agreed to mention numbers for the profitability of their projects, we used all three methods, depending on data from case to case. During the previous steps when risks were analysed, we also looked at the extent of financial support offered in the economic governance structures and by each policy support mechanism. This helped in order to use the third method of profitability assessment mentioned. We select to test the following hypotheses:

- Hypothesis 2 for the market introduction of wind technology during the first support system, 1980-1994
- Hypothesis 1 for the diffusion of wind technology during the second and third support systems, 1995-2000
- Hypothesis 2 for the market revival of small hydropower technology during the first support system, 1980-1994
- Hypothesis 1 for the diffusion of small hydropower technology during the second and third support systems, 1995-2000
- Hypothesis 4 for the market introduction of biomass electricity technologies during the first support system, 1980-1994

- Hypothesis specified for the case of a combination of optimal and political investment contexts (mixture of Hypothesis 1 and 3) for the diffusion of biomass electricity technologies during the second and third support systems, 1995-2000

The rest of Part II of the book is concerned with the testing of these six hypotheses. In Chapter 7 we focus on the wind technology, testing first Hypothesis 2 and then Hypothesis 1, according to the chronological order for the time they refer to. Chapter 8 is dedicated to biomass electricity technologies, and tests the Hypothesis 4 and then the hypothesis specified for the mixture of investment contexts. Further, Chapter 9 concentrates on testing Hypothesis 2 and 1 for the market revival and diffusion of small hydropower technology. Finally, in Chapter 10 we make some general considerations and draw the conclusion for the empirical research regarding the diffusion of renewable electricity technologies in Spain during the 1980s and the 1990s.

Appendix 6.1

The regional programs for the support of renewables.

Autonomous Communities had an early interest in renewables especially because they could stimulate industrial activities and bring economic and social benefits to the regions where projects were located. Regional and local governments with competences in the regions developments of RET projects took place first, supported them sometimes by means of investment subsidies. But more coordinated support programs were adopted only beginning with mid 1990s. Some of these programs were focused on subsidies, others on offering fiscal advantages and still others used mixtures of these instruments.

Of the twelve Autonomous Communities which already developed support programs by the end of 1999, ten of them were offering subsidies for wind systems and six of them were actually targeted at small wind installations. Five Communities were encouraging local developers to invest in mixed solar PV-wind systems. Biomass projects were supported at regional level only in six Communities and small hydropower only in three Communities. In terms of fiscal stimuli, in mid 2001 there was still no law on personal income tax at national level, able to stimulate individuals and private investors to commit their personal funds and savings for projects based on RET, as was the case in Germany and the Netherlands for example. At Community level there are only two cases of tax incentives for investments in renewables in Navarra.

Regional programs for wind, biomass and small hydropower [71]

Regional Program	Technologies & support forms	Beneficiaries
Prosol Program (Andalucia), 1996-1998 extended to 2002. Wind systems of 0,1-15 kW,	Wind energy: subsidies 8,93 Euro/W_p Facilitation of loans with subsidized interest rate; technology insurance.	Families, small private companies, local corporations and public companies
Catalonia (energy agency Icaen): Capital participation and investment promotion programs	Equity participation in wind systems with ‘project finance’. Facilitation soft-loans small wind systems	Families, small companies, associations
Decree 170/1994 by Aragon Government	Wind, biomass, small hydropower. Funding to be established each year.	Public and private companies, local corporations, non-profit institutions, individuals.
Resolution 31 Jan 1997 by Asturias Ministry of Economy	Wind and biomass (forest and agricultural wastes): 60 % subsidy but maxim 29762 Euro / project.	Local corporations, private companies, associations, NGO and individuals
Order 15 April 1997 by Env. Ministry of Balearic Islands	Biomass: 15 % of total budget Wind: max 1,79 Euro/W_p subsidy.	Any natural and legal persons
Order 31 January 1996 by Ministry of Industry & Trade, Castilla y Leon	Wind, small hydropower, biomass systems. Extent of support not mentioned.	Individuals, owners associations, NGOs, local corporations, institutions, administrative bodies.
Order 4 May 1998, Galicia	Stand alone systems: wind or mixed solar-wind; max. = 50 % subsidy	Investors in rural electrification systems
Order 31 May 1996, Ministry of Economy, La Rioja	Small hydropower, biomass and biogas: max. 15 % total costs	Owners of hydropower plants, any companies wishing to invest
Order 25 April 1997, Ministry of Industry, Murcia	Wind, biomass: % subsidy not specified but max. 50 %.	Local natural or legal persons
Order 3542/1998, Madrid	Very small wind <15 kW. Mixed systems of wind and solar energy.	individuals, resident associations NGOs
Order 194/1998 of Navarra	Very smal wind <15 kW = max. 20 % total costs as subsidty	-
Navarra: Foral Decree 669/1996	Biomass 25 %; Wind and small HP: 15 % corporate tax reduction	Investors in Navarra
Navarra: Foral Decree 222/1998	Hydropower with with max. 50 MW Wind: 15 % corporate tax reduction	Residents of Navarra

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[71] Information in this Table is based on 1) the Idae - Sodean "Report concerning subsidy measures in Spain", 29.01.1999 for the Ener-Iure Program of the EU - Analysis of the legislation regarding renewable energy sources in the EU Member States; 2) PROSOL Program, Sodean brochure, Sevilla; 3) "RES Legislation in Spain" Final Report to Ener-Iure EU Project, at www.agore.org.

7

Wind technology diffusion in Spain

7.1 Introduction

In Chapter 6 we analysed the economic governance structure and policy support mechanisms applicable to renewable electricity technologies in Spain. In its framework we also looked at the risk-profitability characteristics of the support system for wind-based power plants. We concluded that for the market introduction of wind technology a support system was put in place that was characterised by high economic-policy risks. But the support system enabled developers to build wind power plants with high to very high profitability. This first support system was kept in place from 1980 to 1994. In our analytical framework the risk-profitability context created was labelled *entrepreneurial investment context*, for which Hypothesis 2 was formulated in Chapter 3.

In 1994 a new economic governance structure, referring also to wind technology, was put in place by means of the 40/1994 Electricity Law and the 2366/1994 Royal Decree. These were replaced by a new economic governance structure defined by the 54/1997 Electricity Law and the 2818/1998 Royal Decree. Besides, new policy support mechanisms were introduced beginning with 1998. In Chapter 6 we discussed that the 1994 and the 1997/1998 support systems had quite similar risk-profitability characteristics that corresponded to the context labelled as *optimal investment contexts*. For this type of investment context Hypothesis 1 was formulated in Chapter 3.

This chapter analyses the diffusion of wind technology in Spain in order to test the two hypotheses. It starts with a short description, in Section 7.1.1, of the methodology of data collection. Section 7.2 is entirely dedicated to the testing of Hypothesis 2. The analysis takes into account the fact that wind technology was still in the stage of development and demonstration during most of this period. In principle the 15-year period, 1980-1994, can be divided into two parts: the decade of the 1980s, which can be described as the development and demonstration period, and the market introduction period 1991-1994. In this context, Section 7.2.1 investigates diffusion patterns of wind technology, with emphasis on the period of market introduction 1991-1994. Section 7.2.2 looks at the installed capacity increase and the features of the socio-economic-industrial context of diffusion by 1994. Section 7.2.3 draws the conclusion regarding the overall confirmation of Hypothesis 2. The largest part of this chapter is concentrated on Section 7.3. This tests Hypothesis 1 for wind technology market diffusion in Spain during the period of the second and the third economic-policy support systems, between 1995 and 2000. Section 7.3.1 investigates the forms taken by the five selected indicators for diffusion patterns in this period. Further, Section 7.3.2 tests the expectations on installed capacity increase and the socio-economic-industrial diffusion context by 2000. After that it looks at the obstacles facing diffusion continuation in 2000 and the extent to which the spin-offs of diffusion processes registered by that time helped reduce some of the obstacles facing the market introduction of this technology since the 1980s - early 1990s. Finally, Section 7.3.3 discusses the extent of confirmation of the theoretical expectations formulated in Hypothesis 1. But in the same time, it disentangles the influence of exogenous factors when deviations from analytical predictions are observed. Section 7.4 summarises the content of this chapter and main findings.

7.1.1 Methodology of data collection

Empirical information regarding diffusion patterns were collected as follows. Data regarding the names of wind projects, the companies developing and owning them, sizes of projects, and types of turbines used were taken from the publication "Renewable energy in Spain - Balance and Perspectives 2000. Edition 1998" of the governmental renewable energy agency for the period up to 1994 and from the special edition on wind energy of the Spanish journal *Energia,* published in 2000 in Madrid, for the period 1995-2000.

Data on types and particularities of financing schemes and in the drivers to invest relied to large extent on communication with developers themselves (face-to-face or phone interviews, or e-mail). But when direct contact with developers was not possible, the following sources were used: interviews with market experts, representatives of the association of renewable energy producers, and employees from the governmental renewable energy agency; papers presented at national (Spanish) conferences and industry workshops; as well as conference papers and discussions with Spanish participants in international conferences we attended.

Additional information regarding the five indicators for diffusion patterns (especially regarding the companies behind the developers of wind projects) and information regarding installed capacity increase, aspects of cost performances, resource potential, obstacles for diffusion continuation and the features of the socio-economic-industrial context of diffusion in 1994 and in 2000 were collected, in addition to the above mentioned resources, from: publications and information from the websites of the governmental renewable energy agency (Idae), the association of renewable energy producers (Appa), and the national center for energy research (Ciemat); as well as annual reports and website information from companies investing in wind projects. A precious source of empirical information of all types was the Spanish journal *Renewable Energy* (*Las Energias Renovables*).

The forms of diffusion patterns' indicators for the projects that entered into operation in the period 1980-1994 are listed in Appendices 7.1 and 7.2, while those for the projects built in the period 1995-2000 are listed in Appendix 7.3. The list of empirical resources is presented in the reference section of this chapter[1].

7.2 Testing Hypothesis 2 for wind technology diffusion in Spain, 1980-1994

This section tests the expectations of Hypothesis 2, for the case study of wind technology market introduction in Spain, where an entrepreneurial type of investment context was created in the period 1980-1994. Section 7.2.1 focuses on testing the expectations for the five indicators of diffusion patterns. Further, Section 7.2.2 looks at the effectiveness of the support system in terms of wind power capacity installed by 1994 and at the prospects for continuity of diffusion process under the entrepreneurial type of investment context. Section 7.2.3 summarises the main findings of this section and draws the conclusion regarding the confirmation of Hypothesis 2 for this case study.

7.2.1 Testing theoretical expectations on diffusion patterns for wind technology, 1980-1994

This sub-section analyses diffusion patterns for wind technology in Spain in the period 1980-1994. Section 7.2.1.1 briefly describes the forms of diffusion patterns for the few demonstration projects built during the 1980s. Further, Sections 7.2.1.2 to 7.2.1.6 analyse diffusion patterns for the period of market introduction 1991-1994. This is the period when investment multiplied and more detailed governmental statistics became available. In Section

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[1] Some data from these empirical sources had to be processed in order to obtain information relevant for the analysis of diffusion patterns and results. The methodologies of calculation for the processed data are presented at the appropriate spots in footnotes throughout this chapter.

7.2.1.7, we draw the conclusions regarding the predictability of expectations on diffusion patterns.

7.2.1.1 Diffusion patterns during the 1980s

Data regarding wind power systems built in the period 1980-1986 were not published by the government. Interviewed governmental agents and market experts explained that most projects were single turbines and small systems built for research and demonstration by the cooperative manufacturer Ecotecnia[2] and by the first wind turbine manufacturer (Gesa) of the largest energy utility Endesa.

Between 1987 and 1990 only eleven wind projects were put into operation. The owners were selling the electricity to the grid. But the main driver to invest was to demonstrate Spanish designs of wind technology. All these projects had very small sizes, that is below 1 MW, and they had a mixed ownership. The investors can be divided into four groups: manufacturers (Made[3] and Ecotecnia); energy utilities (Endesa and Union Fenosa); the Institute for Energy Diversification and Saving (Idae) and; regional and local authorities.

All wind projects used what we named in Chapter 4 as conventional technological designs that is having asynchronous generators, stall blade control and constant rotor speed. Differentiating in terms of installed capacity, eight turbines models were used in these eleven projects. They were conceived and manufactured in Spain, where small-size technology was given priority in research and demonstration, in contrast to the United Kingdom and the Netherlands as we shall see in following chapters.

All projects were financed based on internal financing schemes and benefited of substantial investment subsidies. Six projects were based on multi-contribution financing and all had equity investment from the governmental renewable agency. The agency pursued a policy to help all economic actors interested to invest in wind technology to overpass the financing barrier. There was also one project that used third-party finance, also from the governmental renewable agency. This was meant to test one turbine design of manufacturer Ecotecnia who had financing difficulties, being a small new cooperative. The other four projects for demonstration were financed from the internal financial resources of energy utilities, and they relied heavily on investment subsidies from different sources. Due to the very high technology-specific costs up to 1990 (see Chapter 2), the demonstration projects for wind technology were only able to recovery their investment costs in 12-28 years, even when the contribution of investment subsidies was substantial.

After this decade of development and demonstration, the period 1991-1994 can be characterised as the market introduction stage. Sections 7.2.1.2 to 7.2.1.6 describe the evolution of the five diffusion indicators in this period. The empirical findings are compared to theoretical expectations in Table 7.3 of Section 7.2.1.7 which draws the conclusion on the predictability of diffusion patterns under Hypothesis 2 for this case study.

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[2] The manufacturer Ecotecnia was established in the form of a cooperative in 1981 by eight engineers and it grew in time holding a 10% market share in 2000 in Spain. In late 1990s, it was taken over by a large industrial corporation, Montdragon, which solved its difficulties of financing research and development.

[3] Made was a public company and subsidiary of the largest energy utility Endesa. In 1989, research and development (R&D) work started in wind technology. The attractive part of the R&D program of Made was that all costs were passed over to consumers through the electricity tariffs as a 0,3% charge. In late 1990s Made split away from Endesa and was re-named Made Energias Renovables (Lara 2002). By 2000 Made developed many technological designs and held a 10,5% market share in Spain.

7.2.1.2 Types of project developers, 1991-1994

Hypothesis 2 predicted that under entrepreneurial investment contexts, large and financially strong developers would dominate the investors' picture. In practice, six types of project developers were differentiated in this period of market introduction:

- 'project vehicle companies', which commissioned only seven projects but accounted for the largest installed capacity: 53 MW of the total 70 MW. These are companies especially set-up for the construction and operation of a certain wind project. They were typical for this period in Spain and emerged in order to deal with the financing obstacle and the perceived technological risk. Energy utilities were part in all these seven project-vehicle companies. The other equity investors were regional governments, water utilities and wind turbine manufacturers.
- energy utilities, which commissioned four wind projects with a total of 6 MW (mainly Endesa and its subsidiary Unelco, and in two cases Union Fenosa);
- manufacturers of wind technology, which built eight small wind projects totalling 4,3 MW (Desa as subsidiary of the Spanish Abengoa Industrial Group, and Acsa as business partner of the large Danish turbine manufacturer Vestas);
- the first company specialised in renewable electricity plants Energia Hidraulica Navarra, which entered wind energy market in 1994 and developed one 3 MW project;
- public authorities, which developed seven very small size projects totalling 1,5 MW (the governmental renewable agency and local authorities agencies);
- research institutes, which constructed three wind systems that together had 1,5 MW (The Technological Institute for Renewable Energy of the Canary Islands - Iter - and the national energy research center Ciemat).

Consequently, the first four groups of project developers mentioned above, who can certainly be categorised as large and financially strong developers, were responsible for around 66 MW of the total 70 MW wind capacity built between 1991 and 1994. It can be stated therefore that the expectation regarding types of project developers was *confirmed* by practical developments for wind market introduction during this period in Spain.

7.2.1.3 Types of financing schemes, 1991-1994

Hypothesis 2 predicted that under entrepreneurial investment contexts, internal financing schemes would be predominantly used. The empirical data for this diffusion indicator are presented in the column four of the table in Appendix 7.1 of this Chapter. In the 1991-1994 period, twenty projects out of the total thirty-four projects were based on internal financing schemes, when initially developed. The schemes used were multi-contribution finance, in-house corporate finance, debt-corporate finance and one third-party finance scheme. Beside them, seven very small size projects were based on project finance from foreign financing agents. For seven very small wind projects data were not available. These practical developments can be considered to *confirm* the theoretical expectations of Hypothesis 2 regarding types of financing schemes.

Before discussing the types and particularities of these financing schemes we underline in the next paragraph the main early policy lines of the governmental renewable energy agency for the overcoming of the financing obstacle for wind technology.

The governmental policy for supporting the financing of renewable-based projects

The governmental renewable energy agency was established in 1984. Aiming at a fast and substantial market introduction of renewables in the Spanish energy system, it soon became aware of importance of financing obstacles. As one of its former general managers explained

Concha (1996), in the context of low energy prices and low concerns of industrialists for security of supply in mid 1980s, if the government wanted to have an impact with its promotion activities, it had to "fill this lack on energy priorities (by industrial and energy companies) with alternative instruments that would not represent an added problem to the energy decision-maker". The ideal instruments should have offered both technical and financial support, as well as releasing the developer of investment risks.

Consequently, two policy instruments emerged as most appropriate in the agency's view: the use of third-party financing for developers with no financial resources and no access to bank loans, and the contribution with equity in the capital structure of projects when investment costs were too high for the interested developers. These instruments were often additional to investment subsidies. These forms of direct intervention to address the financing obstacles were meant to induce "a replicability effect to speed up private investments to obtain an economically sustainable renewable energy market" (Concha et al. 1996). For wind energy projects, in the period 1991-1994 the governmental renewable agency contributed with equity investments in three project-vehicle companies that used the multi-contribution financing scheme, while only one project was based on third party financing. In the period 1995-2000, there were two projects for which third party financing was given, while twenty projects using project finance had equity participation[4] from the governmental renewable agency. This type of support for wind projects aimed at "mobilising as many (financial) resources as possible, and facilitating the entry of new agents in the sector, such as private companies, financing institutions" (Ayuste et al. 1996).

Types and particularities of financing approaches used in practice, 1991-1994

Twenty of the total thirty-four projects developed during 1991-1994 used internal financing schemes, of which only four projects benefited of direct financing from the governmental agency for renewables. The main reason is that in these years the main priority of the agency was the market revival of small hydropower plants. The budgets envisaged in the national energy policy plans for this technology were larger than for wind technology.

In addition, the Acsa manufacturer stated that all its seven wind installations built in 1991 and 1992 were based on project finance. A possible explanation for this could be that the turbines used were Danish Vestas turbines, for which the project finance loan was secured abroad by the joint venture partner Vestas. An attempt for a direct explanation by Acsa was not successful. For seven projects, of which five were developed by local authorities, information was not available. But several interviewees argued that, due to their very small sizes and the time when they were built, project finance does not seem likely.

As regards the difficulty to obtain project finance from Spanish banks in this period, many interviewees[5] argued that this was due to three reasons:

- the absence of legally guaranteed minimum contract lengths;
- the absence of a minimum legally guaranteed price;
- the idea that a more substantial track record in Spanish setting was needed to give convincing evidence that wind technology was financially viable.

Some empirical market studies point to the same reasons. For example, a British market study pointed out "lenders mentioned in interviews that they require a formal power purchase

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[4] When financing support took this form, the policy of the governmental renewable agency was to limit its contribution to maximum 49% of the total equity needs of projects. In practice this was however much smaller up to 1994 and increased to 49% only after 1998.

[5] Interviews in April 2001 with Joachim Castillo (Union Fenosa), Cristobal Lopez (Iberdrola Ingenieria y Consultoria), Josep Prats (Ecotecnia), Manuel Bustos (APPA).

agreement to finance a project, despite the fact that, even without a formal contract, the regulations governing these arrangements are covered by law" (Etsu 1996: 112). The legal guarantee on five years contracts came in force only in December 1994 when the new regulations entered into force.

It was hence during the period of the second support system when Spanish banks started to approve project finance. Some interviewees pointed out that project finance became the dominant financing scheme only in 1995/6[6]. For example a market expert explained that "In 1995 the first wind parks were given project finance. But some banks agreed to approve project finance only when large industrial corporations, energy utilities, the governmental renewable energy agency or regional authorities were involved with equity contribution, when the turbine models were already tested, and when the sites had high quality and availability wind regimes. After 1996 this type of financing scheme has become the most used financing approach" (Cruz 2001).

In conclusion, the expectation to see internal financing scheme as the dominant financing tool in an entrepreneurial investment context was confirmed. The risk associated with the support system played an important role in the refusal of Spanish Banks to approve project finance. But, in addition, the need for more substantial track record on the economic feasibility of wind projects was also required by banks.

7.2.1.4 Drivers to invest, 1991-1994

Hypothesis 2 predicted that in an entrepreneurial investment context a balanced presence of (partly-)self-generation, strategic and commercial projects is likely to be observed. In practice the distinction among the three groups is not so clear-cut, and a closer look at the context in which projects were developed was necessary. This means that an 'empirical definition' was needed in order to clarify which projects can by classified in each group.

The third column of the table in Appendix 7.1 mentions the drivers to invest that we derived for the wind projects commissioned in 1991-1994. The reasons to invest were stated by the interviewed developers and market experts. We differentiated among:

- *commercial* projects, when the only benefit expected was profit-making; five projects were classified in this category;
- *strategic: demonstration*, when the main aim was to test new turbine models; seven projects were classified in this category;
- *commercial and strategic*, when the wind plant contained both commercial turbines and new model turbines, or when a commercial project had also another type of strategic component; twenty projects were classified in this category;
- *commercial and self-generation*: there were two projects that had as main purpose the desalinisation of water; when plants were not temporarily used for this purposed, the owners were selling wind electricity to the local energy utility.

As regards strategic drivers to invest, of the wide range of reasons differentiated in the theoretical part of this project, it seems that there were only few dominating investments in Spain. The most frequent was that of demonstration of new turbine models, that mostly consisted of upgrading of installed capacity per turbine. As it can be observed in Table 7.1, the turbine development process was continuous and intensive in Spain and demonstration projects were often needed to prove to potential developers and financing agents that the new models are functioning. In this period, the demonstration of new models was needed both when new designs were produced by Spanish manufacturers and when turbine models were already

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[6] Interviews in August 2001with Carlos Nunies (Financing Director Made) and Ignacio Cruz (CIEMAT).

commercial abroad, but used for the first time in Spain[7]. In addition to demonstration needs, three other strategic reasons to invest were identified in Spain, based on interviews with developers and energy experts: technology learning; removal of technology risk perceptions; and local business opportunity. The first two were present however mainly up to 1994. But local business opportunity remained a reason to join the market of renewables producers after this year too, both for local/regional public agencies and for private companies[8].

The category of commercial and strategic projects in the above empirical classification is more complex than the other ones. For example the turbines installed by the research institute for renewable energy in the Canary Islands were all selling the entire electricity produced to the grid but they were also meant as study instruments (Galvan 2001). The wind systems and individual turbines installed by the manufacturer Acsa were also commercial projects (Marrero 2001). But in its position as a company with the ambition to fill the Spanish market with Danish Vestas turbines, Acsa was also interested to prove the technical and financial viability of this technology and create a future turbine market for itself. Further, the projects commissioned with the financial involvement of governmental renewable agency were also considered to have a strategic component, as the objective behind this type of policy support was to enable potential developers and financial actors to get trust in the technology and spur away risk perceptions. Besides, there were five wind installations commissioned by local and regional public authorities for which information was not directly available. We considered these projects fall in the last category of commercial and strategic projects, since self-generation was excluded in opinion-inquiry with different energy experts and it can be assumed that public authorities were interested both in making use of some good local business opportunities themselves, as they were interested to serve as an example to other potential developers - who could bring regional economic development by investing more in wind projects.

In conclusion, the market introduction of wind technology in Spain took place mainly through commercial and strategic drivers to invest. Almost all projects had a commercial component, either as the main or as the second driver to invest. Among the strategic reasons, the most prominent was the need to demonstrate new turbine designs, followed by interest in technology learning, removal of technology risk perceptions, and local business opportunity. But (partly-) self-generation projects had a very poor presence in the picture of expected drivers to invest, with only two such plants. The main explanation has a cultural nature and relates to the low level of environmental sensitiveness and green image concerns of industrial production companies and commercial consumers who were also expected to invest to some extent. But beside this, interviewed market experts explained that as long as the financial support enables high profitability of projects, industrial production companies and commercial consumers in Spain are not likely to invest in self-generation plants. As long as it is possible to consume electricity provided by energy utilities from the grid and to sell the wind electricity they generate to the energy utilities for a good profitability, Spanish production and

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[7] As an interviewee explains, the argument was that Spain is a mountainous country with quite complicated wind regimes, which has consequences for the most suitable characteristics of wind turbines. As the technical and economic aspects of wind turbines functioning are strongly related to the topographic and wind-regime characteristics of the sites where they are located, the foreign turbines needed to be first proven on Spanish land.

[8] The distinction between profit-making interest and local business opportunity is often not very clear in practice, since the second assumes the first. However, one could observe if a developer invested only because of local business opportunity reasons when, after some time of market presence, he does not extend its business activities beyond the region where he started to invest, or where he is located. For example, in Spain, investments by local or regional public authorities, energy agencies, and local municipalities can be considered as commercial-strategic projects driven by local business opportunity.

commercial companies would surely do so[9]. The theoretical expectations regarding drivers to invest in entrepreneurial investment contexts can be assessed therefore as *partly confirmed* in this case study.

7.2.1.5 Project sizes, 1991-1994

Hypothesis 2 predicted that in an entrepreneurial investment context developers would be most likely to invest in very small, small or medium-size projects, with the overall numerical dominance of small and medium size plants. Empirical data mentioned in the column seven of the table in Appendix 7.1 show that, numerically, very-small size projects dominated in this period. These data are summarises in Table 7.3 comparing theoretical expectations with empirical findings for all five diffusion indicators. From the total thirty-four projects commissioned, twenty-one had very small sizes, with below 1 MW. Further there were eight small size projects with between 1-5 MW capacity, four moderate size projects with between 5-15 MW and one large-size project of 20 MW. These practical developments confirm the generally expected range of sizes, but are in contrast with the theoretical expectations as regards the numerical dominance. More than half of the projects developed were very small wind installations, while we expected that small and medium size plants are likely to dominate numerically.

Two factors could explain the contrast between theoretical expectations and practical developments. Both are rooted in the fact that in Spain the economic-policy support system for market introduction and diffusion was put in place at an early stage, when wind technology was still developing. Firstly, as summarised in Table 7.1, the sizes of national turbines were still quite small. Even when turbines were imported, their sizes were generally below those of the latest models developed by Danish, German and American manufacturers and installed abroad. Secondly, seventeen wind projects were actually constituted by one turbine only. Seven of these installations were demonstration turbines for the testing of new models, but the rest were mainly commercial projects. Given the fact that this period was one of market introduction, it is likely that project developers chose to experiment more with some small-scale wind installations, having in view that they were taking all risks - both technological risks as well as the economic-policy risks - by investing based on internal financing schemes.

Consequently, up to 1994 the dominance of very-small wind projects - 62% - could be explained by the fact that this period of market introduction was following fast, and actually overlapping that of technological development. As manufacturers were producing new turbine models, the market was immediately absorbing them. Because they had to simultaneously face technological risks and high economic-policy risks, projects were often very small in order learn more about the new design first. Therefore, overall this part of Hypothesis 2 can be considered as *partly confirmed*.

7.2.1.6 Technological designs, 1991-1994

Hypothesis 2 predicted that in an entrepreneurial investment context adoption of new and/or existing technological designs with substantial contribution potential to diffusion expansion (diffusion-optimal) is likely to a small extent. Practical developments have *not confirmed* this expectation. Empirical data in Table 7.1 show that in the period 1991-1994, thirteen new wind

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[9] Self-generation projects using wind energy were built only in the form of stand-alone applications based on micro-wind turbines, used either alone or in combination with solar photovoltaic systems. In Spain self-generation is only resorted to when energy is needed at locations remote from grid access (Cruz 2001). Olmos-Garcia (Energia 2000: 47) estimates that less than 1% of the total wind installed capacity in Spain is formed by stand-alone wind systems. Besides, these are based on mini-turbines, which form a different technology industrial and market segment.

technology designs were introduced in the Spanish market, with slowly increasing installed capacity. Table 7.2 mentions the technical characteristics for these technological designs selected in Chapter 4 in order to assess the technical performances in terms of grid friendliness and efficiency of energy harnessing.

Table 7.1 *New wind turbine models introduced in Spain up to 1994*

Manufacturer	1983	1986	1989	1991	1992	1993	1994
national average	30 kW	30 kW	not clear	not clear	125 kW	200 kW	320 kW
Ecotecnia	30 kW	-	150 kW	-	200 kW	-	-
Made	no activities in the wind energy field yet		75, 110, 150 kW	-	180 kW	260 kW	300 kW 330 kW
AWP	not set up yet		-	-	100 kW	disappeared	
Desa	not set up yet						300 kW
Acsa	not set up yet	-	-	55 kW, 225 kW	100 kW	-	-
Gamesa	no activities in the wind-energy field yet						500 kW
Enercon	-	-	-	330 kW	-	-	500 kW

Table 7.2 *Main technical characteristics of wind technology designs adopted in Spain up to 1994, relevant from the perspectives of grid-friendliness and efficiency performances*

Manufacturers in 1994	technical characteristics - grid friendliness perspective and efficiency			
	Blade control	Rotor speed	Generator type	technological design / market share
Ecotecnia	Stall control	Constant	Asynchronous	conventional design (70 %)
Made				
Desa	Pitch control	Constant		modest improvements grid friendliness and efficiency (28,5 %)
Gamesa		Variable (small range)		
Acsa				
AWP/ Kenneth		Variable		
Enercon			Synchronous	substantial improvements grid friendliness (1,5 %)

Empirical data presented in Table 7.2 show that for 28,5% of the capacity installed by 1994 developers used technology designs bringing modest improvements in performance from the perspectives of grid friendliness and efficiency. These technologies were either imported or produced in Spain under technology transfer agreements with foreign manufacturers. However, only 1,5% of installed capacity was based on technological designs able to bring substantial improvements in performance from grid friendliness perspective. This was represented by only two turbines imported from the German manufacturer Enercon[10]. The rest of 70% capacity used the conventional wind technology design. All conventional technologies were produced by the Spanish manufacturers Made and Ecotecnia.

Interviewed experts[11] from these two companies explained that the conventional design of wind technology could be manufactured at lower production costs and had a higher technical simplicity than the other existing designs. Project developers generally preferred simple technical designs. Besides, in those years, developers also preferred technologies that required lower investment costs per kilowatt, even if the more expensive technology designs could

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[10] This was financed by the renewables' research institute of the Canary Islands, with the main purpose of studying its suitability for stand-alone application, for use in an island electricity system.

[11] Interview Spanish manufacturers Prats [Ecotecnia] and Lara [Made] April 2002.

generate more electricity and therefore be more efficient for investors on project economic-life basis. The market adoption of Made and Ecotecnia turbines was influenced by the fact that the government stimulated national technology by means of substantial investment subsidies, third party financing and direct equity investment support from the renewable energy agency. Besides, the two manufacturers were equity investors in some projects to reduce technology risk perceptions of developers.

As regards the third performance perspective for which we operationalised the indicator of technological choice, no improvement was signalled in this period on the Spanish market. No wind technology designs were developed in Spain or imported, having the ability to function in low or moderate wind speeds.

Consequently, having in view the definitions of qualitative labels regarding the degree of hypotheses confirmation formulated in Chapter 5, the expectations on the indicator of technological choice can be considered as *not confirmed*. This is because some predicted forms are missing. We predicted the possible adoption, to a small extent, of technological designs with substantially improved potential for long-term diffusion expansion. In practice we observed only conventional technologies, and designs with modest performance improvements from grid-friendliness and efficiency perspectives only.

7.2.1.7 Conclusion regarding the extent of confirmation of theoretical expectations for diffusion patterns under Hypothesis 2

Section 7.2.1 looked at the diffusion patterns of wind technology in Spain in the period 1980-1994. The five indicators for diffusion patterns took in practice some forms that give a *partly satisfactory* confirmation of the forms predicted to be observed under entrepreneurial investment contexts. They are summarised in Table 7.3.

The expectations regarding types of project developers and types of financing schemes were ‘confirmed’. Large developers and companies with good access to financial resources were the main types of project developers in this period and they used predominantly internal financing schemes. The observed diffusion patterns do not match fully those theoretically expected in the case of drivers to invest and project sizes. For these two indicators, expectations were only ‘partly confirmed’. The expectation with regard to technological design choice was ‘not confirmed’.

As regards drivers to invest, self-generation projects were poorly represented by only two plants. Further, only one project adopted diffusion-optimal designs of wind technology, while adoption was seen likely to at least small extent. Finally project sizes were, as predicted, in the range of very small and modest size. However, very small size systems were dominant - 62 % of the total number developed. A factor strongly influencing the deviation from the theoretically expected forms for these three indicators is the relatively early stage of technology development, when new designs were still being demonstrated.

Nevertheless, we consider that the overall overlap between theoretically expected and empirically observed forms of diffusion patterns offers sufficient for the continuation of empirical research regarding the two dependent variables of the research model. Section 7.2.2 looks at the effectiveness of the support systems, in terms of installed capacity increase by 1994 and the prospects created for sustainable market diffusion processes.

Table 7.3 *The theoretically expected and the empirically registered diffusion patterns for wind technology in Spain, 1980-1994*

Practical developments	Theoretical expectations
Types of project developers	
project-vehicle-companies (formed by governmental renewable agency, energy utilities, regional and local authorities; manufacturers); energy utilities; manufacturers and one renewables specialised company.	large developers predominate (confirmed)
Type of financing schemes	
- 20 out of the 34 projects were based on internal financing schemes (multi-contribution finance; in-house corporate finance; debt-corporate finance, and third-party finance); - 7 very small projects based on project finance; - for 7 very small projects no data available	internal financing schemes predominate (confirmed)
Drivers to invest in wind projects	
commercial-strategic = 20 projects commercial = 5 projects demonstration = 7 projects partly-self-generation = 2 projects	balanced presence of self-generation projects, strategic projects, and commercial projects (partly confirmed)
Project sizes	
- very small (<1MW) = 21 projects - small (1-5 MW) = 8 projects - moderate (5-15 MW) = 4 projects - large (15-25 MW) = 1 project	small/medium size projects predominate (partly confirmed)
Technological designs	
- 70% conventional wind technology designs - 28,5% existent modest efficiency improved designs - 1,5% existent diffusion optimal designs	adoption of new and/or existing ‘diffusion-optimal’ technologies likely to a small extent (not confirmed)

7.2.2 Installed capacity increase and prospects for sustainable diffusion processes in 1994

In Chapter 3 we hypothesised that an entrepreneurial investment context would be able to induce a *modest increase in installed capacity,* operationalised as in the range of 500 MW - 1000 MW, if the support system retains its characteristics for at least a short-medium term period, operationalised as five to ten years. We argued that *market diffusion processes could be sustainable if* the business culture of financing agents is characterised by flexibility in terms of willingness to accept risk. In this case, a sustainable diffusion process could be then seen in long-term, through a gradual change in diffusion patterns.

7.2.2.1 Increase in the installed capacity, 1991-1994

This case study covered a period of fifteen years, 1980-1994. The decade of the 1980s was dominated by technology development and demonstration, resulting in 7 MW of wind power. In the period 1991-1994 could be characterised as the market introduction stage when a 70 MW capacity increase was realised. Therefore over the entire period only a *small capacity* of wind power was installed totalling 77 MW. Table 7.4 shows the evolution of installed capacity annually and the number of projects developed up to 1994. This outcome does *not confirm* our theoretical expectation. Even if at the end of 1994 there were projects under construction or approval - reflecting decisions to invest made under this first economic-policy support system -

and which appeared as commissioned after 1995, this does not change the outcome too much[12]. As regards the projects proposed but which could not be eventually built, the main obstacle signalled by interviewees in this period was that of grid connection. Although this was guaranteed in the 81/1980 Electricity Law, energy utilities often claimed that grid connection would pose difficulties for the technical management of the network whenever they were not co-owners of proposed projects. But statistics were not kept on the number and sizes of projects refused approval in this period.

Table 7.4 *Increase in installed capacity and number of projects up to 1994*

Capacity / Year	up to 1990	1991	1992	1993	1994	Total 1980-1994
Annual MW	7 MW	1 MW	39 MW	6 MW	24 MW	77 MW
Number of projects	11	5	12	5	12	45 projects

Two main explanations could be given for the non-confirmations of the expectation on installed capacity increase. Firstly, the sizes of projects were expected to be predominately small and medium. However, due to the fact that turbines sizes use in that period in Spain were quite small, more than half of the projects were also very small, that is below 1 MW.

Secondly, the number of projects was also very low. Interviewed market experts explained that in this period many potential developers considered the technology did not have sufficient track record in Spain to prove its economic attractiveness. In the context where project finance was not available and internal financing resources had to be used, developers were very cautious whether to enter the market and the size of projects they were willing to experiment with. But beside the track record many developers, including the three largest energy utilities after Endesa, considered the support system not sufficiently protective in terms of economic risks on projects' profitability. Only with the news that the legal guarantees would change in 1994, have more companies started to prepare their entry in the wind energy business. The next subsection looks at the prospects for continuation of diffusion processes under the diffusion context created by 1994.

7.2.2.2 The prospects for sustainable diffusion processes

Hypothesis 2 expected that market diffusion processes could be sustainable if the business culture of the traditional financing community is characterised by flexibility in terms of willingness to accept risk. A sustainable diffusion process could be then seen on a long-term, through a gradual change in diffusion patterns towards those expected under optimal investment contexts. But diffusion was considered as sustainable also in the absence of external financing schemes if the investment interest of large developers is substantial, and especially when the available resource potential could be exploited based on internal financing scheme by the economic actors interested to invest. In Chapter 2, we argued that the prospects for sustainable diffusion processes need to be analysed from three angles: cost performances in relation to the resource potential, technical performances and the features of the socio-economic context to invest.

In this section, we look first at the extent to which the precondition on the business culture of the traditional financing community was met in Spain. After that, we discuss the issue of cost performances, technical performances and remaining resource potential available. In Chapter 2, we mentioned that no theoretical expectations will be formulated regarding the

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[12] In practice it proved very difficult to trace how many projects were in this situation, and since the qualification as a *modest* capacity increase would have meant a total power of somewhere between 500 MW and 1000 MW - too distant from the registered 77 MW, the attempt was not pursued.

possible situation for these aspects of diffusion results because of their national-resource- and technology-specificity, and that they will be analysed empirically.

Availability of financial resources for diffusion continuation

For entrepreneurial investment contexts we considered that if (in the country of analysis) the precondition of flexibility in willingness of financing agents to accept risks is met, then it is more likely to observe in long term a large availability of external financing schemes, attracting also large diversity in types of project developers. These would change diffusion patterns from those hypothesised under entrepreneurial investment contexts towards those expected under optimal investment contexts. The latter were considered to conduce towards a socio-economic-industrial context whose features are favourable for diffusion continuity. However, we assumed that if external financing schemes do not become available, diffusion might also continue but only as long as the involved types of developers could internally finance capacity expansion.

In the period up to 1994, Spanish banks did not approve project finance for new wind energy projects[13]. Financing agents in Spain are not flexible in the extent to which they accept risks on project cash flows. As mentioned earlier there were three reasons why banks did not agree to give project finance up to 1994. Two of them regarded the risks in the economic governance: the absence of a legal guarantee on minimum contract lengths and price. Even if the third reason invoked for refusing project finance would have dimmed - the idea that a more substantial track record was needed for wind technology in Spanish setting - it is highly likely that the first two mentioned reasons would have continued to keep the gate towards project finance. Perhaps some large developers or companies with the involvement of public authorities and energy utilities would have received in some occasions project finance. Banks in Spain have a strong preference to require the presence of such actors in the projects they agree to finance. However a wide availability of project finance for a large diversity of developers would not have been likely without a change in the economic risks embedded in the support system.

Diffusion would have surely continued if no change in the economic governance structure had been operated in 1994. Having in view that the developers involved had good access to financial resources, based on internal financing schemes, the installed capacity would have continued to grow. However, taking into account the limited number of economic actors interested in the industry, the rhythm of market growth would have been rather incremental. Looking at the very large potential for installed capacity in Spain, long-term diffusion continuity was not likely to be possible without the availability of external financial resources. We conclude that from the perspective of availability of financial resources, the prospects for long-term diffusion continuation were feeble unless a change in the risk characteristic of the support system took place[14].

Cost performances, resource potential and technical performances

Firstly, diffusion continuity depends on the extent that the available price support enables the economically feasible exploitation of available resource potential. Therefore, one needs to look at the relationship between *cost performances*, price support, and resource potential. As regards cost performances, the wind technology designs used on the Spanish market achieved substantial reduction in the category of technology-specific costs. The 1998 governmental policy plan for renewables mentions the evolution of overall investment costs per kW since

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[13] There was only one company (Seasa) which in 1993 appeared from the merger of two existing wind projects. When it re-arranged financing, it was the first to obtain a project finance loan (see Appendix 7.2).

[14] We refer to risks because the support system was already offering high levels of projects' profitability.

1986. Taking into account that the share of technology-specific costs in investment costs remained approximately the same during all these years, that is 75%, we calculated the evolution of average technology-specific costs, as shown in Table 7.5. These represent a reduction with 37%.

Key factors in the achievement of these substantial technology cost reductions were the sustained effort of Spanish manufacturers for research and development, and of the Spanish government who invested substantial financial resources to help national technology to emerge and consolidate. The company Made of energy utility Endesa benefited of larger research subsidies, while the demonstration and market introduction of both Made and Ecotecnia technologies was supported by means of investment subsidies. The governmental renewable agency also had direct financial investment for the market introduction of these technologies - equity contribution and third party financing. Therefore, in this case study the observed reductions in technology specific costs are related not to the size of the market, since the installed capacity was small, but to the effort of domestic manufacturers and the governments. This was fuelled by the expectation that wind energy would play an important role in the future of the Spanish electricity system.

Table 7.5 *The evolution of average wind technology-specific costs in Spain up to 1994*

Year	1986	1988	1990	1992	1994
€/kW (specific)	1240	1068	960	856	780

(Based on Idae 1998)

Data on production costs per kWh in 1994 were not available but interviewed market experts made qualitative assessments regarding the role of the other three categories of factors influencing production costs up to mid 1990s[15]. For many wind projects, developers used sites with very high wind speeds, often 9-10 m/s and large annual availability - often more than 3000 hours/year. Technology complementary costs were assessed as often higher than those incurred by developers in other countries. The main reasons were that:

- the terrain around the windy sites is hilly and difficult to access, which increases civil works costs;
- the location of most windy sites was not always close to the grid, which increases infrastructure and civil works costs[16];
- projects sizes were mostly very small or small, which increases the weight of this cost category in production costs.

In other European countries such as the Netherlands, Denmark and Germany the terrain where wind turbines are located is often flat. This enables lower technology complementary costs per kilowatt capacity installed. Finally, as regards context-induced factors, the requirement to shorten the period of investment cost recovery, emerging in early 1990s, put upwards pressure on the extent of financial support that developers had to receive. During the 1980s the main reason to invest was to demonstrate new turbine designs. The owners were usually recovering investment costs in 12-28 years, even when the contribution of investment subsidies was substantial (see Appendix 7.2). Since 1990/1991 when the types of developers diversified slightly, the expectation on investment recovery period changed towards less than ten, even seven years. Therefore, (from the government's point of view) the reduction in technology specific costs could not be accompanied by similarly substantial reductions in financial support

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[15] Interviews Lopez [Iberdrola IyC], Prats [Ecotecnia], Lara [Made], Cruz [Ciemat], April 2001.

[16] In Spain good resources are often located in sparsely populated areas where there is no electrical grid or lines have a very small capacity for electricity transport.

(which came mainly in the form of investment subsidies). Price support had to be maintained high because developers wanted to recover their investment costs faster. But in the period up to 1994, developers could build plants with high profitability, up to 20% (see Chapter 6).

As regards the resource potential, the 1998 National Policy Plan for the Stimulation of Renewable Energy stated that the net technical potential of wind energy in Spain, based on 1998 technology performances was 15.100 MW. The government estimated that by 2010, around 13.000 MW of wind power plants could be installed. But some market experts argue that the governmental potential studies are not updated and do not offer a good basis for investment strategies (e.g. Krohn 1998). In 2002 the regional governments had investment plans reaching 32.000 MW (Bustos 2002). The limit on grid integration of wind capacity as percentage of total electricity consumption is a very heatedly debated topic. But some experts argue that a 30% integration would be possible (Menendez 1997: 97). This could be roughly the equivalent of the 32.000 MW planned by the regional governments.

From the perspective of technical performances, the situation regarding the relationship between resource potential, grid integration ceiling and type of technological design needed with priority in Spain was as follows. The technically feasible ceiling for grid-integration was higher than the net technically exploitable wind energy potential (the same situation as in the end of 2000; see Figure 7.2 towards the end of the chapter). In this context, the technological designs needed with priority to enable the diffusion expansion potential in the long term from technical standpoint were those with substantially higher efficiency and designs able to function in low/moderate wind speeds (see Section 4.2.3). As mentioned in Section 7.2.1.6, in Spain up to mid 1990s, no such designs were developed in Spain or imported. Nevertheless, in mid 1990s the installed capacity was too small to put such technical concerns on the agenda. The short-term priority was to improve technical performances such as reliability, availability, efficiency, and reduce technology-specific costs (see Section 4.2.2)

The features of the socio-economic-industrial context

The features of the socio-economic-industrial context of diffusion form the third angle of analysis of diffusion continuity prospects. In the absence of external financing schemes, the socio-economic-industrial context of diffusion could eventually become sufficiently politically influential if many large financially strong developers contribute to large-scale investments. In this case diffusion would also have good prospects of continuity when (in the absence of political initiative) political pressure builds up to ensure the maintenance or increase of financial support for a larger scale exploitation of available renewable potential. Table 7.6 compares the theoretically expected with the empirically observed features of the socio-economic-industrial context emerging from the small wind power capacity increase in Spain in 1994. A modest size and dynamics of the industrial basis serving developers of wind projects was observed, which *confirms* the theoretical expectations. The expectation that the support system would induce modest socio-economic benefits as a result of diffusion patterns was *not confirmed*.

Socio-economic benefits

The socio-economic benefits from the small-scale market introduction by 1994 were assessed as small. Ownership by local small developers was restricted to few turbines. But in some cases various types of local/regional authorities and public companies had ownership shares in the plants built in their region. There were no or very little extra indirect benefits from the projects of large developers, since both project sizes and the rate of market growth were still very small. The administrative approval of wind projects by the Autonomous Communities was still based on the old methodology common for all energy plants. Regional authorities adopted the regional wind development plans only after the entry into application of the new economic governance structure for renewables in 1994.

Table 7.6 *The features of the socio-economic-industrial diffusion context for wind technology in 1994 - theoretical expectations and empirical findings*

Diffusion context likely to emerge		Area 2- theoretically expected	wind in Spain
Socio-economic benefits		modest	small
Local	Direct: ownership	likely small	partly confirmed
	Indirect: more attractive (than usual) benefits from ~ land rents; ~ local taxes; ~ local economic or social welfare investments	likely modest	not confirmed
	Indirect ~ local employment	technology specific	not significant
National	Ownership individuals (shares)	not likely	confirmed
	Employment in industry	likely modest	confirmed
Industrial basis and dynamics		modest	modest
Number companies offering products / services for wind electricity plants		modest	confirmed
Types of companies involved in industry		large presence of corporations from a diversity of industrial sectors	confirmed
Degree of specialisation in renewables		modest	confirmed

The employment in the industry can be assessed as modest. The governmental renewable agency mentioned that in mid 1990s there were around 1000 jobs in the wind industry (Idae 1996). But more jobs were in the field of research, development and manufacturing of wind technology than in the area of service provision. Consequently, the small-scale market introduction did not manage to create sufficient spin-offs in the socio-economic-industrial context, able to be politically influential towards an improvement of the support system.

Industrial basis and dynamics

In mid 1990s there were four wind turbine manufacturers located in Spain, of which one new (Gamesa) and around 60 companies (ready for) offering services and products for the design, construction and operation of wind power plants. The degree of specialisation in wind energy can be assessed as modest, since except for turbine manufacturers, most companies served other industrial activities. The emergence of specialised companies was signalled only after 1995. As regards the types of companies, many were large corporations from a diversity of industrial sectors were involved or prepared to serve the emerging wind industry (Idae 1996).

Final considerations

When the support system changed in 1994, this was not so much endogenously induced but politically decided. The reorganisation of the electricity industry through the new electricity law in 1994 required a revision of the treatment of renewable electricity. Given the very slow rate of market growth, the targets of the 1991 Plan for Energy Efficiency and Saving for renewables were not likely to be achieved. By that time the governmental agency for renewables invested substantial financial resources, human capacity and effort in bringing renewables on the market. As results seemed slow to come, the renewables agency organised a series workshops and discussions with potential interested economic and financing actors to inquire on which legal guarantees could have brought them into the market. As a result a five-year guarantee on contracts for renewable electricity purchase by energy utilities was introduced in the 1994 law, together with a more specific price design methodology[17]. The next section summarises and draws the conclusion regarding the extent of confirmation of Hypothesis 2 for the case study of wind technology market introduction in Spain, between 1980-1994.

7.2.3 Summary and conclusion Hypothesis 2

This section tested the theoretical expectations of Hypothesis 2 for the case-study of wind technology market introduction in Spain, in the period 1980-1994. The hypothesis formulated the following expectations.

A support system leading to a national investment environment of high to very high economic-policy risk and high to very high levels of project profitability will induce diffusion patterns that are characterised by:

- predominantly large developers, and only to a reduced extent small developers, with
- diverse motivations to invest - commercial, strategic and partly-self-generation, using
- predominantly internal financing schemes, in
- mainly medium and small size projects, based on the use of
- all types of technological designs of which new and/or existing diffusion-optimal technological designs are likely to be used to a small extent.

Such *diffusion patterns* will result in:

- a modest installed capacity increase in short-medium term; and
- possibly sustainable market diffusion processes in the long term for the renewable technology envisaged.

Market *diffusion processes could be sustainable* if the business culture of the traditional financing community is characterised by flexibility in terms of willingness to accept risk and enable external financing schemes. A sustainable diffusion process could be then seen on a long-term, through a gradual change in diffusion patterns towards those expected under optimal investment contexts. However, if the investment interest of large developers is substantial given the available resource potential, diffusion processes have also good prospects of being sustainable in the absence of external financing schemes.

Diffusion patterns

The extent of confirmation of the theoretical expectations regarding diffusion patterns under the entrepreneurial investment context applicable in Spain for wind energy up to 1994 can be assessed as only *partly satisfactory*. For two indicators of diffusion patterns expectations were ‘confirmed’ - types of developers and types of financing schemes. For two other indicators - project sizes and drivers to invest - the expectations were however only ‘partly confirmed’. The expectation regarding the choice of technological design was ‘not confirmed’.

As regards the *drivers to invest*, the above-mentioned expectations were ‘partly confirmed’. We observed a poor interest in self-generation projects based on wind energy. The almost absent concern of industrial production companies and small developers in wind self-generation investments could be explained as due to: low environmental interest/awareness, and low entrepreneurship among small developers, especially with regard to new technologies.

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[17] The government acknowledged in the 2366/1994 Royal Decree the "inadequacy of the current economic regime to the actual reality" and that the increasing complexity of techno-economic relations between renewable generators and grid companies required a new regulatory framework.

Besides, we noticed many projects built for technology demonstration purposes. Given the fact that the study period covered a time when national technological designs were still in development and demonstration, around half of the projects had a demonstration component either as the main or as a second driver to invest.

The expectations regarding *project sizes* were also 'partly confirmed'. We explain this result as being influenced by the early stage of national technology development and demonstration, when turbines had still very small sizes. Even when projects were using more turbines, the resulting plant sizes were still often very small or small.

As regards the choice of *technological designs*, the expectation that the adoption of new and/or existing diffusion-optimal technological designs would be likely, at least to a small extent, was 'not confirmed'. In the period up to 1994, investments were dominated by the Spanish turbine manufacturers Made and Ecotecnia as co-owners of many projects. Both manufacturers chose for conventional technology designs, with asynchronous generators, because of their technical simplicity and lower costs compared to alternative designs. The two companies covered around 70% of the market in 1994. Their market adoption was influenced by the fact that the government stimulated national technology by means of substantial investment subsidies, third party financing and direct equity investment support. Besides, the two manufacturers were equity investors in some projects to reduce technology risk perceptions of developers. Hence the partial confirmation can be seen as the outcome of two exogenous factors: the influence of governmental policy to stimulate national wind technology in Spain, and the choice of Spanish manufacturers for the conventional wind technology design due to its simplicity and lower cost.

Diffusion results

As regards the dependent variables, the expectation on support system effectiveness was *not confirmed*. A small capacity increase was registered (77 MW) in the period 1980-1994, while we expected to see a modest increase in wind capacity (500-1000 MW).

The expectations regarding the likely un-sustainability of market diffusion processes were however *confirmed*. The prospects of sustainable diffusion were regarded as feeble because of non-availability of external financing schemes. There was only a limited number of economic actors interested to invest and willing to do so based on internal financing schemes. Their financing potential was very limited compared to the diffusion potential available for wind energy in Spain. The economic actors interested in the wind market in 1994 would not have been able to sustain diffusion of wind technology in Spain.

As regards the three perspectives for the discussion of long-term diffusion prospects, improvements were booked in terms of cost and technical performances. But further progress was still expected to enable the large resource potential available. The short-term technical priorities were different than those serving long terms diffusion expansion potential. This makes the absence of diffusion-optimal designs understandable. The cost performances of wind technology designs used in Spain booked substantial reductions in the category of technology-specific costs, around 37%. The industrial basis and dynamics emerging from entrepreneurial investment contexts was expected to be modest, which was *confirmed* by empirical findings. The socio-economic benefits associated with diffusion appeared to be small, which does *not confirm* the expectation. This strengthens however the idea that diffusion processes would not have been sustainable in the long-term.

In conclusion, the extent of confirmation of the expectations on diffusion results of Hypothesis 2 are also, overall, only *partly satisfactory*.

Exogenous factors and alternative specifications

The main factors that were identified as playing a role in the partial-/non-confirmation situations are as follows:

- *perception* regarding the stage of technical development by active and potential developers and financing agents (affecting the investment interest and hence, installed capacity); as well as:
- the stage of technological development whereby very small size turbines of national technology design dominated the market (affecting project sizes and installed capacity);
- governmental special financial support for national wind technology manufacturers; and short term market orientation of manufacturers in their decision regarding technical characteristics of turbines (affecting technological choice);
- involvement of manufactures as co-owners in wind projects (technological choice);
- low environmental interest/awareness and green image concerns of industrial production companies/commercial consumers who were also expected be interested to invest to some extent in (partly-)self-generation projects (affecting drivers to invest);
- business culture: many economic actors not flexible to accept risks in the support system; preference for clear signals for long term political commitment for renewables and for involvement of influential corporations viewed as opinion makers in business.

The next section is dedicated to the testing of Hypothesis 1 for the case study defined by wind technology diffusion in Spain in the period 1995-2000. In this six-year period two economic governance structures were applied for the support, among other renewables, of wind energy. But as we discussed in Chapter 6 their risk-profitability profiles did not differ very much. Together with the policy support mechanisms that were used in this period, the support system that emerged was placed in the category of optimal investment contexts.

7.3 Testing Hypothesis 1 for wind technology diffusion in Spain, 1995-2000

This section tests the theoretical expectations formulated under Hypothesis 1 regarding optimal investment contexts, for the case study of wind technology diffusion in Spain, between 1995-2000. The discussion of this new case study starts in Section 7.3.1, which focuses on testing the expectations for diffusion patterns. Further, Section 7.3.2 looks at the effectiveness of the support system in terms of wind power capacity installed by 2000 and at the prospects for sustainable market diffusion process in long term. Finally, Section 7.3.3 summarises and draws the conclusion regarding the confirmation of Hypothesis 1 for this case study.

7.3.1 Testing theoretical expectations on diffusion patterns, 1995-2000

This Section analyses diffusion patterns for wind technology in Spain in the period 1995-2000 and compares them with the theoretical expectations of Hypothesis 1. Sections 7.3.1.1 to 7.3.1.5 describe the forms of diffusion patterns for each of the five selected indicators. In Section 7.3.1.6 we summarise the main findings and draw the conclusion regarding the predictability of diffusion patterns.

7.3.1.1 Types of developers, 1995-2000

Hypothesis 1 predicted that under optimal investment contexts a large diversity of types of developers could be observed, coming from a wide range of industrial, economic and social sectors and activities[18]. Empirical data led to the assessment that theoretical expectations were *confirmed to a large extent with comment*. The dominant developers of wind projects in Spain were large and financially powerful economic actors: electricity companies (former energy utilities), mainly by means of subsidiary companies specialised in investments in renewable power plants; industrial groups from a very wide diversity of industrial and economic backgrounds; financing institutions such as banks and insurance companies; public authorities at different administrative levels; public companies for regional or local economic development; and manufacturers of wind turbines.

These large developers invested mainly by means of two company 'formulas':

- companies specialised in investments in renewables, or wind-projects only, which installed 60% of wind power capacity in 85 projects, and
- project-vehicle companies, which together commissioned 35,8% of the Spanish wind power capacity in 48 projects in the six-year period studied.

The substantial shift from the dominance of project-vehicle companies in the period up to 1994, to the dominance of companies specialised in renewable energy plants development shows the strong professionalisation of the wind electricity production business in the Spanish electricity industry. The remaining 4,2% of installed capacity was commissioned by few private developers, three research institutes and by manufacturers and utilities for the purpose of testing new turbine models. Together these projects form 100% of installed capacity - 2900 MW - mentioned by our first source of empirical data on project developers - the special edition on wind energy of the *Energia* journal (2000), which is based on information from the governmental renewable energy agency.

But in addition to the projects built by large developers, there also wind systems commissioned by small developers. The market entry of small developers was enabled by the three policy support mechanisms discussed in Chapter 6 - project finance loans with subsidies interest rate, private finance loans with subsidised interest rate, and third-party financing by the governmental renewable energy agency. The government became aware of the strong obstacles facing small developers interested to invest in wind energy, and introduced in 1998 these schemes to support their market entry. The target groups of these schemes were: small and medium size production companies, individuals, associations, cooperatives and local authorities. But direct and complete governmental statistics regarding the results of these policy support mechanisms were not available in 2001.

Based on the fragmentary data available we estimated the following:

- the third-party financing line opened by the governmental renewable energy agency led to thirty-one small-size wind projects in 1998 and 1999; but data regarding the total capacity represented by these projects were still not available in 2001; having in view that the capacity per project had to be between 0,3 MW and 5 MW, these projects could represent an installed capacity between 10-155 MW.
- the soft-loan project finance scheme directed at small/medium size production companies for self-generation plants led to the installation of around 63,5 MW of self-generation

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[18] In Chapter 3 we assumed that regulations in the support system do not impose market entry restrictions for any type of possible project developer. As explained in Chapter 6, in Spain the 40/1994 electricity law and the 2366/1994 royal decree referred only to self-generators as eligible target group. But in practice, however, commercial developers of wind projects could also benefit of the 1994 protective economic governance structure. Therefore this eligibility criterion did not pose de facto constraints on the types of developers, which facilitated the testing of expectations for this indicator.

wind plants between 1998 and 2000; but the number of projects representing this capacity is not known[19].

- as regards the small wind plants (up to 4 MW) using soft-loans from the Official Credit Institute, the available data are very restricted; we could only make an estimation for the projects built with the financial resources made available in 1999, which seem to have helped the construction of a capacity (likely) between 30 MW and 43 MW[20]. For 1998 and 2000 no data were available but interviewed governmental experts mentioned that in these years capacity was very low, in the range of few MW.

Based on the above estimations, our rough assessment is that small developers invested in around 90-100 projects in the period 1998-2000, which represented a capacity somewhere between 100 MW and 270 MW. In terms of installed capacity small developers had a small market presence compared to the large developers who constructed together 2900 MW in this period. But in Chapter 3 we argued that in assessing this indicator one should look at the number of projects built by the different types of developers. Looking from this perspective, the presence of small developers can be assessed as significant, having in view that large developers commissioned 168 projects in this six-year period (Energia 2000).

These considerations confirm our expectations on types of developers. However, having in view the poor quality of empirical data regarding investments by small developers and that the above numbers for this category of developers are based on our rough estimations and not on direct hard-fact data, we conclude by assessing the forms of this indicator as *confirmed to a large extent with comment*. The inset 'with comment' relates to the fact that almost all projects of small developers were made possible by the three special policy support mechanisms facilitating their access to financial resources.

The next paragraphs of this section explain in a bit more detail who are the companies behind the six groups of large developers mentioned in the introduction, and which are the main investment obstacles for small developers in Spain. Firstly, the most active investors behind the wind capacity installed in Spain during these years were *energy utilities*. The country largest utility Endesa was the first to be involved in wind-based projects, and it also established a subsidiary to manufacture wind turbines - Made. In 1998, after vertical de-integration as required by the new electricity law for liberalisation, it established a subsidiary

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[19] In 1998 twenty self-generation projects based on renewables were built by small/medium size firms with help from the soft-loan project finance scheme (IDAE 1998). It is not clear however how many projects were based on wind energy and how many MW did each project have. It is known however that wind-based projects built in 1998 represented an energy saving of 1.681 tons of oil equivalent/year. In the same time data were available that the wind projects built in 1999 represented an energy saving of 5.910 tons of oil equivalent/year. Wind projects commissioned in 1999 produced 68.720 MWh electricity per year. Assuming an annual wind availability of 2400 h/year, which experts consider is the average in Spain at the end of the decade (Energia 2000), this means that the projects built in 1999 had probably together an installed capacity of around 28 MW. Applying 'the simple rule of three' for the year 1998 it could be further estimated that wind projects built in 1998 accounted together for around 8 MW (this rule says that if 5910 tons of oil equivalent per year is saved by 28 MW wind power plants, then an amount of 1681 tons of oil equivalent per year is saved by [1681 x 28] / 5910 = 8 MW of wind power plants). This information originated in the Annual Reports of the governmental renewable energy agency (1998 and 1999, Madrid). For 2000 direct data from the same agency show that thirteen projects were commissioned totalling 27,5 MW. This means that in total the soft-loan project finance scheme for self-generation by small and medium size companies brought about 63,5 MW of wind projects in 1998-2000.

[20] We estimated this taking into account that 20.938.000 Euro was available for loans for wind projects in 1999 (IDAE 1999:44). Loans could be between 70% and 100% of total investment costs. We considered investment costs per one kW wind capacity installed as 700 €/kW, which was the average for the Spanish market in 2000.

for commercial investments in renewable and co-generation projects, Endesa Cogeneracion y Renovables. All previous investments of Endesa, Made and other regional-subsidiaries were transferred under its ownership. This way in 2000 Endesa Cogeneracion y Renovables (co-) owned almost 500 MW wind power. At the same time other 400 MW were already authorised or under construction.

The country's second largest energy utility Iberdrola entered the wind-market only in 1994. In 1997 when the utility had to de-integrate vertically, it formed a special subsidiary covering renewables investments - Iberdrola Diversification. But this utility had a very complex strategy as regards renewables, investing by means of more subsidiaries and through companies that were not entirely under its ownership. In 2000, Iberdrola was the owner, directly or indirectly, of 890 MW wind power representing 30% of total capacity installed in Spain. Most of this capacity was installed by its renewables development arms Energia Hidraulica Navarra and Energias Eolicas Europeas[21]. The last company made in 2000 the largest wind-turbine order ever in international history - 1400 MW.

The third largest energy utility Union Fenosa established a subsidiary for renewables only after the approval of the 2366/1994 Royal Decree - Union Fenosa Energias Especiales. The investment strategy of this company was to participate with shares in project-vehicle companies. This way by 2000, the company acquired ownership shares in 16 wind projects representing 360 MW. Its ownership in these projects varied between 10% and 80%. The fourth largest utility Hidrocantabrico opened in 1998 its subsidiary Sinae specialised in renewable energy investments. But the utility owns only 60% of Sinae, while the rest is equally divided between two powerful financial institutions – a bank (Caja Madrid) and an insurance company (Mapfre). Sinae owned in July 2000 only 87 MW. But in April 2001 it had at least fourteen new projects in execution, based on co-ownership project-vehicle companies, and it had applications in different regions amounting to 744 MW by 2000.

The second group of developers behind much of the wind capacity in Spain was formed by *large industrial corporations.* They entered the wind business from a wide diversity of industrial branches such as infrastructure works, construction, engineering, industrial equipment production, naval-construction, aeronautics, ammunition, mining, textile production, chemical industry, metal and agricultural equipment production. Besides involvement as project developers, some industrial groups also expanded their activities in the area of manufacturing or assembly of turbines, production of components for wind systems, and provision of services in the different stages of wind projects' life cycle.

Thirdly, *financial institutions* became also active project developers, often in co-ownership with subsidiaries of electricity companies, large industrial groups and turbine manufacturers. Since 1998/9 their position shifted from barrier-keepers for wind diffusion - through their reluctance or restrictive issue of loans based on the project finance approach - to that of enthusiast investors in wind projects. But very often regional and local public authorities and public companies for regional or local economic development had also ownership shares in wind projects. These increased the local budgets and contributed to the increase of regional economic development. The governmental renewable energy agency also invested equity in twenty wind projects, mostly in 1999-2000. Finally, *manufacturers* were also co-owners and sometimes sole owners in many projects, but investing based on different strategies than before 1994. The formula used by Ecotecnia, Neg-Micon, and Bonus-Bazan was to have small ownership in project-vehicle companies using their technology. Manufacturers Desa, Made and

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[21] In Energia Hidraulica Navarra, Iberdrola held a 37% ownership share while in Energias Eolicas Europeas it owned 87% of shares.

Gamesa chose to establish separate companies with the exclusive economic activity of investing in wind projects using their own technology[22].

As regards small developers, their very poor presence until the adoption of the special policy support mechanisms could be explained by four groups of obstacles. The first obstacle originates in the projects' approval criteria used by regional and local authorities. Beginning with 1995, regional governments of Autonomous Communities adopted wind development plans posing strong requirements to developers for contribution to regional industrial economic and social development. Even in the regions where such plans were not yet adopted, such requirements started to be formulated informally but directly. Besides, it became gradually customary that developers were required to donate parts of their profits to the local or regional municipalities. This became a serious obstacle for market entry obstacle for small developers who could not offer more than local taxes for authorities. In this context, they only can get projects approved when there are still sites left, after the large developers shared among themselves and under regional authorities' supervision, the locations with the best wind resources.

A second obstacle for small developers can be seen in the direct involvement of regional governments, through their energy agencies or some of their companies for regional economic development, in the ownership of renewables-specialised investment companies or project-vehicle-companies. In Navarra, for example, most of the wind capacity was installed by Energia Hidraulica Navarra, in which the regional government holds 38% of ownership shares through its development-company Sodena. This type of public agents' involvement was also signalled in Galicia, Aragon, the Basque Country and Andalucia, among perhaps many others. While the participation of public authorities and companies played an important role in introducing wind technology in the market and accelerating its diffusion speed, their continued participation in large-scale projects with powerful industrial groups and financing agents forms a market obstacle for small local developers.

The third obstacle is related to business culture and business interests of the financing community. The business culture of financing community in Spain is towards the financing of projects developed by or with the presence of large companies with market valuable assets or actors with political influence. As many interviewed developers explained, small developers have financing difficulties and these can only be overcome if an electricity company, industrial group, or public authority/agency is willing to join the project, even if it contributes with only a small share. This requirement of banks is often motivated by the argument that a large company is more likely to be able to dispose of expertise, or hire qualified companies for all stages necessary to get a project from design to construction, and to operate the project properly[23]. Beside this obstacle there is the direct business interest that many banks have either in wind companies specialised in renewables/wind investments, or in project-vehicle companies[24]. There is a direct competition between financing agents and companies of all

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[22] These companies had the largest installed capacity in their ownership from all manufacturers in Spain. At the end of 2000, nineteen projects were installed or under construction by Made Energias Renovables using its technology with a total of 384 MW. Desa opened special subsidiaries in different regions, commissioning six projects between 1995 and 2000 with a total of 191 MW (Energia 2000). But Gamesa had ownership connections with the two largest wind plants developers in Spain - Energia Hidraulica Navarra and Energias Eolicas Europeas.

[23] Interviews with Marta Fernandez (Sinae), Antonio Lara (Made), Marcel Bustos (APPA) in 2001. Conference paper of Mariano Olmeda (Banco Central Hispano, 1996).

[24] The bank Bilbao Vizcaya Argentaria has shares in the manufacturer Gamesa Eolica, together with Iberdola, and therefore it is interested to finance projects developed by Energia Hidraulica Navarra, or Energia Eolica Europea, or projects using Gamesa technology. Caja Madrid Bank has shares in the renewables-specialised company Sinae of the fourth largest utility, and has its own very ambitious

types for financial resources to invest in wind-parks. And from this competition small developers are the least likely to have chances for finance, without policy intervention. Some banks are already entangled in investment alliances with various industrial groups, electricity companies as well as regional and public agencies.

The fourth obstacle lies in the business culture of small developers. In Spain, individuals and small developers have a lower level of entrepreneurship, environmental sensitiveness, and average individual welfare than in countries such as Denmark, Austria, and the Netherlands were various types of small developers were often signalled as powerful motors underlying investments in renewable energy plants. Understanding the difficulties encountered by small developers, the central renewable energy agency implemented in 1998 three special policy support mechanisms. By 2000 they seemed to have brought significant although not entirely clear results in attracting this group of potential wind project developers in the market. The next section tests the expectations regarding the types of financing schemes under optimal investment contexts and looks at the evolution of financing characteristics for wind technology in Spain in the period 1995-2000.

7.3.1.2 Types of financing schemes, 1995-2000

Hypothesis 1 predicted that under optimal investment contexts external financing schemes would be the predominant financing tool - project finance, with the likely presence also of institutional finance. Empirical data summarised in Appendix 7.3 *confirm* this expectation. The years 1995-1997 were a period of transition from internal financing schemes towards project finance. In these three years 14 of the total 34 projects commissioned were based on internal financing schemes. Since 1998 project finance is the dominant financing approach used by large developers as data in Appendix 7.3 of this chapter show.

From the total 168 projects built and under construction in the period 1995-2000, only 28 projects were based on internal financing schemes. In addition, the governmental renewable energy agency used since 1998 the three policy support mechanisms whereby small developers could benefit of three financing approaches: third-party finance (thirty-one projects in 1998-1999), project finance (for self-generation by small and medium size firms), and private finance (based on the special line with the Official Credit Institute. Data were not available on the numbers of projects emerged from each of these three policy support mechanisms. But overall it can be argued that project finance was the dominant investment approach in the period 1995-2000.

In the three years of transition towards the dominance of project finance we observed changes in the way *internal financing schemes* were used, and changes in the financing parameters when project finance was available. As Appendix 7.1 shows, the multi-contribution financing scheme was frequently used before 1994, but it disappeared after 1995. As concerns the use of third-party financing scheme by the governmental renewable agency, the target group changed. While before 1994 this was used to help the cooperative manufacturer Ecotecnia demonstrate its upgraded turbine models, after 1995 this scheme was mainly used to help small developers with financing difficulties for small-size projects. The in-house corporate financing and debt-corporate financing schemes were used up to 1994 both for demonstration and commercial projects. But since 1995 only eight projects used this scheme for commercial plants, while in the rest of projects it was used to demonstrate new turbine models, often in very small (one-turbine) wind systems[25].

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investment plants, which require large financial resources. The fourth largest bank in Spain, the Sabadell Bank, has already equity shares in some project-vehicle companies for wind power.

[25] These two types of financing schemes are the most used for demonstration projects, in general.

During the years of transition towards the ‘business as usual’ access to *project finance*, core financing parameters changed, but not for all projects and developers. Firstly, the loan contribution in projects’ capital structure increased from around 60-70% in 1995-1997, to a general level of 80% after 1998[26]. An important particularity of bank project finance in Spain is that when investment subsidies are available, banks consider them as subtraction from loan contribution they are willing to approve. The consequence is that project developers remain under the challenge to bring the required equity contribution that can range between 10-30%, depending on the type of developer (Carmen Cerro 1996). Secondly, the period of debt-maturity increased after these transition years. Interviewed developers explained that debt-maturity was often five years in the first years after the entry into force of the 1994 regulations, because contracts were also guaranteed only for five years. But later, in 1997/1998, the debt maturity increased to 6-8 years, while in 2000 developers could obtain wind project loans for periods of 10-12 years or even 15 years[27].

The interest rates lowered in time, but there are more factors that affect this parameter than policy and economic risks. Interviewees explained that the risk premiums for the novelty of wind technology and for the risks associated with the support system lowered in time. Due to this risk premium decrease, interest rates for wind project also lowered. But the type of developer makes a difference for the interest rates charged by banks. When a project is owned by a large developer, the interest rate could be only 0,4% - 1% higher than the average inter-bank interest rate level[28] in 2000. But when the same project is owned by a small developer, the interest rate can be 2,5% higher than the average market level. In addition, small developers incur also higher banks fees for account opening than large developers[29]. But interest rates could also vary widely among projects, depending on a series of other variables. Of these, the most prominent are: the risks associated with resource quality and availability at the site where the project is located; and the commercial maturity of the technological design used. These parameters influence very strongly the cash-flows generated by wind plants. Projects are approved only when the combination resource quality/availability and technical-economic performance of turbines used can convince banks that sufficient revenues would be generated to pay back the loan within the expected debt-maturity period. But the higher the resource availability and quality is, and the more commercially-tested the turbine choice is, the lower will interest rates be[30].

Therefore, since 1998 project finance started to be the dominant financing approach and, generally, financing parameters converged towards values typical for traditional business areas. The use of project finance was made possible by the 1994 change in the economic governance structure, while its dominance as financing approach and the improvements in financing

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[26] Interviews Joachim Castillo, Ignacio Cruz Cruz, Josep Preps, Antonio Utrillo, Joachim Castillo, Marta Fernandez (April 2001). Data in Appendix 7.4 show the contribution of bank loans to the projects developed with the equity contribution from the governmental renewable energy agency. These data were calculated based on information from the Annual Reports of the governmental renewable energy agency Idae from 1994 to 1999, and the information brochures regarding wind projects with Idae equity participation. The brochures can be downloaded at the agency's website http://www.idae.es. For developers that have ownership connections with banks or use wind technology manufactured by companies where banks hold ownership shares, loan contribution can be even higher, up to 90%.

[27] Interviews Joachim Castillo, Ignacio Cruz Cruz, Cristobal Lopez, Franco del Pozo (April 2001).

[28] The average inter-bank interest rate is the unified interest rate at European Union level, fixed by the European Central Bank - for which the acronym EURIBOR is used.

[29] Interviews Antonio Lara, Joachim Castillo, Ignacio Cruz Cruz (April, May and September 2001).

[30] Interviews Rafael Anegon, Marta Fernandez, Maria Mendiluce (April and May 2001).

parameters were stimulated by the new economic governance structure established in 1997/8[31]. But in addition to regulatory changes there were also other factors that enabled the use of project finance in 1995-1997 and its fast widespread use after 1998. Firstly, the governmental renewable energy agency organised in the second half of the 1990s numerous round-tables and seminars where the dialog with financing institutions regarding conditions for project finance availability was on top of the agenda.

The agency and other public authorities also used these meetings to offer verbal assurance to all potential financing and economic actors that the political commitment for renewables, and especially wind energy, support is strong, that the economic support framework is not to be withdrawn, and the eventual awkward formulations of the legal protection measures will not be mis-used to endanger projects' economic viability.

But still in the period 1995-1997 banks preferred to lend project finance loans when certain economic actors had ownership shares in projects: the manufacturer of wind turbines used, an energy utility or a public authority[32]. But there were two factors that gave banks a strong impulse to increase and improve the approval of project finance. The first factor stimulating the approval of project finance was that after in the period 1994-1998, all four largest electricity companies (former utilities) opened special subsidiary companies for renewable energy with ambitious investment plans in wind power plants. This made banks realise that wind energy could become a large segment of the electricity industry and they did not want to miss the new business opportunity. Secondly, an important role in the trust-building process in the new business was played by the fact that a powerful financial institution, such as the The Bank Bilbao Vizcaya Argentaria, took ownership shares in the wind manufacturer Gamesa Eolica, in 1994, together with the second largest utility Iberdola. In the same time the bank Caja Madrid and the insurance company Mapfre took each 20% ownership share in the company specialised in renewables investments Sinae, together with the fourth largest utility. Consequently, the risk-profitability context created by the second and the third economic governance structures led to the emergence of project finance. But in the same time its widespread use and improvement in financing parameters were stimulated by three main factors:

- ownership participation of manufacturers, energy utilities or public agencies in projects;
- communication with, and assurance from, governmental authorities that the legal support for renewables would be stable in the long term, and
- the 'follow the leader' attitude after few important financing institutions and the four largest electricity companies made clear their interest in wind energy investments.

Interviewed developers mentioned that in 2001 banks were very enthusiastic about investing in wind energy. These factors, together with the attractive risk-profitability support system, also explain the sudden tremendous increase in installed capacity since 1998 as presented in Section 7.3.2.1.

As regards, *institutional finance*, this scheme was not used yet in 2000. Two foreign companies specialised in equity gathering for institutional financing were preparing to enter the

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[31] The most important provision in the 1997/8 regulations are related to the introduction of the 12% target for renewable energy by 2010 together with a clearer price design in the 1997 electricity law, and the provision in the 1998 royal decree that the price support for renewables will be unlimited in time due to the environmental benefits of renewable resources.

[32] In a round table in 1996, a representative of the first Spanish bank to issue project finance loans for a wind park, Caja de la Madrid, stated that it is very important for a project's economic viability "the participation of the electricity company who will buy the electricity, as well as of public authorities, the company constructing the wind park or the manufacturer" (Carmen Cerro 1996).

Spanish wind market, but a series of obstacles were facing their success, at least in short-medium term. The Merrill Lynch institutional investor announced in 2001 the opening of an investment fund for alternative energy and technology companies. The declared financial power of the fund was 326 Million Euros, to which 90 companies with shares on stock exchange markets were participating. But their investment plans for wind energy in Spain were not publicly-stated yet at that time[33]. Beside it, the German company Energiekontor was considering to use funds from individual investors, in order to put together the equity shares needed to install wind-plants.

But two main problems were standing in the way of project developers who wanted to use the institutional finance approach based on financing resources originating in Spain. Firstly, obtaining project finance loans for such projects from Spanish banks was very difficult for project developers who are new entrants on the market. Spanish banks have a strong preference to finance large companies and long-established business partners, while some also have their own business interest to invest equity in wind projects.

Secondly, as an interviewee explains, private-investor-equity for such projects was difficult to raise in Spain. Investment funds for equity supply are in principle more easily collected by domestic banks or specialised domestic companies. They are likely to have a faster and wider reach over the domestic population of individual investors than foreign companies. But in Spain banks were not attracted by the idea of setting up such funds, which require time and human resources. Besides, there were still many large companies willing (and competing) to provide the equity necessary for wind projects, which did not make the effort of private individuals' equity gathering worthwhile. Further, Spanish companies specialised in private equity gathering have been very rare, since there is no substantial tradition of entrepreneurship in Spain. Therefore private equity gathering is very difficult and not likely in the short term from Spanish equity providers.

In order to address these problems potential institutional developers are more likely to use project finance loans from foreign banks and equity from foreign equity investors - both individuals and companies. An advantage of the use of institutional finance based on foreign financial resources would be that the group of foreign companies and investors with stakes in the Spanish wind sector would grow. This means that the foreign lobby could potentially co-exert political influence in favour of maintenance or improvement of support system for wind energy, hence working positively towards the sustainability of market diffusion processes. The next sub-section discusses the main drivers to invest identified among investors in wind projects in Spain in the period 1995-2000.

7.3.1.3 Drivers to invest, 1995-2000

Hypothesis 1 predicted that under optimal investment contexts commercially motivated projects would predominate, but a presence of strategic and (partly-)self generation projects would also be observed. Based on the empirical data summarised in Appendix 7.3, theoretical expectations can be considered as *confirmed to a large extent with comment* for this case study. This assessment is based on the fact that while commercial drivers were overwhelmingly dominant, there was only a small presence of self-generation projects, which moreover was possible only due to the special governmental intervention by means of policy support mechanisms. Besides, while there was a number of demonstration projects for the testing of

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[33] According to Merryl Linch, "the mixture of environmental pressures, restructuring of industries and technological progresses registered urge investors to become interested in the energy sector, having in view that private investors and large energy companies were already doing it". (Source: news at the website of the renewable energy company IbeRenova http://iberenova.iberdrola.es, 19 March 2001).

new technological designs, other strategic motivations were not identified in developers' decision to invest, taking into account the typology in Chapter 3.
The following numbers per types of projects were differentiated:

- 128 commercial projects (two-thirds of which were commissioned since 1999);
- 13 commercial projects using new turbines (7 during 1995-1998 and 6 in 1999-2000);
- 8 commercial-strategic projects (1994-1997 with governmental agency equity);
- 15 demonstration projects (7 during 1995-1998 and 8 in 1999-2000) and
- an unclear number of self-generation projects, counting for at least 65 MW[34].

As regards the differentiation between demonstration projects, strategic-commercial projects and pure commercial projects, the distinction becomes quite difficult after 1995 if we use the same criteria as we did for the period up to 1994[35]. A first reason is related to the way new turbine models were entering the market. A major change compared to the previous period is that in many cases the new turbines were introduced in the market directly by means of medium-to-large scale commercial projects, without previously testing the turbines in small-size projects. After 1995, only 13 new turbine models were introduced in the market by testing in the traditional approach, through small demonstration projects. Two of these 13 new turbine models were tested in two demonstration projects each, which raises the final number of demonstration projects mentioned above at 15. But since 1995, 11 new turbine models were used for the first time directly in medium or large commercial projects with capacities ranging between 5 MW and 60 MW. In Appendix 7.3 we described these projects as 'commercial with new turbines'[36].

A second challenge in differentiating among the three categories, relates to the projects with equity contribution from the governmental renewable energy agency. For the period before 1994 we considered such projects as having a strategic component. Through its involvement the agency wanted to compensate for the reticence of banks in giving project finance loans and to build up a track record of successful commercial operation of wind plants. In the years 1995-1997 its ownership involvement could also be seen as a strategic move as banks expressed clearly during industry round-tables and workshops that the presence of the agency was still important for the approval of project finance loans.

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[34] We counted here the 6 very small projects mentioned in Appendix 7.3 as (partly-)self-generation from the Energia journal (2000) and the 63,5 MW that emerged in 1998-2000 based on the special policy support mechanisms for self-generation targeted at small and medium size firms. The other two policy support mechanisms (third party financing from the governmental agency, and private finance with soft loans from the Official Credit Institute) covered both commercial and self-generation projects. But we are not aware of results regarding the number of self-generation wind systems emerging from these two schemes. In addition, after 1998, small and medium-size companies could benefit from higher investment subsides than the other developers, which could go up to 40%.

[35] Based on the list of commissioned projects published in Energia (2000) we could see the year when each new turbine model was used for the first time in Spain, by whom, and the size of the project in the framework of which it was used. When a turbine model was used for the first time in a single-turbine project or a project counting with no more than 4 turbines installed by a large developer or manufacturer, those projects were considered as 'demonstration projects' or 'commercial with new turbines'. The following projects, commissioned even in the same year or later, with the same turbine models already tested in one demonstration project, were considered as commercial projects, unless interviewees declared they had some special learning purposes, as for example in the case of the renewable energy research institute of the Canary Islands ITER.

[36] Seven of these eleven new models that were introduced abruptly into the market were actually turbines of foreign manufacturers. They were considered commercially mature abroad, but were being used for the first time in Spain. Their market introduction directly by means of large scale commercial projects suggests that both developers and financing agents acquired trust in wind technology.

During all these years the agency only provided small amounts of equity per project - generally between 2% and 6% in the total equity of a project. But in 1999 and 2000 when project finance became widely available, the number of projects with equity contribution from the governmental agency increased. Also its ownership share in projects raised to between 25% and 49%. This suggests to us that the strategic component of the projects with equity involvement from the renewable agency has in fact disappeared, although it continued to be strongly stated in its annual reports. Based on these considerations we thought adequate to classify only the 8 projects built in the period 1994-1997 as commercial-strategic projects and to consider the rest 16 projects as commercial projects. The next subsection looks at the empirical data regarding project sizes for wind power plants built in the period 1995-2000.

7.3.1.4 Project sizes, 1995-2000

Hypothesis 1 predicted that under optimal investment contexts mainly medium and large size projects will be seen. Empirical data presented extensively in Appendix 7.3 and summarised in Table 7.7 *confirm with comment* this expectation. Looking at project sizes in Table 7.7 it can be observed that between 1995 and 2000 the number of small and very small size projects was almost the same to that of medium, large and very large size projects. These data show that there was indeed a large diversity in project sizes. But the number of small and very small size projects increased only since 1998 with the introduction of the three policy support mechanisms for the improvement of small developers' access to financial resources. For this reason, we assess this indicator as confirmed 'with comment'.

In terms of installed capacity per project, more than half (57%) of the total capacity built in this six-year period was represented by large and very large size projects. But projects started to be increasingly larger only since 1998, after the change to the third support system. It is not clear to what extent this was influenced by the expanded and improved availability of the project finance scheme (see previous section for explanations), or by the increased ceiling of plant size for eligibility to the new economic governance structure for renewable electricity from 1998.

Table 7.7 *Project sizes for wind systems in Spain between 1995 and 2000*

Project sizes		Number wind projects: 1995 –2000[37]	Totals
very large: >=25 MW	together = 57% of installed capacity	35 projects (6 up to 1998 + 29 after 1999)	136 projects
large: 15 - 25 MW		61 projects (23 up to 1998 + 38 after 1999)	
medium: 5 - 15 MW		41 projects (15 up to 1998 + 26 after 1999)	
small: 1 - 5 MW		17 projects (7 up to 1998 + 10 after 1999)	137 projects
very small: <1 MW		19 projects (15 up to 1998 + 4 after 1999)	
small and very small projects based on the three policy support mechanisms for access to financing since 1998[38]		estimated around 100 projects (see Section 7.3.1.1)	

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[37] These numbers were counted based on the list of projects published in the journal *Energia – Ingenieria Energetica y Medioambiental* (Special edition 'El Manual Practico de la Energia Eolica', Madrid 2000). The same list was used as source for Tables 7.8 and 7.10. The journal listed more projects than those published by the governmental renewable energy agency (IDAE 2000), because it also included projects in an advanced stage of execution. For this reason also the installed capacity mentioned in Section 7.3.1.for the period 1995-2000 is higher (2900 MW) than that published by the governmental agency for these years (2270 MW). Throughout Section 7.3 of this chapter we used the more updated data in the journal Energia.

[38] The sizes of projects based on projects finance with soft loans from the governmental renewable agency for small and medium size companies after 1998 are not clear (no size restriction). But interviewed market experts and governmental agents mentioned that they were most likely below 5 MW plants. The projects based on third-party financing by governmental agency for renewables for small developers had small or

In Chapter 3 when we formulated the theoretical expectations, we assumed that decisions on project-size would not be constrained by the economic governance structure nor by the applicable policy support mechanisms. In practice such the support system put ceilings on project sizes on several occasions. But it is not clear to what extent these affected developers' decisions on project sizes. During the period 1995-1997, developers could qualify for investment subsidies when their projects were smaller than 20 MW, located at sites with difficult access, low wind speeds and incurring high grid connection costs. Data are not available on how many of the projects with capacities below 20 MW received investment subsides in this period. However interviewees and some journal articles by market specialists (Wind Power Monthly) mention that after 1995 very few wind projects benefited of investment subsidies and that especially large companies did not enjoy subsidies anymore. In these years there were 4 projects with capacities higher than 20 MW.

It is hence likely that this scheme did not function as a constraint on developers' decisions regarding project sizes. As regards the economic governance structures, we explained in detail in Chapter 6 that there was a direct relationship between project sizes and price design in the 2366/1994 Royal Decree. Only when project sizes were below 25 MW, was it sure that developers qualified for the high tariff price design[39] (6,9 €c/kWh in 1995). In order to avoid price risks most developers invested in plants below 25 MW. Between 1995 and 1998, there were 6 projects with installed capacities between 24 MW and 25 MW. But in the same period there were also 6 projects with capacities higher than 25 MW. One project had even the record capacity, at that time, of 58,5 MW. It is possible that the wind plant had actually more interconnectors to the transmission grid, because this defined a separate wind project in legal terms, making it eligible for economic protection[40].

The 2818/1998 Royal Decree raised the ceiling for eligibility of wind plants to the special regime to 50 MW[41]. In 2000, there were however two projects of 60 MW each commissioned, which were still part of the special regime. An explanation could be also the use of more interconnectors to the grid, making it possible to have two or more wind projects in the administrative papers. But it is also possible that under both economic governance structures, special arrangements were made between governmental/regional authorities, electricity companies and developers for the acceptance of projects larger than the legal limits to the special regime. Based on these ideas, and having in view the possible role of improved access to project finance since 1998/9, we cannot draw a conclusion on the role of ceilings placed on project sizes by the support systems in the period 1995-2000.

The next subsection analyses the technological choice of project developers from the perspective of the technical characteristics selected in Chapter 4.

7.3.1.5 Technological design, 1995-2000

Hypothesis 1 predicted that under optimal investment contexts, the adoption of new and/or existing technology designs with substantial contribution potential to diffusion expansion is likely on a more frequent basis. Practical developments *confirmed* this expectation.

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very small sizes (0,3 - 5 MW). Also the projects based on the private finance special credit line of the Official Credit Institute had small / very small sizes (< 4 MW).

[39] When plants were above 25 MW, special approval had to be obtained from the Ministry of Industry and Energy and it was not clear whether these projects could enjoy the high tariffs during their entire economic life. The alternative price design that developers would have faced was only 2,3 €c/kWh.

[40] The capacity of a wind project is calculated based on how many turbines are connected to the same grid-interconnector. This way, it is possible that a 60 MW wind park is actually linked to the grid through three interconnectors, which transforms it in the administrative papers into 3 wind projects.

[41] Projects over this limit have no guarantee on demand, contract and price and have to submit their output for the trade in the power pool, with only 0,6 €c/kWh given as a premium above the pool price.

Empirical data in Table 7.8 show the capacity sizes of wind technology designs introduced in the Spanish market beginning with 1995. But it also shows, in italics, the capacity sizes of wind technology designs ready for commercialisation but not used yet in the projects built in 2000, and the designs under development by existing and new entrant manufacturers. In total at the end of 2000 there were 24 new technological designs adopted in the market and 12 more preparing market entry in short term.

Of the new versions of wind technology, 13 designs had technical characteristics that bring substantial improvements in grid-friendliness performances. In the same time, by means of the technical characteristics of pitch blade control and variable or two speed rotor, they also bring modest improvements in efficiency. These 13 technological designs were marked with bold numbers in Table 7.8. Further, 22 technological designs had technical characteristics bringing only modest improvements in efficiency and grid friendliness performances. The remaining 14 designs were based on conventional technology[42].

Table 7.9 mentions the technical characteristics selected in Chapter 4 for the assessment of wind technology's technical performances in terms of grid friendliness and efficiency, for each manufacturer listed in Table 7.8. The last column of Table 7.9 mentions the market share at the end of 2000 of the three groups of technological designs.

Table 7.8 *New wind turbine models introduced in Spain during 1995-2000*[43]

Manufacturer / Year / kW	during the 2nd support system				during the 3rd support system	
	1995	1996	1997	1998	1999	2000
	wind technologies based on the horizontal axis principle					
Ecotecnia	500	600	640	750; 700	-	*1250*
Made	-	500	-	600; 660	-	***800;****1320;* ***2000***
Gamesa Eolica	-	**600**	**660**		**1650**	**850** *(two models of which 1 for moderate wind speeds)*
Desa	-	-	-	-	600	-
EHN	no manufacturing activities yet				***1300*** (*two models -1 for moderate speeds)*	
MTorre	no activities yet		***1500*** *(two models of which 1 for moderate wind speeds)*			
Enercon	-	**250**	-	-	-	-
Nordtank	500	-	600	750	-	750 kW
Neg-Micon	-	-	-		600	1500
Bonus-Bazan	-	-	600	-	-	1300
Nordex	-	-	-	-	600	-
Enron	-	-	-	-	-	***750***
De Wind	-	-	-	-	-	*750*
Kenneth	330	-	-	-	-	-
Enerlim	*300 kW* model based on innovative translational principle (in development)					

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[42] The technological designs with substantially improved performances from grid-friendliness perspective (compared to conventional designs) have two technical characteristics that we also used to describe the modest improvements in efficiency (pitch control of blades and variable/two speed rotors – see Chapter 4). For this reason the total number of designs in the three groups mentioned is higher than the total 36 new designs counted in 1995-2000. But the sum of the technological designs in the last two categories results in the total number of new designs mentioned in Table 7.8 for the period 1995-2000.

[43] Data presented in this table were taken from the list of projects commissioned between 1990 to the end of 2000 published in the Special Edition of the *Energia* journal (2000).

Table 7.9 *Technical characteristics - from the perspective of grid-friendliness and efficiency - for the turbines commissioned in Spain by 2000*

Company	Technical characteristics			Market shares[44] in 2000 per type technological design
	Blades control	Rotor speed	Generator type	
Ecotecnia	Stall	Constant	Asynchronous	conventional designs (22,8%)
BonusBazan				
Made				
Nordtank				preparing market entry in 2000
Made	Pitch	Two-speeds	Asynchronous	modest improvements in grid friendliness and efficiency (17,2%)
Acsa		Variable		
Desa		Constant		
Neg-Micon	Stall	Two speeds		
Gamesa	Pitch	*Variable*		
Kenneth	Pitch	Variable		
Nordex	Stall	Two speeds	Asynchronous	preparing market entry in 2000
DeWind	Pitch	Variable		
Enerlim	Pitch	Variable		
Gamesa Eolica	Pitch	Variable	Ingecon system Synchronous	**substantial** improvements in grid-friendliness and modest improvements in efficiency **(55%)** (Gamesa 53,8%; Enercon 1,2%)
Enercon		Variable	Synchronous	
EHN[45]	Pitch	Variable	Ingecon system Synchronous	preparing market entry in 2000
MTorres[46]			Synchronous	
Made			Synchronous	
Enron (Zond and Tacke)	Stall / Pitch		DVAR system[47] Synchronous	

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[44] The market shares calculated in Table 7.9 are based on information regarding market share per manufacturer in 2000 from the governmental agency for renewable energy IDAE, published in the weekly journal Las Energias Renovables, available on line at http://www.energias-renovables.com on May 15th 2001. The total market share of the three categories of technological designs do not add to 100% because 5% of capacity was represented by wind projects with technologies from other manufacturers than mentioned in this table or projects with mixed technologies. Data regarding the technical characteristics of manufacturers were taken for the special edition on wind energy of the Spanish journal Energia (2000) combined with information at companies' websites.

[45] The most active developer of renewable energy systems, Energia Hidraulica Navarra (EHN) decided to become involved also in the manufacturing of wind turbines. In 2000 it realised a 1300 kW prototype. A second version is designed for moderate wind speeds able to work at cut-in speeds of 2,3 m/s and reaching rated power at only 8m/s. Both versions of the 1300 kW turbine are equipped with the innovative Ingecon system developed by the Ingeteam company for Gamesa Eolica that stabilises the voltage at the transmission grid. (Information in Windpower Monthly July 2001: 64 and at the company's website on March 19th, 2001 http://www.ehn.es/ehn/eng_textos/eolica08b.html).

[46] The industrial group M. Torres with experience in aeronautics decided to expand its activities in the wind energy field. Since 1997, MTorres developed a 1500 kW turbine. One version is intended for winds with normal regimes and there is another one especially designed for winds with lower speeds than those for which the rated power of most turbines is calibrated. Though not demonstrated at the end of 2000, wind energy experts expected they would have high quality grid and cost performances. These turbines are planned to use synchronous generators.

[47] Enron turbines are equipped with an innovative system patented by the company, called the Dynamic Reactive Control system (DVAR). This device has the ability to supply reactive power to the grid, at the exact moments when that is needed, resulting in voltage stabilisation and high power quality. As the company states, the "DVAR system opens the door to new opportunities in areas where weak rural distribution systems had discouraged new wind power applications" (http://www.enron.com).

Table 7.9 shows that at the end of 2000, slightly more than half of the installed capacity - 55%[48] - used technological designs with substantial improvements in grid friendliness performances compared to conventional technologies. This confirms our expectation that technology designs with substantial contribution potential to diffusion expansion are likely to be adopted on a more frequent basis.

But this large capacity with superior power quality performances was realised overwhelmingly by means of 4 designs of Gamesa Eolica technology: mainly 600 kW and 660 kW, and to a smaller extent the 850 kW and 1650 kW designs. In 1997 the Spanish company Gamesa Eolica introduced into the Vestas turbine that it was manufacturing under a technology transfer agreement, an innovative system able to generate synchronous current. Although it did not use an asynchronous generator, the introduction of the 'Ingecon variable speed system' developed by the engineering company Ingeteam, resulted in a new design.

This new design had higher power quality and improved efficiency as compared to the original Danish Vestas technological designs[49]. But in addition to these, there were only few German Enercon turbines with synchronous generators imported in the years 1995-2000. Their use was in a niche market because the renewable technology research institute of the Canary Islands aims to develop a stand-alone electricity system based on wind energy, for which Enercon turbines are seen the most compatible.

Consequently, the large market share of technological designs with substantially improved grid-friendliness performances cannot be associated with a wide awareness of developers regarding the long-term importance of such designs. But it can rather be associated with the concern of the market dominant manufacturer for improved technical (and cost) performances for long-term diffusion expansion. The large market share of the Gamesa Eolica technology is the result of two overlapping factors.

Firstly, there were direct and indirect ownership connections between the owners of manufacturer Gamesa Eolica and project developers investing in wind plants based on Gamesa Eolica technology. The companies that invested in most of the wind capacity with Gamesa turbines up to 2000 were the renewables-investment-specialised companies Energia Hidraulica Navarra (410 MW), Energia Eolica Europea[50] (420 MW), Gamesa Energia Iberica (165 MW), Compania Eolica Aragonesa (108 MW) and Corporacion Eolica (65 MW)[51]. In addition, there

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[48] Looking in Appendix 7.3 it can be calculated that Gamesa Eolica installed 1274 MW by the end of 2000. The Ingecon system for voltage stabilisation was introduced only in the spring of 1997. But in 1995 Gamesa Eolica did not install any turbine, while in 1996 only 67 MW were commissioned. Taking this into account, it can be calculated that by 2000, the Ingecon-based turbines of Gamesa Eolica had a market share of 53,8%. Together with the few Enercon turbines (1,2%) grid-friendly turbines had in 2000 a market share slightly higher than half of the capacity installed in Spain, that is 55%.

[49] The Spanish media announced this as a "new wind energy technology which would go down in history as the county's most important contribution to the alternative energy industry to date". The Ingecon system "is claimed to increase a wind turbine's power production by 5-10 % at certain wind speeds, stabilise grid input and extend turbines' life (…). Ingecon basically consists of a generator and control system which allows the turbine to work at variable rotational speeds, produce synchronous current and cut the wear and tear of turbine machinery". (Source: "Ingeteam claims new invention increases production", Wind Power Monthly, May 1997: 14.)

[50] In early 2000, Energia Eolica Europea launched the largest turbine order energy in the history of wind technology development, ordering 1800 Gamesa turbines for 1400 MW capacity split in 31 projects.

[51] The manufacturer Gamesa Eolica was owned during most of these years by the Spanish company Gamesa Energia with 51%, in which the second largest utility Iberdrola had also ownership shares together with a large bank, BBVA. Further Gamesa Eolica was owned by the Danish manufacturer Vestas (40%), and the holding company of Navarra regional government Sodena (9%). The Energia Hidraulica Navarra company was owned 37% by the utility Iberdrola and 38% by the development-company Sodena of the regional government of Navarra. Energia Eolica Europea company, established in 1998, was owned 87% by Iberdrola. Further, the powerful Spanish industrial Group Guascor has ownership shares both in the

were also 12 project-vehicle companies, where in some cases the just mentioned specialised developers or their owners were participating with equity. Consequently, facilitated by high demand for its technology, Gamesa Eolica could invest in research to improve the technical performances of its designs. Besides, the very large orders of 600 kW and 660 kW designs enabled substantial economies of scale and a fast lowering of technology specific costs, that increased its demand even further.

The second factor favouring the domination of Gamesa technology regards the criteria for the administrative approval of wind projects that regional governments gradually started to adopt by the same time when Gamesa Eolica was making its first steps on the market. Since 1995 when the number of applications started to increase some regional governments adopted guidelines and criteria for the authorisation of renewables-based energy projects in general or wind-based plants in particular. Understanding that the increase in interest to install wind turbines can bring substantial economic benefits to regions, creating jobs and enlarging the industrial base, many regional governments developed approval criteria so as to fully harness maximum benefits. These changes in administrative procedures favoured Gamesa Eolica, at least in its competition with foreign manufacturers exporting technology to Spain. The developers using Gamesa technology were able to comply with the approval requirements of regional authorities and offer attractive plans for regional industrial and economic development, since Gamesa Eolica was ready to install manufacturing plants in the regions with good wind energy potential. The company developed in time 10 manufacturing plants in 5 Autonomous Communities. At the end of 2000 it employed 1150 people, compared to only 150 people in 1995 (WPM December 2000: 40). These plants were producing components of wind turbines, blades, towers, as well as executing assembly of turbines.

Nevertheless, Table 7.8 shows that at the end of 2000, four manufacturers decided to start producing grid-friendly turbines, with 8 new such technological designs preparing market entry[52]. But as the Spanish market is very dynamic it is likely that in 2002 and later the number of grid-friendly turbines available on the market will increase. Hence even if Gamesa Eolica technology would loose market share in the future, the market share of grid-friendly and stand-alone compatible technological designs is likely to continue to be high. As the general director of the Spanish manufacturer Made argues[53], “Only the synchronous turbines are authentic generators, as a conventional power plants can be. (…) We believe that they are better options for the future because when the capacity of installed wind power increases considerably, distribution companies could place restrictions on the turbines that are not synchronous”. Consequently, increasingly more manufacturers seem to awake to the idea that the superior technical performances of synchronous generators, which make them the best choice both for grid-connected application and for stand-alone systems, are the design for the future of wind technology.

Besides, also the shift towards designs with modest efficiency improvements is obvious. While in 1994 only 30% of installed capacity used turbines with modest improvements in efficiency performances as compared to conventional technology, by 2000 this market share increased to 77,2%. This was represented by 22 technological designs available for choice in Spain in 1995-2000, from the total 36 designs entering the market in this period. The increase

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manufacturer Gamesa Eolica and in the company Corporacion Eolica. Finally, the company Compania Eolica Aragonesa had also ownership connections with Gamesa.

[52] In 2001 Enron already built a manufacturing factory in Toledo. Besides, three Spanish companies had in development grid-friendly turbines - Made, Energia Hidraulica Navarra, MTorres. The last two companies were new entrants in the manufacturing industry.

[53] Antonio de Lara, interview journal "Las Energias Renovables, 4 November 2000, on line at www.energias-renovables.com in November 2000.

in more efficient designs' supply and demand was facilitated by the fact that the profitability of the Spanish support system enabled the purchase of such designs. These were initially more expensive, but in the meanwhile they lowered the technology-specific costs as compared to technological designs due economies of scale from increase domestic and foreign demand.

As regards the third performance perspective for which we operationalised the indicator of technological choice, modest improvements were also signalled in this period on the Spanish market. Six manufacturers were concerned at the end of 2000 with the development of wind technology designs having the *ability to function in moderate wind speeds*, and reach rated power at nominal wind speeds between 8-10 m/s. These companies were: Ecotecnia (the 750 kW model), Made, Energia Hidraulica Navarra (one 1300 kW model), MTorres (one 1500 kW model), Gamesa (one 850 kW model), and the new entrant using a new technological principle Enerlim (one 300 kW model, to be further upgraded into 900 kW and 1200 kW versions). However no technology was yet able to reach rated power at nominal wind speeds of below 6 m/s. Hence the above mentioned designs can be assessed as bringing *modest improvements* in wind technology's ability to harness energy from lower wind speed sites.

In conclusion, the empirical data presented in this subsection confirmed our theoretical expectation that the adoption of new and/or existing technology designs with substantial contribution potential to diffusion expansion is likely on a more frequent basis. The next section summarizes the empirical findings and degree of confirmation of theoretical expectations on diffusion patterns for wind technology diffusion in Spain 1995-2000.

7.3.1.6 Conclusion regarding the extent of confirmation of Hypothesis 1 for diffusion patterns of wind technology is Spain, 1995-2000

Section 7.3.1 looked at the diffusion patterns of wind technology in Spain in the period 1995-2000 in order to test the first part of Hypothesis 1. The five indicators for diffusion patterns took in practice some forms that are very close to those predicted under optimal investment contexts. The extent of confirmation can be assessed as *good*. The empirical forms for diffusion patterns are summarised in Table 7.10.

Two indicators were confirmed, one was confirmed with comment, and the other two were confirmed to large extent with comment. In all cases the inset 'with comment' related to the fact that some of empirically observed forms could emerged as a result of special policy support mechanisms targeted at their stimulation.

The expectations regarding the *types of developers* likely to invest were 'confirmed to large extent with comment'. We observed the predominance of large companies and developers with good access to financial resources from banks, such as: electricity companies, industrial groups, financial institutions, public authorities and companies, and manufacturers of wind turbines. In the period studied they developed and had under construction wind projects totalling 2900 MW. But with the help of three special policy support mechanisms for access to financial resources as well as increased levels of investment subsidies, small developers could also invest in wind systems since 1998.

Direct and complete empirical data regarding the investments of small developers were not available. Our rough estimations based on the available data led us to assess that small developers built around 90-100 projects with a capacity between 100-270 MW. Due to the fact that these are just rough assessments and having in view that the presence of small developers was made possible by special governmental policy intervention, the expectations for this indicator were assessed as confirmed to large extent with comment.

Table 7.10 *The theoretically expected and the empirically registered diffusion patterns for wind technology in Spain, 1995-2000*

Empirical developments	Theoretical expectations
Types of project developers	
- predominance of financially powerful developers: electricity companies, industrial groups, financial institutions, public authorities and companies, manufacturers - small developers' presence, enabled by policy intervention	all types of developers (confirmed to a large extent with comment)
Type of financing schemes	
- overwhelmingly project finance; - internal financing schemes only for 28 small-scale project plus those based on the two specially designed policy support schemes for third-party finance and private finance - institutional finance being planned by foreign investors	external financing schemes would predominate (confirmed)
Drivers to invest in wind projects	
- Commercial = 128 projects (40 projects in 1995-1998; and 86 projects in 1999-2000 of which 16 with governmental renewable energy participation) - Commercial with new turbines = 13 projects (7 projects during 1995-1998; and 6 projects in 1999-2000) - Commercial-strategic projects = 8 projects (with governmental renewable energy participation, 1994-1997) - Demonstration = 15 projects (7 projects in 1995-1998; and 8 projects in 1999-2000) - Self-generation = 4 projects + those projects built with help from the three policy support mechanisms from governmental renewable energy (at least 65 MW)	presence of all types of projects, with likely predominance of commercial projects (confirmed to a large extent with comment)
Project sizes	
- very large (>=25 MW) = 35 projects - large (15 - 25 MW) = 61 projects - medium (5 - 15 MW) = 41 projects - small (1 - 5 MW) = 17 projects - very small (<1 MW) = 19 projects - small / very small projects with policy support mechanisms for access to financing since 1998 = 90 – 100 projects	medium and large size projects will predominate (confirmed with comment)
Technological designs	
- 55 % of capacity: diffusion-optimal grid-friendliness; - 77,2 % of capacity: modest efficiency improvements - 22,8 % of capacity: conventional wind turbines - six manufacturers developing turbines for moderate nominal wind speeds 8-10 m/s: modest improvements	the adoption of new and/or existing diffusion-optimal technology designs is likely more frequently (confirmed)

As regards the *types of financing schemes*, the expectations were 'confirmed'. We observed a transition from internal financing schemes towards projects finance in the period 1995-1997, when however project finance was still slightly dominating with 20 projects using such loans out of the 34 plants developed. Since 1998, project finance was the overwhelmingly used financing tool. But domestic conditions did not favour yet the use of the institutional financing scheme. Foreign companies were considering using this approach in the future.

The expectations regarding *drivers to invest* were 'confirmed to large extent with comment'. This assessment is based on the fact that while commercially-motivated projects dominated indeed, there was only a small presence of self-generation projects. Besides, while there was a number of demonstration projects for the testing of new technological, other strategic motivations were not identified in developers' decision to invest. Most self-generation projects were possible as a result of government's decision to support such projects with the help of special policy intervention for access to finance.

The ranges of *project sizes* observed in the period studied 'confirmed with comment' the theoretical expectations. A large diversity of project sizes was observed, reflecting the access to financial resources. But large and very large projects dominated the investment preference. The small and very small size projects could be developed mainly as a result of the three special policy support mechanisms for the help of small developers put in place by the governmental renewable energy agency, who also placed limits on project size eligibility. In addition to this, the second and third economic governance structures placed ceilings on the sizes of projects eligible for financial support and guaranteed contracts. In 1994-1998, the size limit was 25 MW, while since 1998 it increased to 50 MW. Due to the policy/legal constraints on project sizes, we used the inset 'with comment'.

Finally, the expectations regarding *technological design* choice were 'confirmed'. The conclusions regarding technological improvements in 1995-2000 in Spain were as follows:

- 55% of the total capacity had technical characteristics able to bring substantial performance improvements from the grid-friendliness perspective
- 77,2% of capacity used designs with *modest* efficiency and grid-friendliness improvements, while only
- 22,8% of the installed capacity was based conventional wind turbines; besides,
- 6 manufacturers were concerned with technological designs for moderate wind speeds between 8-10 m/s; these would bring modest improvements in the ability to increase the technically exploitable wind resource potential.

In conclusion, the overlap between the empirically observed and the theoretically expected diffusion patterns is sufficiently large to support the continuation of empirical investigation regarding the dependent variables of the analytical framework. This analysis is done in the next Section, 7.3.2.

7.3.2 Installed capacity increase and prospects of sustainable diffusion in 2000

This section tests the expectations on installed capacity increase and looks at the prospects for the sustainability of market diffusion processes as they looked like at the end of 2000.

7.3.2.1 Increase in the installed capacity, 1995-2000

In Chapter 3 we hypothesised that an optimal investment context would be able to induce a *large increase in installed capacity,* operationalised as at least 1000 MW, if the support system retains its characteristics for at least a short-medium term period, of 5-10 years. This case study covered a period of six years, 1995-2000. The summing up of the projects mentioned in Appendix 7.3 shows that 2900 MW were installed or in construction phase at the end of 2000, commissioned during the optimal investment context. The annual capacity increases are shown in Table 7.11. To this, the capacity built with the help of the three policy support mechanisms for small developers has to be added, assessed as between 100-270 MW. Of the total 2900 MW, built mainly by large developers, the largest part - 2086 MW - was built in 1999 and 2000. In addition much more capacity was already approved before the end of 2000 while many other projects were in an advanced phase of administrative approval. Therefore the part of the hypothesis regarding the expected installed capacity increase has been *confirmed* for wind technology in Spain.

Table 7.11 *The accumulated increase in installed capacity since 1995*[54]

Capacity / Year	1995	1996	1997	1998	1999	2000
Annual MW increase	115	235	425	834	1476	2900 MW
policy support mechanisms for small developers/projects				(and) 90-100 projects with 100-270 MW		

7.3.2.2 The prospects for sustainable diffusion processes

Hypothesis 1 expected that under optimal investment contexts, the supported technology has good prospects for the sustainability of market diffusion processes in the long term. Both the industrial basis and dynamics, and the socio-economic benefits from diffusion were assessed as potentially large after short-medium term diffusion under optimal investment contexts.

In Chapter 2, we argued that the prospects for sustainable diffusion processes need to be analysed from three angles: cost performances, technical performances and socio-economic-industrial context. In the first part of this section, we discuss the progress in cost performance improvements and the sources of cost reductions, based on the four categories of cost factors distinguished in Section 2.8. After that we refer to the diffusion continuation prospects from the perspective of cost performances in relation to the remaining wind resource potential and the technical performances of wind technology in the electricity system. In the next part of the section, we test the theoretical expectations with regard to the socio-economic-industrial context created by diffusion under an optimal investment context. In the last part, we look at the remaining obstacles to diffusion for wind energy in Spain.

Cost performances[55]*, technical performances and remaining resource potential*

The progress in cost performances of wind technology in Spain by 2000 was substantial. The lower part of the range of production costs per kWh reached the cost competitiveness threshold with 3,6-4,2 €c/kWh at wind speeds 9-10 m/s and minimum 2400 hour/year. For regions with wind speeds higher than 6 m/s and wind availability for minimum 2000 hour/year, production costs were possible in the range of 4,2-6,6 €c/kWh. But cost performances are influenced by many types of factors. They influence the spread of the production costs range upwards, meaning that there were still large areas where the legally guaranteed price since 1998 (6,3-7 €c/kWh) did not enable profitable projects.

Table 7.12 *Cost performances of wind technology in Spain by 2000*

Evolution cost sources	wind technology in Spain, early 1980s – 2000
technology specific[56]	33% reduction (in 1990: ~ 950 €/kW; in 2000: 630 €/kW; up to 750 €/kW[57])
technology- complementary	moderate but increasing slowly
context induced	high and fast increase since 1995
quality / price resource exploited	wind speeds > 6 m/s and min 2000 hour/year; mostly 4,2-6,6 €c/kWh
average (per kWh) production costs[58]	3,6-4,2 €c/kWh at wind speeds 9-10 m/s and minimum 2400 hour/year

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[54] At the end of 2002 there were already 4830 MW installed in Spain (Source http://www.appa.es).

[55] We collected data and conducted empirical analysis regarding cost performances in 2001 and early 2002. In December 2002 a study was completed by the Association of Renewable Energy Producers APPA for the Ministry of Economy with regard to the profitability of wind projects in Spain and cost performances of wind power plants. This report underlines the causes in the evolution of production costs changes (costs per kWh). Our empirical findings summarised in Table 7.12 and discussed in this sub-section have been fully backed up in this report. The findings of the APPA report are summarised in the newsletter APPA Infor No. 9 of December 2002, Barcelona downloadable at http://www.appa.es.

[56] Source Energia Journal (2000) and IDAE ([1] 1999).

[57] Lowest technology specific costs in Spain are 540 €/kW (Energia 2000: 22).

[58] Coal based electricity had a cost of around 4 €c/kWh in Spain.

In Chapter 2 we differentiated among four categories of costs: technology-specific, technology-complementary, context-induced, and resource quality/availability. Empirical research shows that, in spite of substantial reductions in technology-specific costs, there was an increase in the weight of the second and third group of factors mentioned, as summarised in Table 7.12. We explore below the changes in the four categories of cost factors for wind technology in Spain.

As regards cost performances, we argued in Chapter 2 that the category of technology specific factor*s* has the second heaviest weight in production costs. This includes technology costs per kW based on factory price, as well as all technical characteristics that could influence electricity generation such as availability and efficiency. Empirical research showed that significant *reductions* were achieved in *technology-specific costs*. In 1995 the average factory costs were 744 €/kW.

The lowest technology costs in 2000 were 540 €/kW factory price. This represents a 27% decrease as compared to the 1995 costs. Market experts explained that in 2000 turbines in the 600-660 kW band had the lowest costs because the very large demand for these models helped manufacturers achieve economies of scale. However Table 7.8 shows that there were higher size turbine models entering the market since 1998 as technological progress in wind technology continued. Because of the novelty of higher size turbines, technology specific costs spread in 2000 in the range up to 750 €/kW, and possibly even higher. But more sources (Idae 1999; Energia 2000) and interviewees considered the value of 630 €/kW as typical in 2000.

The following factors converged towards the lowering of technology-specific costs. Firstly, there was intense competition among manufacturers. The lowering of economic risks, while the opportunities for high profitability remained large, raised the interest of increasingly more economic actors to invest. Besides, the gradual increase in project finance availability made possible the implementation of developers interest to invest. Consequently, since 1995, increasingly more foreign manufacturers signed technology transfer agreements with Spanish companies from various industrial sectors in order to produce their technology locally. Other manufacturers opened offices for technology import. In 2000, 16 manufacturers were present in Spain, compared to only 7 in 1994 (see Tables 7.1 and 7.9).

Secondly, the requirement of local authorities that project developers pay (increasingly high) royalties for local socio-economic development, and the increase in land rent costs urged developers to look for the lowest cost technological designs, so that these extra expenses do not affect too much the profitability of their projects. Thirdly, the administrative approval criteria required manufacturers to produce the technology in the region or locally. This avoided transport costs and reduced slightly labour expenses, leading to lower factory costs. Fourthly, the design of the support systems indicated to manufacturers and developers that a gradual reduction in financial support for wind energy would take place, which was an extra incentive to take care that technology-specific costs decrease. The price design in the two economic governance structures envisaged the revision of price levels both annually and after a 4-5 year period. The annual updates were connected to consumer prices. But in the 4-5 year assessments the government was taking as reference the progress in technical and cost-performances of technologies. In addition, as Chapter 6 explained, the level and target group of investment subsidies shrank substantially in the second part of the 1990s, while the 1998 policy plan for renewables eliminated them.

In addition to technology-specific costs, the availability and efficiency of turbines on the Spanish market also improved substantially in the second half of the 1990s. In 1996 the national average level of efficiency of all functioning turbines was 1000 kWh/m^2 while in 2000 this increase to 1500 kWh/m^2 or even more. In the same time availability increased to 98-99,5% by 2000 (Energia 2000; IEA 2000).

In the second category, *technology complementary costs increased* since 1995 and the trend continues (Idae[1] 1999). These costs are influenced by resource location, site accessibility and topography, and the characteristics of electricity transport grid to which the wind plant has to be attached. In the last years of the 1990s, new resources were detected that are mostly located in unpopulated hilly and mountainous areas with difficult access. These aspects increase the costs for civil works, electrical-mechanical infrastructure and grid connection. The spatial pattern and availability of electricity transport grids across the Spanish territory do not match very well the spatial distribution of wind resources. On the one hand, there are sites with good wind resources for which there are difficulties with grid connection because transport lines are already saturated with electricity flows from long-established points of generation and consumption. This requires extra expenses for grid reinforcement and electrical-mechanical infrastructure. On the other hand, there are many good resource sites situated far away from the electricity transport grids or any possible point of consumption. Special distribution lines have then to be constructed purposely for the wind projects at those sites. This requires more costs for grid expansion, civil works, transportation, and electrical-mechanical infrastructure.

Developers of projects facing such difficulties incur substantially higher technology-complementary costs. Having in view that in Spain wind generators are paid the same price per kWh no matter the costs incurred, these extra expenses lead to the reduction of projects' profitability[59]. When wind energy resources are not sufficiently high to compensate for the extra costs, projects become unprofitable and have to be abandoned (Idea [1] 1999). The 1998 policy plan for renewables acknowledged this problem and proposed that a study be done regarding the location and size of grid expansion and reinforcement needs. It also proposed several ways of financing such works. Developers have doubts however regarding the possibility to raise the funds envisaged in the plan, because the contribution from public finance is too small, and there is no vision on how could private finance be attracted[60].

In the third category, the overall *context induced costs increased* since 1995. The increase was quite fast in the years 1999-2000 due to intensified competition to invest. We differentiated in Chapter 2 among three segments in the category of context induced cost factors: monetary consequences of financing and trade arrangements; expenses in project life-cycle stages, and administrative(-social) expenses. We expected that in time the costs in the first two mentioned segments would decrease and practical developments confirmed this. In Section 7.3.1.2 we discussed the changes in the financing parameters in the period 1995-2000. Interest rates lowered, the period of loan reimbursement required by banks increased, and the equity contribution requirement by banks lowered[61]. Besides, since 1998, developers do not link anymore the expectation on investment costs recovery period to the guaranteed contract length of 5 years, because the third economic governance structure improved the perception of

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[59] As it was presented in Chapter 6, the governmental renewable agency's criteria for investment subsidies eligibility in 1998 and 1999 envisaged 30% or 40% maximum subsidies for wind systems in locations with difficult access or high grid connection costs, below the size of 5 MW. But the 1999 policy plan for renewables does not envisage any form of financial support for such projects after 2000.

[60] The plan estimated that 9,6 billion Euro would be necessary, of which 69,5% are expected to come from private investors based on the project finance formula, combined with investments funds, capital risk brokers, futures credits and guaranteed bond issues, among other. Besides, 17,4% are expected to come from the internal financial resources of the developers of wind projects themselves, while the little rest is planned to be secured from European Union development funds, from funds of the Ministry of Energy and Industry, and regional governments.

[61] But higher financing costs were still signalled for small companies who cannot accede to joint ventures with large developers - which would make project finance terms more attractive.

policy stability. Interviewees mentioned that in 2000 many companies accepted investment recovery periods of 10-12 years. All these changes contributed to production costs' reduction.

As regards expenses in project life-cycle stages, these also lowered. On the one hand, the competition for providing wind technology and components, and services in all stages of wind projects' life cycle increased substantially, as discussed below in the section on industrial basis and dynamics. Besides, many companies were offering vertically integrated services for many or all phases in project development, construction, operation and maintenance, which also contributed to lowering costs in this segment[62]. But, on the other hand, the vertical integration in the wind industry also included to some extent the segment of wind project owners. Many developers were subsidiaries of manufacturers, or companies holding ownership shares in either manufacturers or other companies in the wind industry offering various services. Hence, *ownership connections* also contributed to the lowering of expenses in project life-cycle stages, leading to lower production costs.

But in the third segment, costs increased to an extent that sometimes cancelled the reductions achieved in the other two segments. In this segment, costs relate to social and administrative permit approval, taxes for different public authorities, land rent fees and even expenses for various local/regional social/economic benefits. In some cases additional environmental impact studies are required for local approval or investments that can reduce such impacts. But these cost increases are small, compared to those assumed by the royalty requirements of local authorities, regional investments and land rent fees.

Local public administration plays an important role in what projects are approved. Local agencies in regions with good wind resources realised that the harnessing of wind energy can bring important economic benefits locally. Gradually and informally the majority of local authorities started to condition the approval of projects on the payment of a special financial contribution by developers to local budgets, referred to as 'royalty'. This can be paid either when the wind project is put into operation or during the entire operational life of the wind farm, as a percentage of project's profitability. As these private agreements were not part of a regulated framework in the period 1995-2000, the level of royalty differed largely from one place to another and increased with the intensification of competition in resource rich areas. This led sometimes to the situation that projects were not anymore economically feasible because, based on the overall economics of the project, developers could not afford to pay the requested royalty[63]. The 1998 policy plan for renewables signalled this problem. But it only proposed that the royalty be nationally harmonised and that developers do not have to pay taxes for them.

Beside this, or sometimes alternatively, regional/local authorities require that developers make specific investments for social welfare, such as the construction of public libraries, sport facilities, schools, local transport facilities and so on. In some cases these investments came on the account of the wind projects to be constructed and hence had to be added to the overall production costs per kWh of the wind projects built there. In other cases the regional/local investment requirements were larger, such as the construction of a car manufacturing factory or other industrial activities in the region. These large-scale investments were separate from the wind projects and represented just new businesses of the developer(s) in the region without

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[62] For example in 2000 there were 45 companies specialised in turn-key project construction. Developers using turn-key services can realise savings as compared to hiring more companies for the different phases of the project before setting it into operation.

[63] As governmental experts mentioned in the 1998 renewables' policy plan "A positive attitude of municipalities can make redundant wind projects successful in the approval process, while a negative attitude can create delays or make impossible the commissioning of an installation" that could otherwise be a good project (Idae [1] 1999).

implications for the level of production costs of wind electricity. Finally, land rent fees also increased steadily since 1995 both in the case of the public land of municipalities and for private land. According to some sources, land rent fees can represent 1,5% of the price received per kWh of wind electricity (Energia 2000). In contrast to the problem of technology complementary costs, the weight of context induced costs related to administrative and local fees is smaller. While the industry average of technology complementary costs is 20% in overall investment costs per kW installed, context induced costs are assessed to have a weight of 5%, also as a national average. However, in some cases, having in view the complex interaction of factors in the four categories differentiated, some projects can be made economically un-feasible due to inflated expenses in one or these two categories or both.

The fourth category of factors differentiated, which has the strongest influence on production costs, is formed by *resource quality and availability*. Experts suggest that in 2000 wind projects using turbines of 600-660 kW rated power (in the lowest cost band), at sites with annual average wind speeds of at least 8- 9 m/s (at 10m height), and annual availability of nominal wind speeds[64] above 2400 h/year could generate electricity at around 4 - 4,2 €c/kWh, when it was possible to minimise technology complementary costs and the impact of context induced factors[65]. Calculations made by governmental experts and (Olmos et al. in Energia, 2000) showed that projects under such circumstances were able to generate electricity at the production cost of 3,6 €c/kWh[66]. Having in view that the average cost of coal-based electricity in Spain and the average market pool price were around 4 €c/kWh[67], it can be therefore said that for specific resource-technology niches, cost-competitiveness was achieved in Spain in 2000. It is not clear how much capacity, in terms of MW, was installed by that year able to generate wind electricity at market prices. This is something developers would not say when guaranteed prices are still round 7 €c/kWh. Nor it is known how much resource potential was left for which production costs at market prices were possible, or where these sites were located. In the frenzy to install as much as possible as soon as feasible, many developers were actually poorly aware of the resource potential available at the sites where they applied for projects, or elsewhere.

Beside this cost-competitive niche, there was also a chunk of potential that was economically feasible with the price support available in 2000. Taking into account that the legally guaranteed price in since 1995 was in the range of 6,3-7 €c/kWh, market experts mention that sites with wind speeds above 6 m/s and a minimum annual availability of 2000 hours per year were economically feasible in this period (Menendez 1998: 97; Cruz 2001; Lopez 2001). But this does not mean that automatically all sites with such characteristics could be developed into wind plants. Factors in the technology complementary category and/or context induced category were often making such sites not profitable. Finally, there were sites with technically feasible potential, using state-of-the-art technology at the end of the 1990s, but for which production costs were above the available price support. Market experts estimate (Cruz 2001; Energia 2000) that the net technically available potential in 2000 assumed

[64] As we discussed in Chapter 4, the nominal wind speed of a turbine is the speed at which the turbine can function at the maximum capacity for which it was designed, called rated capacity/power. Most turbines have nominal speeds of between 11-16 m/s, although moderate wind turbines have already been developed which require speeds of 8-10 m/s for rated capacity.

[65] Combined information IDAE (1999), Energia (2000), APPA website, Menendez (1998), Ibarra (1996).

[66] The assumptions were: plant size 15 MW (which was the size of 40 projects installed during 1999); annual wind availability of 2400 hour/year; use of turbines of 600 kW or 660 kW; site with normal topographic accessibility and 10 kW connection lines (Energia 2000: 42).

[67] Mato mentions a cost of coal-based electricity of around 4 Ec/kWh, while nuclear-based electricity could have costs up to 8,4 €c/kWh depending on the degree to which the investment costs of the nuclear plant have been amortised (Mato 1998).

production costs between 4 - 9 €c/kWh. In the same time, the governmental renewable agency assessed at the end of 1998 the net technically available potential at 15.100 MW (Idae[1] 1999). Having in view that between 1998 and 2000 a capacity of at least 2.100 MW wind power was already installed, this means that at the end of 2000 the remaining technically exploitable potential was roughly 13.000 MW. For this potential, the production costs spanned across the three types of cost performances just mentioned, as showed in Figure 7.1

Diffusion continuity depends on the extent to which the available price support enables the economically feasible use of the technically exploitable resource potential. Figure 7.1 represents the situation in 2000 in Spain, where some unknown part of the potential technically exploitable with state-of-the-art technology was economically feasible. It suggests that unless substantial cost reductions occur in the technology specific and context induced categories (which are the two categories liable for governmental and/or market influence), the governmental price support needs to increase in order to realise the remaining technically exploitable potential. Assuming that this price increase takes place, diffusion continuity requires then the expansion of the exploitable resource base by means of technical improvements. Figure 7.2 represents the relationship between resource potential, grid integration ceiling and type of technological design needed to be adopted with priority in Spain, for the year 2000 and the expectation for long-term.

Figure 7.1 *The situation on cost-performance and wind resource potential in Spain, 2000*

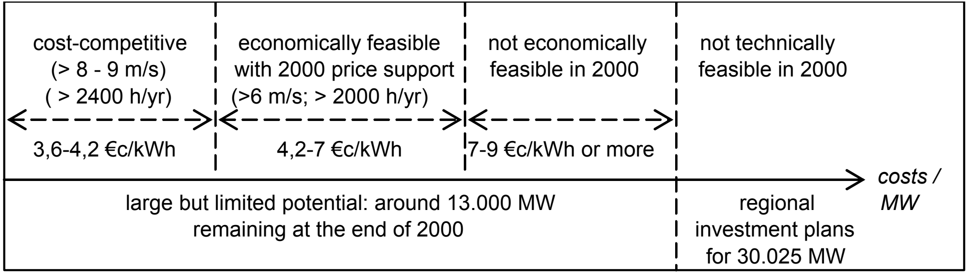
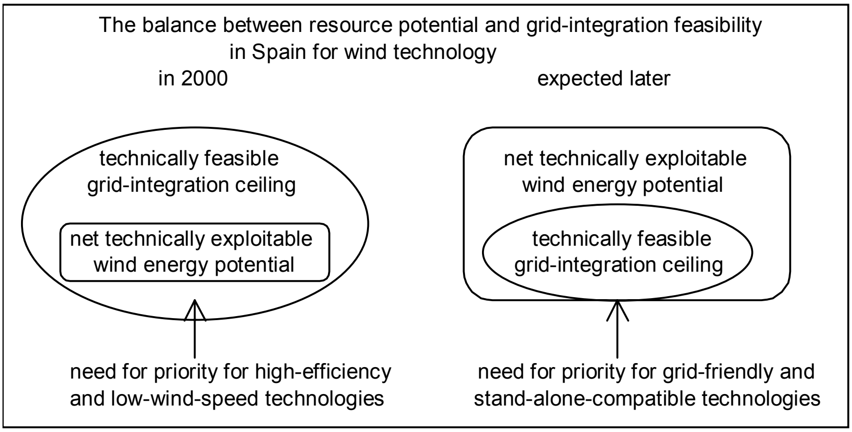


Figure 7.2 *The relationship between resource potential, grid integration ceiling and type of technological design needed with priority in Spain*



There is currently (in 2002) no agreement regarding the technically feasible grid integration ceiling. The main reason for disagreement is actually political, because once the government admits that the ceiling is high, the industry pressure builds up to maintain price support until that ceiling is reached. In 2002 the government considered the ceiling for grid-integration of wind power as around 13.000 MW, which happened to be the same with its new target for 2011 (Bustos 2002)[68]. But technical experts consider that grid-ceiling can be as high as 30% contribution to total electricity consumption from the grid. Assuming consumption levels in 1998 remain the same (although a very effective energy saving policy would be needed), and also that technology performances remain the same, this would be the equivalent of around 33.600 MW wind power. Regional governments have their own investment plans because they are interested in the socio-economic benefits wind energy harnessing can bring locally. In 2002 their investment plans totalled 30.025 MW. This would approach the 30% grid integration ceiling discussed by some technical experts.

In any case from the perspective that interests us, of long-term sustained diffusion through market expansion, the situation in 2000 in Spain was that net technically exploitable wind energy potential was equal, but more likely smaller, than the technically feasible grid integration ceiling. This situation, represented in the left side of Figure 7.2, requires the development with priority of technological designs with substantial improvements in efficiency and the ability to operate at rated capacity in average and low wind speed, below 10 m/s (see Chapter 4). However, the development of wind technology designs able to function in low wind speeds is viewed by the government in the 1998 policy plan for renewables only as ‘research priority 3’ (Idae [1] 1999). But as mentioned in Section 7.3.1.5, manufacturers and developers, who are taking the pulse of the market more closely, already engaged in the development of turbines able to function in moderate wind speeds.

It is hoped that by 2010 when the technically exploitable potential with current technologies is likely to be exhausted, new technology designs would be available on the market in order to sustain diffusion through capacity expansion. As long as this does not happen, diffusion can only be sustained by means of re-powering the wind plants whose technical life ended. If technologies with such characteristics become widely available and price support for their diffusion continues, it is possible to see in the long term a reverse of the situation, whereby the grid-integration ceiling would be lower than the technically exploitable resource base (right side of Figure 7.2). In this case the technological priority for market adoption would be the use of grid-friendly and stand-alone compatible designs. But the grid-integration ceiling can be raised more substantially, the earlier grid-friendly designs start to dominate market adoption[69]. In Section 7.3.1.5 we showed that indeed in 2000 these technological designs already represented 55% of installed capacity while more manufacturers were preparing market entry with grid-friendly designs.

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[68] This is replacing the target in the 1998 renewable energy plan of 8974 MW by 2010.

[69] This does not take into account changes that are possible to be made to increase wind contribution in a network by means of restructuring the technological and fuel base at national level. If more flexible power plants, such as open cycle carbon technologies or pumped storage hydropower plants have a larger presence in the energy resource structure of a national energy system, the contribution of intermittent renewable energy resources in that system can be increased (Hartnell and Landberg 2000) - see Section 4.1.

Figure 7.3 *Possible levels of wind energy contribution growth in electricity supply*

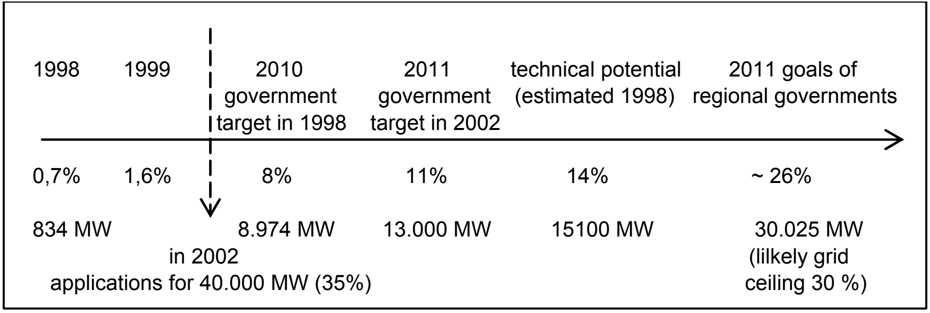

Figure 7.3 shows some data on wind contribution in electricity consumption from the grid at the end of the 1990s, and potential contribution under investment initiatives of developers in 2002, governmental targets formulated in 1998 and in 2002, the technically exploitable potential in 1998, and the total of regional targets for 2011. Leaving aside the issue of technical feasibility, which remains a serious challenge, the governmental target for renewables appears much smaller than the total target of regional governments, which in its turn represents a lower capacity than the total number of applications that developers already forwarded to approval authorities in March 2002, which was as high as 40.000 MW (Bustos 2002). In its new infrastructure electricity plan for 2011 (adopted in September 2002) the government promised the “continuity of the favourable regulatory framework currently in place” for the new target of 13.000 MW wind power by 2011.

This political statement means that the chunk of remaining technically exploitable potential which was not economically feasible in 2000 (see Figure 7.1) is likely to receive the increase in price support when production cost reductions are not sufficient to reach the target. But the maintenance or even further price increase in order to install the capacity aimed at by regional governments and developers depends on the political will and/or the success of the wind industry and all actors having a stake in wind energy harnessing to lobby for continuity in one form or another of support system able to offer the necessary price levels to cover wind electricity production costs. The following paragraphs will look at the features of the socio-economic-industrial context of diffusion in 2000, comparing them with theoretical expectations and discussing their political lobby potential. This section will end with a review of the main obstacles facing diffusion beside those pertaining to the economic and technical aspects just discussed.

The features of the socio-economic-industrial context of diffusion in 2000

In Chapter 2 we formulated the expectation that under optimal investment contexts market diffusion processes are likely to be sustainable in long-term. The diverse and large ownership of wind plants created by technology diffusion, the large industrial basis likely to emerge, and the substantial and pervasive socio-economic benefits expected to accompany the patterns and scale of diffusion were considered likely to successfully exert political lobby in favour of preserving and/or improving the support system for the respective renewable technology towards long-term sustained diffusion.

Table 7.13 compares theoretically expected with empirically observed features of the socio-economic-industrial context emerging from the large wind power capacity increase in Spain by 2000. As regards the socio-economic benefits from wind technology diffusion, we expected them to be the largest under this type of support system, which was confirmed by empirical findings. A *large size of the industrial basis* serving developers of wind projects was observed with intensive dynamics favouring competition, which *confirms* the theoretical expectations.

Table 7.13 *The features of the socio-economic-industrial diffusion context for wind technology in 2000 - theoretical expectations and empirical findings*

Diffusion context likely to emerge		Area 1- theoretically expected	wind in Spain
Socio-economic benefits		Large	Large
Local	Direct: ownership	Likely present	Partly confirmed
	Indirect: more attractive (than usual) benefits from ~ land rents ~ local taxes; ~ local economic or social welfare investments	Likely high	Confirmed
	Indirect ~ local employment	Technology specific	High
National	Ownership individuals (shares)	Likely present	Not confirmed
	Employment in industry	Likely high	Confirmed
Industrial basis and dynamics		Large	Large
Number companies offering products / services for wind electricity plants		Large	Confirmed
Types of companies involved in industry		Large presence of corporations from a wide diversity of industrial sectors	Confirmed
Degree of specialisation in renewables		High	Confirmed

Socio-economic benefits

As regards the socio-economic benefits from wind technology diffusion, we expected these benefits to be the largest under this type of support system. Empirical findings point indeed towards large overall socio-economic benefits. But this assessment rests on slightly different elements than theoretically expected. We considered direct benefits to be coming from local ownership by various types of actors, from investments in the form of share participation by individuals in investment funds at national level. Indirect benefits would come from investments of large developers, as well as local and national level employment.

In practice in Spain there was a poor representation of small local developers in the projects developed locally or regionally, while no projects based on equity investments by individuals in special investments funds for wind were realised. But there was very high local and national level employment related to wind plants' construction, operation, manufacturing and other industrial activities. Besides, there were very high benefits from the investments of large developers especially in terms of generous fees for land renting and investments in local economic development and social welfare. We considered that the extent of these indirect benefits and the large scale of wind related employment compensates for the absence of the other two forms of expected benefits. The very large contribution through local taxes and regional socio-economic development transformed regional authorities in Spain in powerful advocates for economic protection and price support for renewable energy. For this reason we assessed the overall socio-economic benefits as large. The lesson from the analytical framework standpoint is that only indirect socio-economic benefits could be enough to consider a discontinuation of price support for renewables politically costly, when such benefits are sufficiently large and widespread.

One of the channels for social-embeddness considered was the direct involvement of local municipalities and people in wind projects by means of small ownership shares or direct economic benefits. Co-ownership is difficult to track down because many projects have been developed by vehicle-companies with unique names and non-transparent participation. The involvement of large industrial companies, energy utilities, regional authorities and financial agencies in some vehicle-companies could be mapped to some extent from interviews. But this was difficult to do for small local companies, individuals and even local authorities in small cities. Some interviewees suggested that the involvement of local authorities occurred sometimes, especially in the first period of market diffusion, up to 1994, and then again towards the end of the 1990s, while small local firms and individuals started to receive small shares in the projects of large corporations only towards the end of the 1990s. Beside this, some projects could be developed by small developers with help from one of the three policy support mechanisms put in place by the governmental renewable energy agency after 1998. But their number was too small to consider the ownership involvement of small developers and local authorities of small cities and villages as representative at national level.

However, this was compensated by the increasing economic benefits that the same group has been receiving in the form of royalties - by local municipalities, as well as land rent fees - payable to individuals owners of private land or again to municipalities as owners or administrators of municipal lands. For example, land rent fees can represent as high as 1,5% of the wind plants revenue, which is very attractive for local agents[70]. But arrangements are also made on a long-term basis. For example, the Bonus Town Hall of Valencia concluded with a renewables-specialised company an agreement for the use of municipal land over the following 49 years, for which the town hall received the amount of 4,3 million Euros[71]. And this type of arrangements can be found in almost all Autonomous Communities where good wind resources were identified. As the long-term rented lands are often remote from social and industrial sites and in difficult-access areas, this is a good indicator for the sustainability of market diffusion processes for wind technology, suggesting that companies specialised in renewables are confident they can stay in business at least half a century. In consequence, although ownership involvement is a durable channel of socio-economic embeddness, the fact that direct economic benefits for local people and authorities are possible suggests that the sustainability of market diffusion processes will be supported along its social-economic dimension, or - in any case - will not be obstructed.

Another social-embeddness channel assumed the creation of jobs, both directly and indirectly. A strong representation in trade unions important for the political lobby that these could exercise for the maintenance of economic-policy support systems in case there would be a threat of premature withdrawal. But in the same time it plays an important role in creating an atmosphere of acceptance towards the commissioning of wind energy projects, especially, as regards population in the proximity of resource-rich sites. From these perspectives, both the number of jobs created at national level and their distribution inside the territory are important. In Spain, at the end of 2000 there were no publicly available governmental studies focused on counting the jobs created by wind energy.

An information note issued by the trade union the Communist Workers Commission in mid 2001 mentioned that according to its estimations there were 5000 direct jobs and 7000 indirect jobs created by the wind industry. Based on our assessment, these jobs were not evenly distributed among the Autonomous Communities. But they were rather concentrated in the regions were governments adopted early enough, in 1995-1998, their regional development plans for wind, and have linked the administrative approval criteria to jobs' creation and the strengthening of the industrial base of the region.

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[70] An example here is the agreement reached in the Somozas municipality of Galicia, between the developer Energias Ambientales and the 165 property owners, whereby for each wind turbine an annual fee of 1503 Euro is paid. Most of those properties have never been used for any economic purpose, while some were considered good future sheep grazing sites - which can still take place (Windpower Monthly, April 2000: 39, "Regional plan gives boost to Galicia - first phase of Somozas line".

[71] Windpower Monthly, February 2000: 21, "Valencia calls a halt under avalanche".

For example, in 1995 Galicia was the first Community to issue a regional plan for wind development whereby direct requirements for contribution to regional employment, industrial development and welfare were made in order to qualify to invest in the resource rich region. The Plan required that at least 70% of the manufacturing process for any single wind farm installed in Galicia be carried out in the region. At the end of 2000 Galicia had the largest wind installed capacity in Spain (617,5 MW) among the 17 Autonomous Communities. But it also had a large diversity of turbine types installed, bringing production plants of many manufacturers in the region - Desa, Gamesa, Bonus-Bazan, and Ecotecnia[72]. The regional energy agency suggested that the 1995 regional wind plan created 12 industrial plants, providing 650 jobs[73]. The number of wind-related jobs was also high in Navarra, the Community with the second largest wind-capacity (470,4 MW) at the end of 2000. This is the region where the manufacturer Gamesa had its main headquarter from the beginning. By 2002, Gamesa employed around 1150 people. Following these two, were the Communities of Castilla la Mancha, and Castilla y Leon and Aragon.

Canary Islands, Andalucia and Catalunia had only modest levels of wind development, although each Community counts with the presence of a Spanish manufacturer, respectively Aerogeneradores Canarios SA, Dessarollos Eolicos SA and Ecotecnia. In the first case the reason is that the integration of wind energy is limited in an island system and planning needs to be done more carefully. In the other two cases the delays in the adoption of the regional wind development plans have retarded approval of projects and gave incentives to manufacturers to expand their production plants elsewhere. In early 2000, there were still Communities without a final plan for wind energy, such as Valencia, Asturia, Extremadura, Andalucia and the Basque Country. The resource assessment work, consultations and the elaboration of regional development plans for wind energy lasted much longer than in the other Communities. However, the future seems to be promising for many Communities, since many of them have reshuffled their plans after the adoption of the 1998 Royal Decree and the 1998 governmental plan for renewables[74].

Therefore, the number of jobs in the new wind industry of Spain will surely increase quite fast. The Communist Workers Commission expects that by 2010 at least 8000 direct permanent jobs will be created for the commissioning of the 8140 MW target. But looking at the expected number of jobs per region, this number seems to be much higher. Governmental experts made some more detailed estimations and expect that 105820 people will be needed per year for design and construction works, while 1625 permanent jobs will emerge for operation and maintenance for the achievement of the 8140 MW target[75]. The Association of Renewable

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[72] Ecotecnia has traditionally not manufactured the components of its wind turbines but it subcontracted their production to other industrial companies, and it used the factories in Galicia and Navarra to put pieces together and assembly the turbines (Prats, interview 2001).

[73] Windpower Monthly, August 2000: 10, "Galicia revises wind strategy".

[74] Valencia adopted in 2000 a plan for wind development aiming to install 1700 MW by the year 2010. The regional government maintains that the plan will create 20000 jobs, the key objective of the plan being to reduce to half the energy import dependency while bringing wealth and employment "to more socially and economically depressed areas in the mountainous interior". The new development plan of Castilla y Leon was adopted also in 2000, envisaging the installation of 2980 MW by 2010, which is expected to create over 10000 jobs. Of these, 485 jobs will be permanent maintenance and operation jobs. The new regional wind plan of Galicia also expects 2000 direct jobs more and 3000 indirect jobs, to increase its installed capacity to 2800 MW by 2010. (Sources: Windpower Monthly November 2000: 32, "Valencia finally get wind strategy - favouritism feared"; Windpower Monthly June 2000: 32, "Regional long-term plans at last - interdepartmental co-operation"; Felix Avia Aranda and Ignacio Cruz Cruz, CIEMAT, "Breathing ahead: Spain", in *Renewable Energy World*, May-June 2000).

[75] Information from www.ccoo.es and Energia, 2000:13.

Energy Producers mentions another estimation, expecting to see 19616 jobs in the Spanish wind industry by 2010.

Consequently, this channel of socio-economic embeddness can be considered already 'fluent' in Spain at the end of 2000, and for the future. Wind technology diffusion has created large social-economic benefits, as expected under optimal investment contexts.

Industrial basis and dynamics

Table 7.14 mentions the number of companies offering different types of services and products necessary along wind projects' life cycle.

In 2000 there were 10 turbine manufacturers with production facilities located in Spain, 24 suppliers or manufacturers of towers and 6 producers or suppliers of blades. Further, there was intense competition for engineering and technical consultancy services (65 companies), for the very important service of turn-key supply (45 companies) and maintenance and operation services (32 companies). In total, 200 companies formed the wind industrial sector in 2000, which can be viewed as a large and dynamic industrial basis[76]. The 2001 report on renewable energy and employment of the Communists Workers Commission mentions that in terms of production capacity, the Spanish wind industry produced, in 2001, 5% of the wind capacity installed in the world, while in many other industrial sectors Spanish production only represents 1% of output at world level.

Table 7.14 *Industrial companies offering products and technical services for wind energy systems in Spain at the end of 2000*

Products[77] / Services related to wind energy systems	Number of companies offering the product / service
Wind turbines	10
Mechanical construction	24
Constructions based on polyester and vidrio fibers	8
Electrical equipment	30
Regulation and control equipment	32
Hydraulic equipment	9
Operation and maintenance services	32
Forge, foundation and lamination works	20
Generators	5
Engineering and technical consultancy	65
Turn-key construction and installation services	45
Installation	21
Meteorological instrumentation	12
Multiplicators	9
Blades	6
Towers	24
Transformers	10
Other services / products	32
Total companies forming the wind industrial sector in 2000	200 companies

Based on Energia, 2000: 132-135

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[76] The government estimated that the wind industrial companies located in Spain are able produce 1500 MW of wind power per year. If in the period between 2000-2011 the industry would provide this capacity annually, an additional wind capacity of 16.500 MW could be installed (Idae [1], 1999).

[77] For the products of wind turbines and blades we counted only those companies offering such products for medium and large size turbines. The rest of the data were left as aggregated numbers - for both mini-turbines (<100 kW) and for medium/large size turbines - because it was not possible anymore to disentangle which companies offer services/products for which types of turbines.

The degree of specialisation in wind energy can be assessed as high, since many companies were focused only on wind plants related services while others were even more narrowly specialised in offering only certain types of services and/or products. Based on the data in Table 7.15 it can be observed that 70% of the companies were only offering 1 or 2 types of services/products. Further, 20% of the companies were integrating 3 or 4 types of services/products, and only 10% were simultaneously offering more than 5 types of services/products.

Table 7.15 *The extent of vertical integration of wind industrial companies along the value chain of wind energy systems production and development*

Number of services / products offered by wind industrial companies	Number of companies offering certain number of services / products
1	103
2	41
3	21
4	18
5	11
6	3
7 or 8 or 9	3
-	Total 200 companies

As regards the types of companies, many large corporations from a diversity of industrial sectors were involved in serving the growing demand for wind plants construction and operation. The number or companies with links in other industrial sectors is larger than the number of new entrants who joined the wind industry without previous industrial activities. For example, the factory for blades manufacturing in Toledo is a joint venture between the Danish LM company and the national company for ammunition production. The manufacturer Bonus-Bazan involved the national shipbuilding concern Bazan. Both these companies experience shrinking demand and found a good refugee in the wind industry. Similarly, many of the country's biggest construction and infrastructure corporations were offering services and/or components for the wind sector.

Other large corporations specialised in electrical, hydraulic and mechanical equipment have large orders from manufacturers and companies who assembly wind energy systems on the ground. Companies with experience on legal advice and environmental impact studies, working also for other industrial branches, expanded their activities also in the wind sector where the demand is high for speedy procedures. This way the Spanish wind industry grew up as a self-standing but not isolated industrial sector. It has slowly grown out of other existent industrial branches, sometimes filling up decreasing demand in some areas, other times offering space for development of corporations in search for diversification, but always extending its roots more deeply and widely in the overall industrial-economic system.

In conclusion, the Spanish wind industry base at the end of 2000 was able to offer a very high diversity of products, there was competition for supplying all types of products and services needed to construct wind-based energy systems, while the new sector was strongly rooted in the industrial structure of Spain, ensuring it also substantial back up in trade unions and political lobby. Consequently, the expectations regarding the features of the socio-economic-industrial context after diffusion under optimal investment context can be assessed as *confirmed,* for wind technology diffusion in Spain 1995-2000. In 2000 a series of factors were still interfering with market diffusion processes, which we discuss in the last part of this sub-section.

Overcoming other types of obstacles that do not assume technical solutions

Specialised Spanish literature, interviews with developers and policy documents point towards several factors confronting the market diffusion of wind technologies, the removal of which assumes solutions placed outside the scope of technical answers. Some of these factors can be qualified as 'obstacles' in the sense that they impede new investments, or drastically reduce the number of wind farms that can be commissioned, threatening directly this way the sustainability of market diffusion processes. Other factors act however, in our opinion, as 'filters' for market diffusion patterns, rather than as obstacles, in the sense that they do not cancel the opportunities for new investments but favour certain types of developers, or place - directly or indirectly - constraints on the technological choice of investors or on the sizes of projects that can be developed.

We place the following factors in the category of *obstacles* for sustainable market diffusion processes: 1) grid connection options and costs; and 2) environmental-administrative problems. The main constraining factors acting as *filters* for diffusion patterns are of an 1) administrative-economic nature and 2) social-economic nature.

The *obstacle of grid-connection options* is quite complex and requires a clear-cut analysis in order to understand the magnitude and timing of its impact on the sustainability of diffusion processes for wind technology. This is related to one of the major technical problems of wind technology, namely the macro-fluctuations in the volumes of wind-based electricity production due to the hourly, daily and seasonal variations in wind energy availability and mis-match with electricity demand. This is seriously challenging the role that wind energy can play in electricity supply systems. Even assuming that complementary meteorological tools are developed so as to predict these fluctuations, the variability of wind electricity generation still remains an issue for grid managers who will have to find back-up power when consumption demand increases while wind availability decreases. Technical experts argue that this inconvenient could be minimised if wind plants do not have too large sizes and if they are attached to the transport grid as dispersed as possible. The smaller and more disperse wind installations across a network are, the higher the theoretical ceiling of grid integration of wind technology in that network can be[78]. In the same time the need for back-up capacity at system level decreases as windfarms located at sites with different patterns of wind variability can smooth out each other's 'peaks' and 'valleys', making grid management an easier task.

But this solution to the macro-fluctuation problem is difficult to implement in practice because several reasons. Firstly, it is difficult to control the sizes of wind farms. Both the 2366/1994 Royal Decree and the 2818/1998 Royal Decree tried to do so by placing limits on the sizes of wind plants eligible to the special regime - 25 MW and 50 MW respectively. Wind plants have been defined as a number of wind turbines that are connected to the transport grid through a single interconnector, and did not account together for more than 25 MW, respectively 50 MW after 1998. But legal constraints did not stop developers to construct wind farms one next to the other making grid management very difficult in some regions.

For example in the Autonomous Community of Castilla la Mancha there were around 300 MW wind capacity installed at the end of 2000, of which approximately 250 MW are concentrated in a very small area. As one interviewee explains, "they are split into windfarms of 40-50 MW in the administration and commercial papers because that is the limit to get the bonus, but they are located one next to another and for the grid is like a huge plant at one site,

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[78] This does not take into account changes that are possible to be made to increase wind contribution in a network by means of restructuring the technological and fuel base at national level. If more flexible power plants, such as open cycle carbon technologies or pumped storage hydropower plants have a larger presence in the energy resource structure of a national energy system, the contribution of intermittent renewable energy resources in that system can be increased (Hartnell and Landberg 2000) see Section 4.2.

with variable and unpredictable output". Given the market rush to install as much as possible wind turbines in the attractive investment framework created after 1998, these developments could possibly be stopped through the introduction of special technical approval criteria regarding the grid-compatibility of new investments in the administrative authorisation process. But a disadvantage for this would be however that large sites with good wind resources will only be possible to be exploited partially.

Secondly, it is difficult to steer market diffusion of wind technology in sites with a good dispersion across the electricity network. On the one hand, wind energy resources are not always located where technical grid managers would have liked to see them placed based on grid-compatibility considerations. On the other hand, the Spanish electricity network integrates generation systems from 15 Autonomous Communities, all interested in wind energy systems. Attracted by the economic, industrial and social benefits brought about by investments in wind energy, but also by the ideas of clean electricity production and energy self-sufficiency, all regional governments have designed ambitious plans to approve investments in wind energy systems within their territory. Some Communities even designed special policy support mechanisms to attract wind investors in their regions.

At national level the government aims at a cumulated installed capacity of 8974 MW by 2010 (according to the 1998 target), but the cumulated target of regional governments - although referring to different time horizons - indicates a higher level of ambition than the governmental target. Consequently, given the competition that has emerged among Autonomous Communities, it is difficult to predict the consequences for the degree of spatial dispersion of investments with regard to grid structure and strength. If some regions are faster in adopting regional plans for the strategic development of wind energy and if the authorisation procedures run also faster there, it is possible that investments will concentrate in those regions, posing problems for grid management at national level. Differences in the speed of administrative reaction have already led to observable results at the end of 2000, when most of the investments were concentrated in Galicia and Navarra, followed by Aragon, Castilla y Leon and Castilla La Mancha. But in 1999, wind energy represented only 1,6% of total electricity generation in Spain, which does not pose unsolvable problem for grid management yet. However if developments continue to be similarly unbalanced this may lower the technically feasible ceiling of grid integration for wind technology on a long-time span, as the installed capacity increases.

The second obstacle facing the sustainability of market diffusion processes has an *environmental-administrative nature*. Although "the public image of wind energy is generally favourable, sometimes this is not sufficient for finalising large wind-park projects. (…) While the most important environmental groups in the country are in favour of wind energy development and act positively towards its implementation, local groups are frequently raising disproportionate objection against the visual impact, or the impact on birds and land of wind installations" (Idae[1] 1999).

Beside these more classical types of environmental arguments, the complaint that environmental benefits do not accrue locally has also been raised. In the Autonomous Communities where the added wind capacity is exported to other regions in Spain, either because the wind farms are large and need to be directly connected to the high-voltage transmission grid or because the region has already a surplus of generation capacity, this argument has also been confronting wind developers. Several interviewed developers mentioned that local opposition based on environmental grounds can produce delays between 3 to 5 years for the construction of wind plants (Lara, Lopez 2001). The overall number of projects refused due to environmental impact reasons is low, compared not only to the number of successful projects in Spain, but also to the number of rejected projects in other countries.

However, local environmental opposition is considered an important obstacle for wind technology market diffusion by Spanish wind developers.

This obstacle is magnified by the absence - at the end of 2000 - of a coherent national approach and set of criteria for the way the environmental impacts of wind projects should be analysed and what the approval conditions should be. On the one hand, the political and administrative division of competencies between the central government, the regional governments and local authorities results in the dominance of local criteria for environmental approval, instead of a harmonisation with the national environmental interests. On the other hand, the regional ministries of environment did not have still in 2000 a harmonised set of assessment-approval criteria. Acknowledging this environmental-administrative obstacle, the 1999 policy plan for renewables proposed that action be undertaken for the national harmonisation of the environmental treatment of wind plants.

Beside these two obstacles, investments in wind technology are also constrained by some factors acting as filters for the diffusion patterns of wind systems. Firstly, there is a different type of administrative bottleneck challenging the market diffusion of wind technology. Agencies of local public administration play an important role in what projects are approved or not. Local agencies in regions with good wind resources have realised that the harnessing of wind energy can bring important economic benefits locally. Gradually and informally the majority of local authorities condition the issue of their approval of projects on the payment of a special royalty by developers to the local budgets. This royalty can be paid either when the wind project is put into operation or during the entire operational life of the wind farm, as a percentage of project's profitability. As these private agreements are not part of a regulated framework, the level of the royalty differs largely from one place to another and increases with the increase of competition to install wind projects among developers. This created a situation where sometimes projects were refused approval by local authorities - on environmental or social opposition grounds - because developers could not afford to pay the requested royalty[79].

In this context, we argue that this is not an obstacle for the technology itself, because ultimately one or another of the projects proposed will be approved, since municipalities are interested that wind capacity is installed in their territory. It is rather an obstacle for small developers, such as small private firms, associations, co-operatives or even individuals who might be interested to invest locally, favouring large companies and industrial groups, which in turn creates local opposition for allowing local resources make outside companies rich. Besides, in order to manage the problem of increasing costs due to local royalties, developers may also be forced to look for lower-cost technologies, to secure the initially intended levels of project profitability and returns on equity. And, in addition to this, the royalty requirements of local authorities are discouraging for the commissioning of self-generation plants by local firms and individuals.

Consequently, local royalties act altogether as a filter for three of the indicators for diffusion patterns we are focusing on - types of project developers, technology choice and possibly also drivers to invest (favouring commercial projects). The 1998 policy plan for renewables signalled this bottleneck and proposed a nationally uniform system whereby the private economic agreements between local authorities and developers should not attract extra costs for developers. The proposal is to allow developers full exemption of taxes on the money paid to local authorities as royalty, and to limit this royalty at twice the annual business tax for the wind plant.

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[79] As public experts themselves mentioned in the 1999 renewables' policy plan "A positive attitude of municipalities can make redundant wind projects successful in the approval process, while a negative attitude can create delays or make impossible the commissioning of an installation" that could otherwise be a good project (Idae[1] 1999).

Secondly, social opposition grounded on economic considerations is also a factor in delaying projects and shaping diffusion patterns. Local population is often embittered by the fact that utilities and large corporations may install large windfarms on the municipal land or neighbouring private land and make fast and substantial profits. As a consequence, private land-owners adopted a double strategy. Some owners increased the rent, which according to some sources can represent 1,5% of the price received per kWh of wind electricity. Other landowners, when approached by large companies with the request of land renting, combine this price strategy with that of asking first local firms and individuals if they are interested in constructing wind plants on their resource rich lands. Only when no local economic actor shows interest, do land owners give their agreement to large corporations. This approach has been first noticed in Andalucia where there are some sites with very good wind resources, such as Tariffa and Cadiz (Sodean 2001).

In contrast to the problem of grid connection feasibility and costs, the weight of land-renting related costs is far smaller than the weight of grid expansion and reinforcement costs in the overall costs of a project. Moreover, no cases have been mentioned in the specialised empirical literature of wind projects rejected as a result of social opposition based on economic considerations. In this context we are of the opinion that this is also rather an obstacle not for the wind technology itself but for specific non-local project developers - which actually works positively towards the socio-economic embeddness of wind technology that will be discussed in the following paragraphs.

The next section summarises the main findings of this section and draws the conclusion regarding the extent of confirmation of the theoretical expectations under Hypothesis 1.

7.3.3 Summary and conclusions regarding Hypothesis 1

This section tested Hypothesis 1 for the case study defined by the diffusion of wind technology in Spain in the period 1995-2000. In Chapter 3 we formulated Hypothesis 1 as follows.

A support system leading to a national investment environment of low to medium economic-policy risk and high to very high levels of project profitability will induce *diffusion patterns* that are characterised by:

- the involvement of all types of project developers, having
- predominantly commercial motivation to invest, using
- predominantly external financing schemes, in
- mainly medium and large size projects, based on
- the use of all types of technological designs of which new and/or existing diffusion-optimal technological designs are likely to be more frequent.

Such diffusion patterns will result in:

- a *large installed capacity* increase in short-medium term; and
- *good prospects for the sustainability* of market diffusion processes in the long term for the renewable technology envisaged.

Diffusion patterns

Section 7.3.1 analysed the diffusion patterns of wind technology in Spain in the period 1995-2000. The extent of confirmation of the theoretical expectations regarding diffusion patterns can be assessed as good. For two indicators of diffusion patterns - the choice of technological design and types of financing schemes - the expectations were ‘confirmed’. For other two indicators - types of developers and drivers to invest - they were ‘confirmed to large extent with comment'. And finally, for one indicator - project sizes - the results 'confirmed with comment'. The inset 'with comment' means that special policy support mechanisms were responsible for the fact that certain predicted patterns could be indeed observed. These results represent a large-degree of overlap with the theoretical expectations. We summarise here the main findings regarding diffusion patterns.

In the case of the indicator *types of project developers*, the expectations were 'confirmed to large extent with comment'. Most projects were owned by large developers and there was substantial diversity among economic actors involved. The main investors were electricity companies, which had shares in more than two-thirds of capacity installed by 2000. They were followed by financially-strong industrial groups, as new entrants from a wide variety of industrial sectors, banks, insurance companies, and manufacturers of wind turbines. Public authorities and agencies at all administrative levels were also co-owners in numerous projects. The presence of small developers was smaller and possible only because the governmental renewable energy agency introduced in 1998 three policy support mechanisms especially targeting their market entry[80].

As regards *drivers to invest*, the diffusion of wind technology between 1995-2000 took place overwhelmingly by means of commercial projects. There was an unclear but presumably small number of self-generation projects. This was mainly due to the special policy support mechanisms aiming to help self-generators overcome the financing obstacle. The number of projects dedicated for the demonstration of new technological designs (or existing designs but used for the first time in Spain) was not very large. This happened because technology risk perception lowered so much among all types of economic and financing actors that often new designs were tested as part of large commercial projects, where proved models were also used. Beside demonstration, other strategic motivations were not identified, taking into account the typology in Chapter 3. The drivers to invest for this case study were considered as confirmed to large extent (with comment because of governmental intervention for self-generation).

The indicator of *project sizes* was considered as 'confirmed with comment', because the three policy support mechanisms that influenced the observed forms of drivers to invest and types of developers also affected its forms, enabling small and very small projects. Large developers have been exclusively interested in large and very large projects.

Diffusion results

In Chapter 3 it was discussed that the theoretically expected diffusion patterns would lead - on a short/medium time span - to diffusion results that are able to support the continuity of market diffusion processes in the long-term. This diffusion results would consist of large increase in installed capacity, sufficiently strong socio-economic embeddness of the respective technology, and a large supportive industrial basis and intensive industrial dynamics. The assumption was that no other obstacles would impede market diffusion processes. Section 7.3.2 reviewed these indicators of diffusion results at the end of 2000, the cost and technological performances reached by wind technology, as well as the remaining non-technical obstacles confronting the continuity of market adoption processes after 2000. The empirically observed diffusion results regarding installed capacity and the features of the socio-economic-industrial context of diffusion emerging *confirm* the theoretical expectations. We are summarizing them here.

The increase in wind *installed capacity* in the six year period, 1995-2000, was indeed large, as expected, with 2086 MW built and many more hundreds under construction.

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[80] One scheme was based on third party finance by the renewable agency Idae and the other two were soft loan schemes (see Chapter 6).

Cost-performances have improved significantly in the period studied. The technology-complementary and context-induced costs increased - mainly due to higher grid connection costs, infrastructure costs, land renting and local royalty costs. But the technology-specific costs decreased quite substantially. Thanks to increasing competition among manufacturers and service suppliers, substantial cost reductions have been achieved in technology components, especially the turbines, as well as both technical and non-technical services related to wind plants commissioning and operation. This way it became possible, in certain high-quality resource sites, to construct wind plants for production costs that are competitive with conventional technologies. However, it is estimated that for the economically feasible exploitation of technically available resources, increases in price support might be needed in the future when the potential for technology-specific cost reduction is exhausted.

The improvements in *technical performances* have been significant and fast, although challenges still remain. The challenges of high efficiency and performance at low/moderate wind speeds have been only in the last years tackled more seriously. No breakthrough has been so far achieved at international level in these areas, but the incremental improvements registered so far are being increasingly reflected in the preference of Spanish manufacturers and investment preference of developers in Spain. At the end of 2000 there were six Spanish manufacturers developing turbine models for moderate-wind regimes located in Spain, and increasingly more switched to or were considering switching to diffusion optimal technology design (from grid-friendliness standpoint). Besides, as competition for high-resource sites is getting increasingly tougher, developers are also becoming interested in turbines for moderate wind-regimes. Consequently, it can be argued that there was both diversity and quality in the improvements of the technical performances of the wind turbines developed and adopted in Spain, reflecting the state of the art of the technology at international level.

As regards the *socio-economic benefits,* significant progress has been achieved since 1995 when the market diffusion rate started to accelerate. In terms of employment, wind technology offered direct permanent jobs to 5000 people while other 7000 received indirect jobs. Many of these jobs were created in the regions with high levels of installed capacity, improving the social acceptability of wind projects construction. Expectations for the future differ but they are all optimistic. They vary between 10.000 and 100.000 wind-related jobs by 2010. The political lobby in favour of the long-term maintenance of economic support system for wind energy on grounds of job protection counts already with the support of regional governments and national trade unions. Besides, it also extends to influential industrial groups from other traditional branches, such as shipbuilding, construction and even weaponry who extended their, sometimes seriously demand-endangered activities, into the emerging wind sector.

The second channel of socio-economic embeddness considered - the economic benefits for local population surrounding wind parks - has also been opened by the end of 2000. Although direct ownership in wind farms by local population is rather rare, the economic benefits have been increasingly obvious. In some cases they are coming in the form of substantial land rent fees. But, in most cases they are indirect, through the royalties paid by developers to local authorities and through the projects for regional and local economic and social welfare some developers are implementing as part of the agreements preceding the administrative approval.

Positive developments were also registered in terms of *industrial size and dynamics*. Spain counted at the end of 2000 with the presence of around 15 manufacturers, among which all world top-ten turbine producers. At least 200 companies were forming the already consolidated wind industrial sector. There was competition at all levels on the value chain of project development and project operation, both for technical and non-technical services, and for all types of technology components. The toughest competition was for the services of engineering and technical consultancy, with at least 65 companies, and for turn-key construction and installation processes, with 45 companies. Besides, at least 30 companies were offering maintenance and operation services. The stability of the industrial basis and the potential for political lobby were also already considerable, since most of the companies were subsidiaries or had ownership connections with energy utilities and large industrial groups from other branches.

All these diffusion results for wind technology in Spain respond to the theoretical considerations and expectations underlying and included in Hypothesis 1. They create the framework for sustainable market diffusion processes in the long-term, provided that the remaining technical as well as the still existing non-technical barriers are eventually removed. As discussed in Section 7.3.2.2, technical innovations are still expected, and they should be able to lead to much higher levels of efficiency in wind energy extraction and to exploit low-wind energy regimes. Unless these sorts of innovations are developed and become fast commercially available, the technically feasible wind potential will be at a certain moment exhausted and wind technology will only supply the available repowering market.

Apart from this, market diffusion processes are also challenged by difficulties with grid connection options, costs and patterns. In many cases good resource areas are remotely located from grids. When grids are available they are often already overloaded. And often infrastructure and grid extension and reinforcement costs are high. Besides, the investment patterns of developers themselves run the risk of turning against the chances for a large degree of penetration of wind technology in the electricity system. In a rush to invest and make the most out of good resource sites, wind plants are becoming extremely large and placed one next to another. This poses increasing difficulties for the technical management of grids, which at a certain moment might no longer be able to accommodate additional intermittent and unpredictable wind power. Our research showed that as a result of using a very favourable economic-policy support system, in Spain the continuity of wind energy market share increase is highly likely, having in view the forms taken by diffusion patterns and the impressive diffusion results registered after only 6 years of support system applicability.

Therefore, the extent of confirmation of the expectations on diffusion results of Hypothesis 1 can be assessed as *good*.

Exogenous factors and alternative specifications

The following factors emerged as influencing the diffusion patterns in this case study:

1. the criteria for projects' approval by regional authorities since 1994/1995; they favoured developers able to offer as many benefits as possible for regional economic development and social welfare; small developers had little to offer except for taxes;
2. business interests of the regional and local authorities, which often were interested to develop or co-own the resource rich sites in the regions themselves;
3. the business culture and business interest of the domestic financing actors: banks have inflexible requirements on client types and loan volumes they are willing to finance; but since 1998/9 they started to invest equity in many projects and companies becoming competitors to many developers, including small developers;
4. the business culture of small developers: individuals and small developers have a lower level of entrepreneurship, environmental sensitiveness, and average individual welfare than in countries such as Denmark, Austria and Netherlands were such features were often signalled as underlying investments in renewable energy plants;
5. ownership connections/agreements between manufacturers and developers;
6. special policy support mechanisms to enable small developers, self-generation wind plants and (very) small size projects: one scheme was based on third party finance by the renewable agency Idae and the other two were soft loan schemes.

The first three mentioned factors acted as obstacles for the presence of small developers, small size projects and self-generation projects. The last mentioned factor aimed to counteract the effect of them.

7.4 Summary

In Chapter 6, we specified the hypotheses to be tested in the framework of empirical research in Spain regarding the diffusion of renewable electricity technologies. In this chapter we tested, in Section 7.2, Hypothesis 2 for the case study of wind technology market introduction in the period 1980-1994. Further, in Section 7.3 we tested Hypothesis 1 for the case study defined by wind technology diffusion in the period 1995-2000.

In the case study for the testing of Hypothesis 2, the independent variables of economic-policy risks and ranges of project profitability *did not appeared to have a strong explanatory powe*r with regard to the diffusion patterns and diffusion results of the supported technology. The extent of confirmation of the theoretical expectations under Hypothesis 2 was ‘partly satisfactory’ for both diffusion patterns and diffusion results (for which theoretical expectations were formulated). Beside the influence of the two independent variables, we identified a set of six factors that influence diffusion patterns and results. Two of these relate to the business culture of economic actors in Spain. One factor was constituted by the additional governmental policy interference to stimulate the domestic wind technology manufacturing industry. And finally two factors relate to the level of technological development of wind systems at that time, both in terms of de-facto technical performances and perception of technological risks.

In the case study for testing Hypothesis 1, the independent variables of economic-policy risks and ranges of project profitability *appeared to have a strong explanatory powe*r with regard to the diffusion patterns and diffusion results of the supported technology. The extent of confirmation of the theoretical expectations under Hypothesis 1 was *good* for both diffusion patterns and diffusion results. Beside the two independent variables, we identified a set of six factors that influence diffusion patterns and results. Three of these are circumstantial in nature: ownership connection: developers - manufacturers - financing agents, regional administrative approval criteria, and business interests of administrative authorities. Two factors relate to the business culture of economic actors in Spain - financing agents and small developers. Finally, one factor was constituted by the additional governmental policy interference to steer diffusion patterns and help disadvantaged developers (while in Chapter 2, Section 2.5 we assumed that no such interference would act of diffusion patterns).

The next chapter tests two more hypotheses regarding the diffusion of biomass electricity technologies in Spain during the 1980s and the 1990s. After that, Chapter 9 will focus on the testing of the same hypotheses as in this chapter - Hypotheses 1 and 2, for the case studies of small hydropower technology diffusion. Chapter 10 concludes Part II of the book, which focused on theory testing for renewables diffusion in Spain.

Appendix 7.1: The wind-based energy systems and the indicators for diffusion patterns of wind technology during 1980-1994

Year	Project names	Drivers to invest	Type of financing scheme	Project developer	Technical design	Project size
1987 to 1990	11 projects: Ampurdam, Granadilla 1; Estaca de Bares; Ontalafia; Tarifa 1 and Tarifa 2; La Muela 1; Exttenstion La Muela 1; Cabo Creus; Juan Grande; Cabo Vilano	Strategic: demonstration of national turbines	All with internal financing: multi-contribution finance 6 projects; in-house corporate finance (4 projects) & third-party finance 1 project. All with subsidies.	IDAE; Energy utilities (Endesa, Unelco, Union Fenosa); Manufacturers (Made, Ecotecnia); Regional authorities	Spanish conventional designs for testing: Gesa 37,5 kW; Ecotecnia 25 kW, 30 kW and 150 kW; Made 75 kW, 110 kW & 150 kW; Awec 1200 kW.	all very small (0,12; 0,3; 0,45; 0,45; 0,30; 0,30; 0,15; 0,185; 0,59; 0,15; 1,200 MW)
1991	5 projects					
	Granadilla 2, ITER	Commercial & Strategic	In-house corporate finance	research institute ITER	Enercon 330 kW	0,330 MW
	Aringana Acsa		Project finance	manufacturer Acsa	Acsa225 kW	0,225 MW
	Granadilla 3		Internal multi contribution + subsidies	IDAE; Canary Government; energy utility Unelco	Ecotecnia 25 kW, Acsa 55 kW	0,080 MW
	Cabo Vilano 2		In-house corporate finance	Utility Union Fenosa	Vestas 100&200kW	0,300 MW
	Santa Comba	Demonstration	n.a.	Energia Galicia	G.A 55 kW	0,055 MW
1992	12 projects					
	P.E del Sur (Pesur) in Tariffa	Commercial & Strategic	Corporate finance (in-house + debt) + subsidies. Later changed to project finance	Initially built by energy utility Endesa; later sold to PESUR (project vehicle company)	Made 150 kW; and AWP 100 kW	20,1 MW
	P.E. E3 in Tariffa }	Commercial & Strategic	Internal multi-contribution+ subsidies. Later merged; changed to project finance	project vehicle company: Energias Eolicas del Estrecho	Ecotecnia 150 kW and Made 180 kW	10,38 MW
	P.E Levantera in Tariffa }	n.a.	n.a.	local authority Tariffa	Made 150 kW; AWP 100 kW	0,650 MW
	Aguatona – El Garrizal	Commercial & Strategic	Project finance	manufacturer Acsa	Acsa 225 kW	1,125 MW
	P.E de Tenefe					1,225 MW
	P.E Costa Calma					1,225 MW
	P.E Mt. Mina	Commercial & Strategic	Project finance	manufacturer Acsa	Acsa 100 kW	0,100 MW
	Aguatona Ingenio					0,100 MW

	Arinaga				Acsa 225 kW	0,225 MW
1992	P.E Cabo Villano 2	Commercial	Internal multi contribution + subsidies	energy utilities Endesa and Union Fenosa	Made 150 kW	3 MW
	Granadilla	Demonstration	In-house corporate +subsidies	Endesa (sold to ITER)	Made 300 kW	0,300 MW
	P.E Tariffa 3	Demonstration	Third party financing + subsidies	IDAE and Ecotecnia	Ecotecnia 200 kW	0,200 MW
1993	5 projects					
	Valverde Hierro	n.a.	n.a.	Energy Council Canary.	Acsa 100 kW	0,100 MW
	La Aldea	n.a.	n.a.	Energy Council Canary.	Acsa 225 kW	0,225 MW
	Jandia Puerto Cruz	Water desalinization / commercial	internal multi-contribution + subsidies (50%)	national energy research institute - Pajara Townhall		0,225 MW
	Agaete, Las Palmas	n.a.	n.a.	Energy Council Canary Island	Made 150 kW	0,150 MW
	Eolicas de Lanzarote	Commercial and partly water desalinization	Combined: in-house corporate and debt-corporate finance	project vehicle company (water utility; energy utility Unelco)	Made 180 kW AWP 100 kW	5,28 MW
1994	12 projects					
	P.E Monteahumada	Demonstration	In-house corporate finance	energy utility Endesa	Made 300 kW	0,900 MW
	Turbine Desa A 300	Demonstration	n.a (interview)	new manufacturer Desa	Desa 300 kW	0,300 kW
	P.E de Aragon (La Muela 3)	Commercial and strategic	Internal multi-contribution + subsidies	Made, energy utility ERZ, Aragon Government	Made 300 kW	5,28 MW
	P.E. Barranco de Tirajana 1	Commercial	Internal multi-contribution	energy utility Unelco and Canary Government	Made 180 kW	1,26 MW
	P.E. Canada Rio	Commercial	Debt-corporate finance	water company + energy utility	Made 180 kW /300 kW	10,26 MW
	Turbine in Mt. de S. Juan	Commercial	In-house corporate finance	energy utility Unelco	Made 180 kW	0,180 MW
	P.E Juan Adalid-Garafia	Commercial				1,26 MW
	2 turbines in Granadilla	Commercial/strat.	In-house corporate finance	research institute ITER	Enercon 500 kW	1,0 MW
	Turbine in Valladolid	n.a.	n.a.	private individual	Oleohidraulica 110 kW	0,110 MW
	Turbine in Calaf	n.a.	n.a	public agency Barcelona		0,110 MW
	P.E Sierra del Perdon 1	Demonstration	Debt-corporate finance	renewables-specialised EHN	Gamesa 500 kW	3,0 MW
	Juan Grande Tirajana	Demonstration	In-house corporate fin.	energy utility UNELCO	Made 330 kW	0,330 MW

Appendix 7.2: Wind projects with financial investments from governmental renewable energy agency IDAE, up to 1994

Yr	Name project / Type of financing scheme	Capital structure				Investment costs recovery	Would-be owners / other actors involved	Size, MW	Technological design	Price €c/kWh
		IDAE equity	Subsidies	Equity others	Bank loans					
1987	Granadilla 1, multicontribution finance	yes	yes	yes	-	n.a.	n.a.	0,30	Ecotecnia, Gesa & Acsa	n.a.
1987	La Muela 1 multicontribution finance	36,8 %	19,8 % based on the Electricity Law 82/1980	43,2 %	-	~ 28,6 yr	IDAE; energy utility Endesa; regional government	0,45	Gesa 37,5kW	6,2
1987	Estaca de Bares multicontribution finance	37,4 %	17,2 % based on Law 82/1980 + 8 % regional government Galicia	37,4 %	-	~ 14,4 yr	IDAE; utility Endesa	0,45	Gesa 37,5kW	6,7
1987	Ontalafia, third-party finance	65,8%	yes	n.a.	n.a.	n.a.	n.a.	0,30	n.a.	n.a.
1988	Tarifa 1 multicontribution finance	56,2 %	22,6 % based on Law 82/1980 + 7 % regional government Andalucia	10,2 %	-	~ 11,7 yr	IDAE; manufacturer Ecotecnia	0,30	Ecotecnia 30 kW	6,2
1989	Tarifa 2 multicontribution finance	28 %	16,4 % based on Electricity Law 82/1980 + 22,6 % European Union + 5 % regional government Andalucia	28 %	-	~ 16,2 yr	IDAE; manufacturer Ecotecnia	0,15	Ecotecnia 150 kW	6,2

1991	Granadilla 3 multicontribution finance	yes	yes	yes	-	n.a.	IDAE, Ecotecnia, Canary Islands regional government	0, 08	Ecotecnia 25 kW & Acsa 55 kW	6,2
1992	Tarifa 3, third party finance	66,8 %	33,2 % European Union	-	-	~ 4,6 yr	IDAE; manufacturer Ecotecnia	0,20	Ecotecnia 200 kW	6,3
1992-1993	Seasa, project finance	0,92 %	9,86 European Union + 8,9 % national government + 7,15 % regional authority Andalucia	13 %	60,2 %	~5,5 yr loan recovery	IDAE, Ecotecnia; Made; Abengoa; regional grid utility; regional development agency	both plants = 30 MW	AWP 100 kW; Made 150/180 kW Ecotecnia 150 kW	~7,2

Appendix 7.3: The wind-based energy systems and the indicators for diffusion patterns of wind technology during 1995-2000.

Diffusion patterns during the period of the 2nd economic-policy support system, 1995-1998						
Year	Number projects and names	Drivers to invest	Type of financing scheme	(Type of) Project developer	Technical design (degree of maturity)	Project size (MW)
1995	total 4 projects					
	Kilowatto-Tariffa S.A	Commercial (with new turbines)	equity + loan	project-vehicle company (American utility; U.S. Kenneth manufacturer; regional grid utility Sevillana; 2 construction companies)	New in Spain: Kenneth 330 kW	29,7 MW (over upper legal limit)
	Planta Eolica Europea	Commercial (with new turbines)	n.a.	project-vehicle company (Danish utility; Danish manufacturer; regional grid utility Sevillana)	New in Spain: Nordtank 500 kW	6 MW
	Turbine in Gran Canaria	Self-generation	In-house corporate fin.	Water company Maspalomas	Oleohidraulica 110 kW	0,110 MW
	P.E Bajo Ebro	Commercial	Project finance	project-vehicle company PEBESA (public authorities: IDAE, ICAEN, 1 regional & 1 local; Ecotecnia)	Commercial: Ecotecnia 150 kW	4,05 MW
1996	total 13 projects					
	Turbine in Tariffa (1)	Demonstration	Third-party finance	IDAE and Ecotecnia	New: Ecotecnia 500 kW	0,500 MW
	Turbine in Tariffa (2)	Demonstration	Third-party finance		New: Ecotecnia 600 kW	0,600 MW
	Turbine in Mt. Ahumada	Demonstration	In-house corporate fin.	Endesa	New design Made 500 kW	0,500 MW
	P.E. de la Plana 3	Demonstration	n.a.	Manufacturer Gamesa	New: Gamesa 600 kW	15 MW
	P.E. de Borja 1	Commercial	Project finance	Company specialised in renewable projects: CEASA	Commercial (by then): Gamesa 600 kW	16,2 MW
	Turbine in Gran Canaria	Self-generation	In-house corporate fin.	Water company Maspalomas	Oleohidraulica 110 kW	0,110 MW
	2 turbines in Gallarda	Commercial	In-house corporate fin. + subsidies local bodies	energy utility UNELCO	Commercial Made 180 kW	0,360 MW
	P.E Cueva Blanca	Commercial			Commercial Made 330 kW	1,32 MW
	P.E. Granadilla	Commercial	In-house corporate fin. + subsidies local bodies	UNELCO-ITER	Commercial Made 300 kW	4,8 MW
	Turbine at ITER	Commercial		ITER research institute	Commer: Enercon 230 kW	0,230 MW
	P.E. Llanos de Juan Grande	Commercial	n.a.	Manufacturer DESA (Canary subsidiary)	Commercial: DESA 300 kW	20,1 MW
1996	P.E Sierra del Perdon 2	Commercial	Debt-corporate finance	Company specialised in	Commer: Gamesa 500 kW	17 MW

	P.E. Leiza Berbete			renewables investment EHN	Commer: Gamesa 600 kW	19,2 MW
1997	total 17 projects					
	P.E. de Enix 1	Commercial	Project finance	Roject vehicle company: PEESA	Commercial: Made 300 kW	13,2 MW
	P.E Vadecuartos	Demonstration	In-house corporate fin.	Taim-Nordtank Eolica	New design in Spain: Taim-Nordtank 600 kW	0,600 MW
	P.E La Muela 2 (Vale del Ebro)	Commercial	Project finance	Project-vehicle company: PEVESA	Commercial Made 330 kW	13,2 MW
	P.E. el Pilar	Commercial	n.a.	Project-vehicle company Wind Corporation Zaragoza	Commer: Gamesa 600 kW	15 MW
	P.E de Remolinos	Commercial (new turbines)	Project finance	Company specialised in renewable projects: CEASA	Altered design: Gamesa 660 kW	9,76 MW
	2 turbines private	Self-generation	Private finance	Private individual	Oleohidraulica 132,5 kW	0,265 MW
	P.E de Santa Lucia	Commercial	Project finance	Project-vehicle company: PESLSA	Commercial Made 300 kW	4,8 MW
	P.E Olvega Noviercas (Sierra del Madero)	Commercial	Project finance	Project-vehicle company: PESMSA	Commercial Made 330 kW	14,85 MW
	P.E de A Capelada	Commercial	Project finance	Project-vehicle company: A.I.E. Capelada	Commercial Made 330 kW	16,5 MW
	P.E de Malpica	Commercial	Project finance	Project-vehicle company: PEMALSA	Commercial: Ecotecnia 225 kW	10,075 MW
	P.E de Barbanza	Commercial	Project finance	Project-vehicle company: PEBSA	Commercial Made 330 kW	19,8 MW
	P.E Coriscada 1	Commercial	Project finance	Project-vehicle company: SEMOSA	Commercial: Gamesa 600 kW	12 MW
	P.E Paxareiras 1	Commercial (new turbines)	n.a.	Specialised wind-investment company: Eurovento Seawest	New in Spain: Bonus-Bazan 600 kW	20,4 MW
	P.E. Paxareiras 2A		n.a.			19,2 MW
	P.E San Martin Unx	Commercial	Project finance	Company specialised in renewable energy: EHN	Commercial: Gamesa 600 KW	24,6 MW
	P.E. Lerga					19,8 MW
	P.E. Leoz					24,6 MW
1998	total 32 projects					

	62 mini-wind & wind-PV projects, < 47 kW	self-generation or mechanical use	Private finance	Individuals and small companies	other type of turbine market	
	2 turbines Aguimes	Partly self-generation	n.a.	Artes Grafica Atlantico S.A.	Commercial: ACSA 225 kW	0,450 MW
	1 turbine La Vereda		n.a.	Cooperativa Agricol Vereda		0,225 MW
	1 turbine at Centro CIEA	R&D,commercial & self-generation	100 % EU subsidies	research center ITC (Canary Islands)	Commercial: Enercon 230 kW	0,460 MW
	1 turbine in Palencia	Demonstration	In-house corporate fin.	Manufacturer MADE	New design Made 600 kW	0,600 MW
	1 turbine in Barcelona	n.a.	n.a.	Town Hall Llacuna	Commercial: Enercon 250 kW	0,250 MW
	1 turbine in Barbanza	Demonstration	In-house corporate fin.	Manufacturer MADE	New design Made 660 kW	0,660 MW
	P.E. Tahivilla	Commercial	n.a.	Manufacturer DESA	Commercial Desa 300 kW	30 MW
	P.E Muel (Zaragoza)	Commercial	Project finance	Project-vehicle company: EEMSL	Commercial Taim-Nordtank 600 kW	19,2 MW
	Remolinos (extension)	Commercial (new turbines)	Project finance	Company specialised in renewable projects: CEASA	New design: Gamesa 660 kW	1,98 MW
	P.E. Planas de Pola 1		Project finance			27 MW
	Bahia de Formas	n.a.	n.a.	Private company	Commercial: Enercon 500 kW	2 MW
	P.E. Granadilla 2	Commercial	Debt-corporate finance	ITER research institute		5,5 MW
	Faro Fuencaliente	Commercial	Project finance	Manufacturer MADE	Commercial Made 300kW	1,5 MW
	P.E. Finca de Mogan	Commercial	Project finance	Project-vehicle company: PEFMSA	Commercial Made 300kW	10,5 MW
	P.E. El Pradell 1	Commercial	Project finance	Project-vehicle company: Entrocaderro S.A.	Commercial: Ecotecnia 225 kW	14,85 MW
	P.E. Corriscada 2	Commercial	Project finance	Project-vehicle company: Manon-Ortigueira	Commercial: Gamesa 600 kW	12 MW
	P.E Zas La Coruna	Commercial	Project finance	Manufacturer DESA	Commercial Desa 300 kW	24 MW
	P.E. Muras 1	Commercial	Project finance	Project-vehicle company Energeticos de Muras S.A.	Commercial: Gamesa 660 kW	24,42 MW
	A Capelda (extension)	Commercial	Project finance	Project-vehicle company: A.I.E A Capelada	Commercial Made 330kW	14,85 MW
	P.E. Vicedo (Lugo)	Commercial	Project finance	Project-vehicle company: P.E. Vicedo S.A.	Commercial: Bonus-Bazan 600 kW	24,6 MW
	P.E. Bustelo Muras 1	Commercial	Project finance	Project-vehicle company: P.E. Ascoy S.A.	Commercial: Gamesa 660 kW	5,94 MW

1998	P.E. Serralta	Commercial	Project finance	Company specialised in wind projects: Eolica Cabanillas (of Elecnor & EuroEnergia)	Commercial: Ecotecnia 600 kW	15 MW
	P.E. San Gregorio	Commercial				15 MW
	P.E. Echague	Commercial	Project finance	Company specialised in renewable energy: EHN	Commercial: Gamesa 660 kW	23,1 MW
	P.E. Alaitz					26,4 MW
	P.E. Izco					33 MW
	P.E. Aibar					16,5 MW
	Xistral Soan 1	Commercial (new turbines)	Project finance	Project-vehicle company: AEGA	New design: Neg-Micon Nordtank 750 kW	58,5 MW
	P.E. Barbanza	Commercial	Project finance	Made E.R.	Commercial Made 330 kW	19,8 MW
	P.E. Arico 1					11,5 MW
Diffusion patterns during the period of the 3rd economic-policy support system, starting to function in 1999						
1999	31 wind projects					
	1 turbine in Tariffa	Demonstration	n.a.	Wind Iberica Espana	New model launched: Gamesa 1650 kW	1,650 MW
	5 projects: Arico; Sierra del Madero 1; Bustello 2; Barbanza 2; La Muela 3	Commercial	Project finance	MADE E.R. (manufacturer and developer)	Commercial: Made 330 kW; & Made 660 KW	Total: 68 MW (11,5; 14,9; 15,8; 9,24;16,5)
	Tahivilla2	Commercial	project finance	Manufacturer DESA	Commercial Desa 300 kW	30 MW
	Corme	Commercial (new turbines)	project finance		New model launched: Desa 600 kW	18,3 MW
	P.E. A Capelada	Commercial (new turbines)	Project finance	new renewable subsidiary of energy utility: Union Fenosa Energias Especiales (UFEE)	New design in Spain: Neg-Micon-Nordtank 600 kW	33 MW
	Los Lances	Commercial	Project finance	new renewable subsidiary of en. utility: Endesa Cogenerat ion and Renewables (ECYR)	Commercial Made 660 kW	5,28 MW
	2 projects: Finca S. Antonio; Finca Mogan 2.	Commercial	Project finance	New subsidiary of energy utility: Unelco Participadas	Commercial Made 330 kW & Made 660 kW	Total: 8,25 MW
	2 projects: P.E Tause; P.E. Torazno	Commercial	Project finance	Company specialised in reneweable energy: CEASA	Commercial: Gamesa 660 kW	Total: 55,5 MW
	El Canto	Commercial	Project finance	Company (new) specialised in reneweable energy: CESA		15,18 MW

	3 projects: Lega; Salajones; San Esteban	Commercial	Project finance	Company specialised in reneweable energy: EHN		Total 51,5 MW
1999	4 projects: Higueruela; Llanos 1&2; Cerro Punta	Commercial	Project finance	Company (new) specialised in reneweable energy: EEE	Commercial: Gamesa 660 kW	Total 111,5 MW
	3 projects: La Plana 2;El Tablado; Monte Seixo	Commercial	Project finance	Gamesa Energia Iberica (subsidiary of manufacturer)		Total 60,5 MW
	Les Colladetes	Commercial	Project finance	Company specialised in reneweable energy: Enervent		26,74 MW
	5 projects: Dehesa del Coscojar; Los lances; Trucafort 1; La Cabrera; El Pupal.	Commercial (2 with new turbines)	Project finance (assumed from general interviews)	Project-vehicle companies: DESEBRO, SELL, SEESA; ACILOE; Eolica de Moncayo	New in Spain: Nordex 600 kW; Commercial models Ecotecnia 640 kW;225 kW Gamesa 660 kW; Neg-Micon-Nordtank 750 KW	Total: 71,5 MW
2000	35 project commissioned during 2000 and at least 30 projects large / very large project under construction (+ mini wind and wind-solar PV systems)					
	3 R&D projects, with 1 turbine each	Demonstration	n.a.	Gamesa Energia Eolica, manufacturer	New designs: Gamesa 1650 kW; & 850 kW	Total 5 MW
	1 turbine in Echague	Demonstration	n.a.	Specialised developer EHN	New: Gamesa 850 kW	0,85 MW
	1 turbine in Tariffa	Demonstration	n.a.	Bonus Bazan Manufacturer	New design: Bonus-Bazan 1300 kW	Total: 1,3 MW
	Valdecuadros	Demonstration	In-house corporate financing	Taim-Neg-Micon Eolica	New deisgn: Taim-Nordtank 750 kW	1,5 MW
	Pozalmuro	Demonstration	In-house corporate fin.	Neg Micon EREN	New: Neg-Micon 1500 kW	1,5 MW
	6 projects: Montes de Cierzo; Punta Gaviota; Trucafort 2; As Somozas; Caparroso; la Bandera	Commercial (3 with new turbines)	Project finance	Project-vehicle companies using Ecotecnia turbines: Mostes Cierzo SA; PEGASA; SEESA; EASA Somozas; Eolica Caparroso SA; Eolica la Bandera SA	Commercial: Ecotecnia 700 kW; 600 kW; 640 kW and 750 kW	Total 194,6 MW

	11 projects: Careon; Cabezo San Roque; Grisel; Acampo Armigo; Bosque Alto; Plana de la Balsa; Plana de Jarreta; La Carracha; Oncala; Xistral extension; Sotavento Moinfero.	Commercial	Project finance	Project-vehicle companies using Tain-Neg-Micon turbines: Carreon SA HIDROGES; BBB; AERSA; E.E Bosque Alto; Plana de la Balsa; Plana de Jarette SA; La Carracha SA; CETESA; Acciona; Sotavento Galicia	Commercial: 1st = Taim-Neg-Micon 600 kW; the rest: 750 kW	Total ~306 MW
2000	5 projects: El Cerro; Yerga; Sotavento; Elgea; Cabimonteros	Commercial	Project finance	Project-vehicle companies Valle Sedano; Eolicas Rioja; Sotavento Galicia; Eolicas de Euskadi; DER Rioja	Commercial: Gamesa 660 kW	Total ~121 MW
	4: Sierra Selva; Cuerda; Virgen Belen, Aizkibel	Commercial	Project finance	Specialised renewable-projects company EHN	Commercial: Gamesa 660 kW	Total 121,6 MW
	4: Muela-Tortosila; Meula Malefaton; Vilanueva,	Commercial	Project finance	Specialised renewable-projects company: EEE		Total 154 MW
	4: Serra Cando; Muras 2; Forguesello; Outeiro Coto	Commercial	Project finance	Gamesa Energia Iberica, developer of manufacturer		Total: 87,8 MW
	4 projects: La Torrada; Los Llanos; Pena Alta; Toranzo 2	Commercial	Project finance	CESA		Total: 48,6 MW
	4 parks: Aldeavieja; Avila; Cruz Hierro; Ojos Albos	Commercial	Project finance	Company specialised in reneweable energy: SINAE		Total: 55,5 MW
	Les Colladetes 2	Commercial	Project finance	Enervent		11,88 MW
	La Serreta 2	Commercial	Project finance	Molinos del Ebro		25 MW
	Borja	Commercial	Project finance	CEASA	Commercial: Neg-Micon-Nordtank 750 kW	14,2 MW
	Carba-Vilalba; S. Madera; P. Trinidad; Pena Luisa + 7 projects in construction	Commercial	Project finance	MADE ER	Commercial Made 660 kW	Total ~283 MW
	2 projects: Puenta Teno; Granadilla	Commercial	Project finance	UNELCO Participads		Total 9,3 MW
	3 projects: A Runa; Virxe Montel; Sotavento	Commercial	Project finance	Specialised wind-projects company: EUROVENTO	Commercial: Bonus-Bazan 600 kW	Total: 46,2 MW

	2 projects: Concepedino; Careon.	Commercial	Project finance	UFEE (utility subsidiary)	Commercial: Neg-Micon-Nordtank 600 kW	Total 40,8 MW
since 1998	Policy support mechanisms by IDAE leading to approximately 100 projects (100-270 MW)	self-generation or commercial	third party finance IDAE 31 projects (1998-1999)	individuals all types of small develoeprs	not available	0,3 - 5 MW
			private finance ICO-IDAE			up to 4 MW
		self generation	project finance PYMES	small/medium size firms		

Appendix 7.4: The financing and investment characteristics of wind plants with the equity involvement of the governmental renewable energy agency 1995-2000 in Spain

Yr	Name project / Type finance scheme	Capital structure				(Possible) period of loan recovery	Project developers (contributors to vehicle companies)	Size, MW	Technological design
		IDAE equity	Subsidies	Others' equity	Bank loans				
1995	P.E Baix Ebre (project finance)	4,93%	27,5% EU + 12,1% national + 4,8% reg. authority Catalonia	14,57% other actors	36%	~ 4 yr loan recovery	PEBESA (Public agencies. IDAE, ICAEN. Ecotecnia, two regional councils)	4,05 MW	Ecotecnia 150kW, (commercial)
1995	P.E Gaviota (project finance)	4,9%	21,9% PAEE +1,5% reg. auth.	11,5% (3 actors)	62%	> 4 yr loan principal	PEGASA (IDAE, R&D insti-tute, manufacturer energy company)	10 MW	Ecotecnia 225 kW. (Commercial)
Dec 1995	La Muela 2 (project fin.)	6,1%	15% national	19,9	59%	> 5,3 yr loan principal	EVESA (regional agencies, ind comp., IDAE manufacturer)	13,2 MW	Made 330 kW (commercial)
1996	P.E. Malpica (project finance)	5,1%	23,8% PAEE	13,7% (5 actors)	57,4%	> 4,3 yr loan principal	PELMASA (IDAE, utility, manufacturer, regional agencies, industrial-energy company)	15 MW	Ecotecnia 225 kW. (commercial)
1996	Tarifa 4 (third-party fin.)	50%	n.a.	n.a.	-	n.a.	IDAE, Ecotecnia	0,50 MW	Ecotecnia 500 kW (new design)
1996	P. Tausta (project finance)	8,4%	n.a.	n.a.	-	n.a.	IDAE, Ecotecnia	5,17 MW	Ecotecnia 225 kW (commercial)
1996	P.E Enderrocada (project finance)	2%	9,9% PAEE	2% Icaen + 16,4% others	69,7%	n.a.	SEESA (IDAE, + utility manufacturer, industrial company + ICAEN)	30,8 MW	Ecotecnia 225 kW and 600 kW (last = new model)

1997	Sotavento (project finance)	5,6 %	-	21,8%	72, 5%	-	Sotavento (IDAE, three utilities, three regional agencies)	17,6 MW	different technologies
1998	P.E Ascoy (project finance)	4,3%	-	18,7% (3 actors)	77%	n.a.	ASCOY (IDAE, two energy investment companies, one bank	5,94 MW	Gamesa 660 kW (commercial)
1998	La Muela 3 (project fin.)	n.a.	-	n.a.	n..a.	n.a.	EVESA (regional agencies, industrial company, IDAE manufacturer)	3,3 MW	Made turbines
2 more wind parks based on purpose-for-the project established companies in 1998 with IDAE equity participation							n.a.	n.a.	n.a.
99	Los Lances (project finance)	5,3%	-	21,3% (4 actors)	73,4%	n.a.	SELL S.A. (IDAE, two utilities, regional agency, manufacturer)	10,6	Ecotecnia 640 kW (adjusted model)
99	wind park (project finance)	49%	n.a.	n.a.	n.a.	n.a.	S.G Recursos	100 MW	various turbines
99	P.E. Tause (project finance)	40%	n.a.	n.a.	n.a.	n.a.	ARVISA	10 MW	n.a.
99	La Bobia (project finance)	30%	n.a.	n.a.	n.a.	n.a.	Proiect Energet As	25 MW	n.a.
99	Villayon Valdes (project finance)	30%	n.a.	n.a.	n.a.	n.a.	Cantaber	30 MW	n.a.
99	Medina Sodinia (project finance)	25%	n.a.	n.a.	n.a.	n.a.	Medina Sidon	10 MW	n.a.
99	P.E Ayora (project finance)	45%	n.a.	n.a.	n.a.	n.a.	E.R Levante	10 MW	n.a.
99	4 more projects with IDAE equity participation in 1999				n.a.	n.a.	n.a.	n.a.	n.a.
98- 99	31 third party finance small size projects	average 85,6%	subsidies and / or equity would-be owners. Small/medium scale self-generation/commercial projects		n.a.	n.a.	individuals; industrial/ commercial companies public agencies	0,30 0 - 5 MW	Not specified but probably Spanish (small size)

since 98	self-generators: soft-loan project finance based on ICO-IDAE agreement	30% or more	up to 70 %	5, 7 or 10 years	all interested in self- generation	<4 MW	n.a.
since 98	IDAE-FEDER scheme for small/medium size companies (soft-loan project finance)	remaining	up to 100 %	~8 years loan recov.	small/medium ind. companies	n..a.	n.a.

Chapter 8

Diffusion of biomass electricity technologies in Spain

8.1 Introduction

This chapter analyses the market diffusion patterns and processes for biomass energy use in Spain, in order to test Hypotheses 3 and 4. Section 8.1.1 makes a short overview of the use of biomass resources for energy purposes in Spain. In Section 8.2, we discuss the diffusion patterns in the period up to the end of 1995 in order to test Hypothesis 4. Section 8.2.1 investigates the forms of the five indicators for diffusion patterns of biomass electricity technologies technology in the period up to 1995. Section 8.2.2 discusses the diffusion results in mid 1990s based on the indicators introduced in Chapter 2. Section 8.2.3 draws the conclusion regarding the overall confirmation of Hypothesis 4.

Further, Section 8.3 focuses on testing the hypothesis specified for the mixture of optimal and political investment contexts, which combines expectations of Hypothesis 1 and 3. This starts in Section 8.3.1, which investigates the forms of the five indicators for diffusion patterns of biomass electricity technologies in the period 1996-2001. Section 8.3.2 discusses diffusion results at the end of 2001, in terms of installed capacity increase and the main features of the investment context created, in order to get an idea if and how diffusion processes would continue without a change in the economic governance structure. The last Section, 8.3.3, draws the conclusion regarding the extent to which the predicted diffusion patterns are confirmed by practical developments, and the overall confirmation of the hypothesis specified for this investment context regarding the diffusion potential. Section 8.4 summarises the content of this chapter and main findings.

The methodology of data collection and processing is specified for each indicator in the sub-sections where they are discussed. The empirical data for biomass technology diffusion in Spain were far less specific than in the case of wind technology. Hence, it was necessary to combine information from more sources, to make inferences, and sometimes also calculations, in order to derive the forms of the indicators in which we were interested.

8.1.1 Short overview of biomass energy use in Spain

The use of biomass resources in Spain was overwhelmingly dominated by thermal applications, roughly 95%, throughout both decades studied. Domestic thermal applications claimed around 55% of biomass resource use (Era Solar 1997: 38). The rest was used in several industrial sectors, characterized by large production of organic wastes and biogas (Fernandez 1997: 45). The situation in 2000 changed to some extent, with the appearance of commercial projects based on clean agricultural and forestry wastes, developed by other types of investors. In late 1990s, energy utilities and new independent energy production companies entered the biomass energy sector.

The technology mostly used was the mature version of combustion technology, based on steam turbines. However, in late 1990s some demonstration projects using the more innovative version of fluidized bed combustion were commissioned, as well as some plants based on gasification technology. Solid urban wastes were also used since early 1990s but they will not be discussed in this chapter as we do not consider them as clean renewable resources. The clean biomass electricity technologies on which this chapter focuses are based on the following resources: forest and agricultural wastes, energy crops, industrial and agricultural organic wastes, and biogas from landfill wastes and anaerobic digestion of organic wastes. All types of technologies using these resources will be considered.

8.2 Testing Hypothesis 4 for biomass electricity technologies' diffusion in Spain, 1980-1995

This section tests the expectations of Hypothesis 4 on diffusion patterns and support system effectiveness, for the case study of biomass electricity technologies market introduction in Spain, where a minimal investment context was created in the period 1980-1994. The new legal framework entered into function in the beginning of 1995. But we decided to test Hypothesis 4 for the period up to the end of 1995, in order to account for the longer construction time of biomass power plants, as compared to wind energy plants[1].

8.2.1 Testing theoretical expectations on diffusion patterns, 1980-1995

Sections 8.2.1.1 to 8.2.1.3 analyse diffusion patterns for biomass electricity technologies in Spain in the period 1980-1995 and compares them with the theoretical expectations of Hypothesis 4. In Section 8.2.1.4, we draw the conclusions regarding the predictability of diffusion patterns.

8.2.1.1 Types of project developers and drivers to invest, 1980-1995

Hypothesis 4 predicted the predominance of small developers investing in (partly)-self-generation projects. In the group of small developers we included medium/small-size industrial production companies, small new-entrant firms, cooperatives, communities, associations and individuals. A possible small presence of energy utilities and larger industrial companies with strategic projects was also predicted.

For the period 1980-1990, no statistical data were available for individual projects or industry level developments that could suggest the values of these two indicators. The analysis of the indicator *drivers to invest* was done by combining governmental statistics on biomass plants with interviews carried out with several governmental energy experts. Beginning with 1992, the national grid company Red Electrica Española collected data on the total capacity of biomass plants selling electricity to the grid. Comparing these numbers with the capacity annually installed (recorded by the governmental renewable agency Idae), we derived the share of self-generation projects. This way, it appeared that between 1992-1995 around three-quarters of annual capacities were used for self-generation, as it can be seen in Table 8.1. From this data, it is not clear whether the remaining 25% was formed by pure commercial plants, selling all electricity to the grid, or were coming from projects used partly for self-generation and delivering the surplus to the grid. But in both cases, the theoretical expectation of finding predominantly (partly) self-generation investments is confirmed for this four-year period.

For the period previous to 1992, we relied on interviews with market experts, who discussed developments during the entire period studied in this section: 1980-1995. One interviewee (Carrasco 2002) explained that, since the first oil crisis up to mid 1990s, paper companies and some other industrial production firms disposing of organic wastes were the only developers of biomass-for-electricity plants. The oil crisis impinged them to move away from fossil fuels - when they were using them as self-generators, and find ways to avoid energy price hikes - when they were buying energy from utilities. In 1975, the paper company Papelera Navarra was the first to convert its coal-based plant into a biomass wastes system

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[1] It is generally known that, if there are no obstacles, construction can take for large plants up to 2 years (Vitales 2001). But we considered here an average time of one year, having in view the characteristics of plants built in this period: conventional technologies using industrial organic wastes or biogas, both produced close to the energy-generation sites.

(Carrasco 2002). Another paper-company followed in Andalucia with 27 MW (Colinet 2002). The plants were in few cases based on cogeneration but were using mainly the heat, selling the surplus electricity to the grid based on bilateral agreements with utilities[2]. Saving energy costs remained the main reason to build plants based on organic wastes in the first half of the 1990s too. But a new driver to invest was then added, namely that companies started to be required to take responsibility for their environmental impacts and find ways to reduce wastes. The generation of electricity was then seen as the most financially attractive option. The types of industrial companies building biomass electricity technologies projects before 1995 can be observed in Table 8.2.

Table 8.1 *The annual cumulative capacity of biomass electricity plants, and share of self-generation capacity 1990-1995*

Biomass plants capacity	1991	1992	1993	1994	1995
MW installed (cumulative)	107	110	102[3]	126	152
MW selling to the grid	n.a.	23,7	23,7	25,9	39,5
% self-generation plants	n.a.	78,5%	76,7%	79,3%	74%

Based on REE 2002[4]

Table 8.2 *Total capacity of biomass-electricity plants developed by industrial production companies by 1996*[5]

Type of industrial sector	Total installed capacity
Pulp and paper	109,88 MW
Sewage treatment stations (biogas)	15 MW
Vegetal oil	13,44 MW
Waste dumps (biogas from landfill sites)	6,25 MW
Alcohol factories (biogas)	2,1 MW
Wood	1,73 MW
Central heating	1,7 MW
Sugar factories (biogas)	0,672 MW
Animal wastes (biogas)	0,280 MW
Others	1,2 MW
Total these industries end 1996	152,365 MW
Total installed capacity in 1996	182,8 MW

Source: Idae 1997 in Era Solar

Combining the two information sources, it can be concluded that the majority of the plants built before the entry into force of the 1994 Royal Decree were self-generation projects, with a strategic environmental component. In some cases, developers were also selling some surplus to the grid. There were yet no plants owned by energy utilities, for which a very small presence with strategic projects was theoretically expected. However, the theoretical expectations for this indicator can be considered *confirmed to large extent*.

The analysis of the types of developers investing in biomass-electricity plants has relied on interviews and journal articles[6]. These indicate that, in the period up to 1995, the main

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[2] Sancho (Ghesa) and Carrasco (Ciemat), April 2002; Menendez (1997: 128).

[3] This figure is smaller than that of the previous year because some capacity was shut down.

[4] "The Special Regime in Spain - Statistical information regarding the grid-purchase of renewable electricity under the special regime" at http://www.ree.es

[5] We will consider in this sub-section the developments at the end of 1996 because data for the end of 1995 were available.

developers were industrial production companies. As shown in Table 8.2, the industrial sectors where most projects were realized were those of: pulp and paper, followed by industries of food, drinks[7], wood and wastes management. These sectors together commissioned more than 84% of the installed capacity at the end of 1996 (Idea in: Era Solar 1997: 38). In addition, there were also several small companies and agricultural cooperatives, as well as few companies harnessing biogas from waste sites in the form of landfill gas[8]. These *confirm to large extent* the theoretical expectations regarding the types of project developers of Hypothesis 4.

8.2.1.2 Technological designs and project sizes, 1980-1995

Hypothesis 4 predicted that investments would rather be in the form of small or very small plants, using conventional commercially mature technological designs. The empirical testing of the indicator for technological design relies on interviews with energy experts and specialized publications (mentioned below). In order to determine project sizes some rough estimations were made based on a restricted set of governmental statistics published.

In contrast to other technologies, in the case of biomass the discussion on technology needs to be made in parallel with the specification of resources employed (see Section 4.4). In Spain, the resources used for the power plants developed in industrial sectors were mainly in the form of black liqueurs from the pulp and paper industry. These were followed by various types of organic wastes, mostly residual wastes (Menendez 1997) that were transformed in biogas (in around 24 MW, see Table 8.2). Besides, chip wood and powder, olive wastes, and bark wastes were also used to some small extent for electricity generation (Idae in Era Solar 1997).

The technology used to generate electricity from these resources was the conventional direct combustion technology using steam turbines and engines. Only one plant used the new design of combustion called ‘fluidized-bed’ (Menendez 1997: 138). There were no demonstration projects based on gasification or pyrolysis technologies in the private industry sphere[9]. The majority of plants were based on co-generation (Menendez 1997: 137; Carrasco 2002). In Spain only some universities were involved since late 1980s in fundamental research on these technologies[10]. But there was no cooperation with the industry until late 1990s (Fernandez Jesus 2002). These findings *confirm* the theoretical expectation to see only conventional technological designs.

With regard to project sizes, this indicator could not be measured directly. A list of sizes of biomass/biogas electricity projects in terms of MW installed capacity for this period was not

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[6] Sources: Journal Era Solar, interviews Fernandez, [Idea] April 2002; Sancho, [Ghesa], April 2002; Maria Jose Colinet, [Sodear} April 2002.

[7] The food and drinks industries had problems with the resulting polluting water. The extraction of biogas from their organic matter was part of the task to deal with environmental problems (Menendez, 1997: 129)

[8] Sources: Era Solar, 1997, interview Fernandez Jesus [ADABE] April 2002.

[9] Interviews with Sancho, Ghesa, 2002; Fernandez Jesus [ADABE] 2002; Cascarro, CIEMAT 2002. At international level these three technologies were still in demonstration phase. Private companies were involved in RD&D only in few countries: Sweden, Finland, United States, Brazil and the Netherlands. (http://www.europa.eu.int/en/comm/dg17/atlas/htmlu/bioetech.html)

[10] In 1988 the first Spanish demonstration project for gasification was initiated at the University of Zaragoza. The project was financed by Idae, the national energy research center CIEMAT and the regional government of Castilla y Leon. The “down-draft technological design was tested. In the 1990s the number of RD&D projects for gasification at universities increased and several departments also expanded towards pyrolysis technology. These research activities remained however in the public sphere until late 1990s (Arauzo Madrid 2000).

available. Statistics made by the governmental renewable agency Idae have been only collected since 1991 and give project sizes in terms of tonnes of oil equivaleny (toe). Besides, the listed projects include both thermal and electric applications of biomass. This prevents a clear cut analysis for this indicator. In order the get an idea about the likely sizes of projects we transformed the 'toe' sizes both in terms of equivalent MWh electricity generated per year and in likely MW installed capacity, as if all projects would have produced electricity[11]. Looking at the resulting numbers in Table 8.3, for the projects built between 1991 and 1995, is seems that, no matter how many of these projects were actually electricity generation plants, project sizes were either 'very small', that is below 1 MW - as it was operationalised in Section 4.3, or 'small', meaning lower than 10 MW. There was actually only one moderate size plant of 12,5 MW (Oleicola El Tejar, built in 1995).

Table 8.3 *Sizes of biomass projects developed in the period 1991-1995 in Spain*

toe	MWh	MW	no projects	qualitative
< 1000 toe	< 389	< 0,44	71	very small
< 5000 toe	< 1 945	< 2,22	16	small
< 10 000 toe	< 3 890	< 4,44	2	small
> 10 000 toe	> 3 890	> 4,44	3	small

Based on Idae in Era Solar 1997

Of the 92 biomass projects developed in the period 1991-1995 the overwhelming majority were heat production systems, since governmental sources mention that only 5% of total biomass was used for electricity generation during these years (Idae 1997). Nevertheles, the statistics of the renewable energy agency show that the installed capacity increased in these years only with 46 MW, and 106 MW were installed before 1991 (see Table 8.5). One interviewee indicated that in late 1970s there was a medium size plant in Andalucia, of 27 MW developed by an industrial paper company (Sodean, 2002). But information regarding sizes of other plants before 1991 were not available. In conclusion, the theoretical expectations regarding the likely sizes of projects were *confirmed* for the period 1991-1995 but could not be tested for the decade of the 1980s. Since most projects built before 1995 were for self-generation purposes, project sizes in Spain were influenced by two main factors: 1) availability of waste biomass resources and 2) energy demand of the developers. The next section addresses the aspect of financing schemes

8.2.1.3 Types of financing schemes, 1980-1995

Hypothesis 4 predicted the use of internal financing schemes. In empirical research we could not test the forms of this indicator. Neither the governmental renewable agency nor the

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[11] For the first transformation we used the figure provided by Idea [1] (1999) for the case of biomass plants: 1 toe = 0,389 MWh per year. For the second transformation we considered the case of the straw based plant of the company Energia Hidraulica Navarra with 25 MW capacity that consumes 55 500 toe biomass per year with an efficiency of 31% (Idae, Madrid October 2000, Seminar on biomass in Spain). In the case of this plant 1 MW consumes 2250 toe of primary biomass. We also made similar calculations for few other plants for which both data on MW and toe were available, such as the Allarluz plant (2,35 MW with 5109 toe) and the Oleicola el Tejar Nunsa (12,5 MW with 30.000 toe). As these values were slightly above and below that for the plant of the EHN company, we used the transformation: 1 MW = 2250 toe (for an efficiency of 31%), meaning that 1 MW plant fuelled with biomass generates energy equivalent to 2250 tons of oil equivalent. These are very rough transformations meant only to give a general idea about the ranges, rather than sizes, of biomass electricity projects up to 1996.

Association for Renewable Energy Producers dispose of databases with information regarding the owners of biomass electricity plants in period up to 1995 and contact details.

There are reasons to believe that the majority of projects were financed based on internal financing schemes, taking into account that:
- around three quarters of the installed capacity was used for self-generation only, and
- it is quite clear that when a project consumes its output, it cannot guarantee non-recourse loans with cash-flows from selling the output to the grid.

Nevertheless since it was not possible to contact project developers we *cannot test* the expectations regarding the types of financing schemes under Hypothesis 4.

8.2.1.4 Conclusion regarding the extent of confirmation of theoretical expectations for diffusion patterns under Hypothesis 4

The previous three sub-sections looked at diffusion patterns of biomass electricity technologies technology in Spain in the period 1980-1995.

The expectations regarding types of developers and drivers to invest were confirmed to large extent. The prediction for project sizes and technological designs were confirmed. But the expectation for the indicator of types of financing schemes could not be tested. The results on empirical research are summarised in Table 8.4. Overall, the extent of confirmation of expectations regarding diffusion patterns can be assessed as *good*.

The next section tests the expectations under Hypothesis 4 regarding the diffusion results for biomass electricity technologies in mid 1990s, in terms of capacity increase and the prospects for market diffusion continuity.

Table 8.4 *The theoretically expected and empirically registered diffusion patterns for biomass electricity technology up to 1994 in Spain*

Empirical developments	Theoretical expectations
Drivers to invest	
(mainly) self-generation and strategic reasons (fuel/cost saving and environmental)	dominance of (partly)-self-generation projects; few strategic projects (confirmed to large extent)
Types of project developers	
mainly industrial production companies; also few agricultural cooperatives and private companies	predominantly small developers (including industrial production companies); few utilities (confirmed to large extent)
Type of financing schemes	
internal financing schemes likely for at least three-quarters of capacity	internal financing schemes (could not be tested)
Project sizes	
- before 1991: no info available. - 1991-1996: very small and small	likely dominance of very small /small size projects (confirmed)
Technological designs	
conventional direct-combustion technologies for organic wastes	conventional technology designs dominate (confirmed)

8.2.2 Installed capacity increase and the prospects for sustainable diffusion processes in mid 1990s

Hypothesis 4 predicted that under minimal investment contexts there will be only a *small increase in installed capacity,* on a short-medium time span and that diffusion processes will be *unsustainable*.

8.2.2.1 Installed capacity increase of biomass electricity, 1980-1995

Based on the operationalisation in Chapter 5, a capacity increase can be described as small if it is below 500 MW, and is achieved in a short-medium time span, of 5 to 10 years. The period for which diffusion was analyzed in this section lasted 16 years, between 1980 and 1995. At the end of 1995 there were 152 MW of biomass electricity plants operating in Spain. This included some power systems developed in the period 1975-1980. Data regarding the annual operating capacity was only available since 1990, as shown in Table 8.5. This finding *confirms* the expectation to see only a small capacity increase.

Data regarding the number of projects and their MW capacity awaiting administrative approval in 1995 were not available. However, interviewees[12] explained that there was a very small interest to invest in mid 1990 given the unclear (but in any case small) price support. Besides, a high risk was perceived in securing the needed plant-life biomass resources, while the more efficient technology designs of gasification and pyrolysis were considered as still in need for demonstration and improvements. The biomass plants in function in mid 1990s were operating overwhelmingly based on organic wastes from industrial sectors using forestry and agricultural products. Biogas had a very low contribution. Clean forestry and agricultural wastes and energy crops were not used yet for electricity generation (Idae in Era Solar 1997).

Table 8.5 *The annual cumulative installed capacity of biomass electricity plants, 1990-1995*

Biomass	1990	1991	1992	1993	1994	1995
MW	106	107	110	102[13]	126	152

Source: Idae 2002, Bulletin No.3

8.2.2.2 The prospects for market diffusion in mid 1990s

This-subsection makes a short overview of diffusion results in mid 1990s and obstacles for biomass electricity technologies diffusion.

Table 8.6 *The diffusion results of biomass electricity technologies in Spain in mid 1990s*

Diffusion context likely to emerge		Biomass in Spain 1980-1995	Theoretical expectations
Socio-economic benefits		not present	very limited
Local	Direct: ownership	not confirmed	likely small
	Indirect: more attractive benefits than usual from ~ land rents; ~ local taxes; or for ~ local economic or social welfare investments	confirmed	not likely
	Indirect ~ local employment	un-likely	technology specific
National	Ownership individuals (shares)	confirmed	not likely
	Employment in industry	no data	likely very small
Industrial basis and dynamics		very small	small
Number companies offering products / services for renewable electricity plants		confirmed	small
Types of companies involved in industry		confirmed	mostly conventional energy companies
Degree of specialisation in renewables		confirmed	small

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[12] Carrasco (Ciemat); Sancho Ros (Ghesa); Alberto Fernandez (Idae); Fernández (Adabe) April 2002.

[13] This figure is smaller than in previous year because some capacity was shut down.

The socio-economic-industrial context for biomass electricity technology diffusion
Diffusion results show that the socio-economic-industrial framework for investments in biomass electricity plants was basically too weak to sustain diffusion in mid 1990. Table 8.6 summarises the situation for the seven selected indicators of diffusion results. The empirically encountered features of socio-economic-industrial context *confirm* theoretical expectations.

Socio-economic benefits
Most of the capacity was developed by industrial companies and small cooperatives using the organic wastes from their production activities for on-site plants. The main gains were for the owners, in terms of wastes' elimination and saving electricity bills. Maintenance and operation was most likely done with personnel from the owning company/association, since power plants were so small, leading to the assumption that local employment for plant operation must have been very restricted. At industry level, the size of installed capacity was too small to generate employment in the manufacture and service sectors. We could not identify any data on national employment in biomass technology activities. Given the plant ownership and the size of installed capacity not even the expectation to observe very limited socio-economic benefits can be confirmed. Beyond the very few owners, it may be argued that socio-economic benefits from biomass power investments were basically not present.

Industrial basis and dynamics
The industrial basis was very small relying on services and products provided by companies specialised in conventional energy technologies. The technologies used were based on biomass combustion and were imported. The aspects of industrial basis need to be discussed for the three segments involved in the transformation of biomass into electricity: suppliers of biomass and collection-processing systems, biomass-to-feedstock systems, and electricity generation technologies (See Figure 4.3, Chapter 4).

In terms of suppliers of biomass, by 1995 only around 30% of the biomass resources used were traded. This took place always by means of direct contracts between biomass fuel owners and other types of industrial companies interested in producing electricity (Idae in Era Solar 1997). Specialised traders in biomass resources did not appear because of the two main reasons discussed above: 1) no incentives to use other resources than secondary biomass, which were generally needed by the waste producers themselves; 2) the potential was limited.

As regards the market for collection-processing systems, there was no demand for special systems that collect and process biomass resources. Biomass was mostly used on-site, where wastes were produced, and its processing was not technically demanding, as in the case of forestry wastes, straw or energy crops. For biomass-to-feedstock systems, only conventional combustion technologies were used, and they were supplied by few domestic companies. There was not a serious demand in sight for more innovative systems, such as gasification and pyrolysis projects, which discouraged technology groups to move in this direction of research and design. Interviews suggest that before 1995 there was no national technology for these two biomass processing principles[14] (Carrasco 2002).

With regard to electricity generation technologies, in Section 4.4 we discussed that when biomass combustion and biogas systems are used, electricity can be generated in engines or by steam turbines. When gasification systems are used, gas turbines can also be used, as well as

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[14] The utility Union Fenosa was conducting research on biomass pyrolysis in its R&D department but the project was gradually abandoned at the end of 1990s (Castillo 2001). The University of Zaragoza had a small demonstration gasification plant since 1988, but its technology did not reach the private industry sphere yet.

integrated gas and steam cycles, which are more efficient. In all cases, the plant can produce only electricity or both heat and electricity (co-generation). All these are conventional generation technologies and Spain has sufficient industrial capacity to supply this last segment in biomass-for-electricity chain of systems (Idae 1997; Carrasco 2002).

Governmental agency Idae mentions that in 1996 there were around 60 companies in Spain ready to offer services and products in the area of biomass energy projects[15]. These 60 companies were according to Idae: manufacturers of energy equipment and of biomass treatment equipment, biomass resource suppliers and engineering companies (Idae in Era Solar 1997). However, taking into account the above mentioned empirical sources[16], it is likely that the majority of these 60 companies were offering services and equipment for the third segment - electricity generation plants, and perhaps also more general services such as project feasibility and plant engineering.

Therefore, it could be argued that in mid 1990s the domestic industrial basis for biomass energy projects in Spain consisted basically of companies for electricity generation equipment and engineering groups, due to the overlap with conventional fuel energy systems. There were only few Spanish companies manufacturing equipment for biogas collection, and for the direct combustion of biomass and biogas. The industrial basis for biomass electricity technologies was very small because the resource market was dominated by organic industrial wastes for self-generation plants used on site, with limited growth potential. Moreover, no change of situation was in sight, as there were no signs that the resource market was to be organized or that financial support for biomass electricity was to be sufficiently increased.

The overview of diffusion results in mid 1990s support the conclusion that the minimal support system present up to 1994 did not help the creation of a socio-economic-industrial context surrounding the investments in biomass power plants able to sustain diffusion. Hypothesis 4 is hence confirmed both in terms of diffusion patterns and potential.

Obstacles for diffusion

The main obstacle for diffusion was that the support system did not stimulate the interest of investors in biomass for commercial projects. The 82/1980 Energy Conservation Law did guarantee contracts for biomass-electricity sale and a special price, but only for self-generators selling surplus to the grid and for demonstration plants[17]. Besides, the decision to leave all details on price and contract design to Ministerial Orders attracted a higher risk than in the case of wind energy. This is because, one the one hand, from late 1980s (some) energy utilities, the governmental agency Idae and regional public authorities were interested in wind energy. Together with the emerging manufacturers they were co-owners of demonstration and commercial plants. This improved, in early 1990s, the perception on contract and price risks for other companies interested in wind energy[18]. But utilities and public agencies did not show interest in biomass electricity projects, which could explain the absence of demonstration and commercial-only biomass projects.

On the other hand, the perception of lower investment risks for wind energy projects is related to the fact that although investment costs were quite high, resources themselves are

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[15] It is not clear how many were focused on technology for electricity generation and co-generation, and not only on heat production plants.

[16] Idae 1997; Carrasco interview 2002; Idae website company-index at http://www.idae.es.

[17] As we explained in Chapter 5, there was clear eligibility for commercial plants only when they used small-hydropower < 5 MW.

[18] It wouldn't had been politically acceptable that only a privileged group of actors can enjoy long-term guarantee on contracts and high tariffs from the Ministry, without offering similar terms to other developers.

always cost-free. Developers had the option of testing the technical-economic feasibility of wind projects, as well as the trustworthiness of governmental guarantees, by means of smaller-scale projects, of one to several turbines. For biomass electricity projects, energy resources come at a cost that, depending on the type, can be very high. In addition, economies of scale start with sizes above 20-30 MW to ensure good profitability to commercial projects. In the context of high economic risks investments in expensive commercial biomass electricity projects were unlikely.

This way the system stimulated the use of cheapest resources and only when self-generation and waste elimination were needed. By mid 1990s the only resources used were organic industrial/agricultural wastes and biogas. Governmental assessments suggest that the remaining potential of the first group was quite small (Idae in Era Solar 1997). As this market niche was approaching its exhaustion, biogas from organic wastes' decomposition was the only resource for which capacity increase could have been expected in the near future.

One could wonder why would not have been expectable for industrial production companies interested in self-generation to shift to clean forestry and agricultural wastes, for which potential was clearly so high. This has two answers. Firstly, these resources assume high costs, due to the special labor, infrastructure and pre-processing needed. These costs were higher than the price of natural gas, which started to drop again. Some companies were even considering switching to gas plants rather than re-powering their biomass systems[19]. Secondly, resource competition did not favor such a shift. As Table 8.2 shows, companies in the pulp and paper industry were the main developers of biomass electricity technologies plants. For them clean biomass wastes, including straw (Menendez 1997: 128), represent raw materials for their products, even if of lower quality. Besides, in agriculture straw was important for several traditional applications in animal farming. Consequently, before the adoption of the 1994 support system, (partly-)self-generators had no stimuli to expand biomass electricity projects beyond the small market niche of secondary biomass resources. Combined with the lack of incentives to invest in commercial plants, one could argue that market diffusion processes of biomass electricity technologies would have been restricted to the niche market discussed, which was already under competition from natural gas.

8.2.3 Summary and conclusions regarding Hypothesis 4

This section tested the theoretical expectations of Hypothesis 4 for the case-study of biomass electricity technology market introduction in Spain, in the period 1980-1995. The hypothesis formulated the following expectations.

A support system leading to a national investment environment of high to very high economic-policy risk and low to modest levels of project profitability will induce *diffusion patterns* that are characterised by:

- the dominance of private investments for (partly)-self-generation,
- in the form of very small/small projects,
- using conventional, commercially mature technological designs,
- commissioned by small developers and industrial production companies,
- based on internal financing schemes;

These investments may be accompanied by:

- small presence of energy utilities,
- driven by certain strategic reasons to invest,

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[19] In 2002 this option is still on the table of some industrial production firms (Carrasco 2002).

- using also rather conventional commercially mature technological designs,
- based on internal financing schemes.

Such diffusion patterns will result in:

- *a small installed capacity* increase in short-medium term; and
- *unsustainable* diffusion processes in the long term for the technology envisaged

Diffusion patterns

The predictability of diffusion patterns under the minimal investment context applicable in Spain for biomass technology up to 1995 can be assessed as *good*. For two indicators of diffusion patterns expectations were ‘confirmed’ - project sizes and choice of technological design. For two indicators - types of developers and drivers to invest - predictions were ‘confirmed to large extent’. The empirical forms of the types of financing schemes could not be tested. We summarise here the main findings regarding the indicators for which the expectations were not fully confirmed.

The expectation regarding *types of developers* in a minimal investment context was that investments would be dominated by industrial production companies and/or small developers (mainly by means of partly-self-generation and strategic projects) with a small-extent involvement of energy utilities. This expectation was ‘confirmed to large extent’. We observed investments by industrial production companies of various sizes. They were coming from sectors such as pulp and paper, food, drinks, wood processing and wastes management. Besides, several cooperatives and associations also owned very small biomass systems. But there was no involvement of energy utilities in biomass power plants investments. As regards the *drivers to invest*, we also considered the expectation as ‘confirmed to large extent’, because the main reason was to generate for auto-consumption and the presence of strategic projects by energy utilities was not observed.

Diffusion results

As regards the dependent variables, the expectation on support system effectiveness was *confirmed*. A small capacity increase was registered (up to 152 MW) in the period up to 1995. The expectation that the features of the socio-economic-industrial context of diffusion would not be able to sustain diffusion in long term was as well *confirmed*.

Exogenous factors and alternative specifications

We assess that the following factors may be playing a role in the forms observed for diffusion patterns:

- business requirement on profitability of economic actors, especially here - energy utilities; and
- perception on the stage of technical development by large developers - including energy utilities.

The next section tests the theoretical expectations specified for the support system applied in Spain in the period 1996-2001. This support system combined features of optimal and political investment contexts, for which we specified in Section 6.9.2.2 a hypothesis that builds on the predictions of Hypothesis 3 and 1.

8.3 Testing the hypothesis for biomass electricity technologies' diffusion in Spain, 1996-2001

For the period beginning with 1995, the economic-policy risks for biomass power projects in Spain discussed in Chapter 6 were considered as low/modest (as assessed by economic actors in Spain). But the range of profitability for projects was observed to expand from the low/modest range up to 1998, to the high range after 1999. However, after 1999 the market niche where projects with high profitability were possible was still restricted due to limited resource potential that was feasible for the applicable price support. In Chapter 6, we formulated the following expectations with regard to diffusion patterns:

- diffusion patterns will take the forms expected under political investment contexts in the period 1995-1998 (forms under Hypothesis 3); and
- a transition towards the forms of diffusion patterns expected under optimal investment contexts (according to Hypothesis 1) may be seen after 1999.

As regards the potential for installed capacity increase, we hypothesised it to be 'modest' in short-medium term of diffusion, because of the limited opportunities to build high profitability projects. Further, we considered that in this case the features of the social-economic-industrial context of diffusion would rather have the characteristics expected under political (Area 3) investment contexts. The prospects of diffusion continuity are strongly dependent on the availability of biomass resources at costs that would still enable projects with high or at least modest profitability.

This section tests the theoretical expectations of the hypothesis for biomass power diffusion after 1996 in Spain. In Section 8.3.1, each sub-section starts by formulating the expectations for the diffusion pattern indicator(s) discussed. In Section 8.3.2 we look at the empirical data with regard to installed capacity increase and the prospects for diffusion continuity after 2001 when our empirical analysis of biomass in Spain ends.

8.3.1 The diffusion patterns of biomass electricity technology, 1996-2001

This section presents the empirical findings regarding the values of the five diffusion patterns' indicators for biomass electricity technology in the period 1996-2001.

8.3.1.1 Types of project developers and drivers to invest

The hypothesis predicts that during the diffusion period when a political investment context applies, the drivers to invest would be characterised by a balanced presence of (partly-)self-generation, strategic and commercial interests to invest. These projects would be commissioned predominantly by small developers but also energy utilities and large industrial companies to limited extent. When high profitability projects become possible, this picture of developers-motivations would gradually change towards the dominance of commercial projects by large developers[20]. This subsection analyses the two indicators together for the entire period since 1996.

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[20] Under Hypothesis 3 we formulated in Chapter 3 two options of diffusion in long-term. When one of three pre-conditions identified was not met, we argued that the installed capacity increase may only be small in short-medium term while diffusion processes would not be sustainable. This prediction was formulated based on the expectation that small developers would be the predominant investors under political investment contexts. Nevertheless, in this case study the support system displays a partial transition towards the optimal investment context. Since in such a context large developers are expected to enter the

As compared to the previous period, there are four developments characterising investments in the second half of the 1990s. Firstly, energy companies[21] and few large industrial technology corporations enter the market with projects having a strong demonstration component. They mainly test new biomass resources - clean forestry wastes, clean agricultural wastes, and energy crops[22]. One interviewee (Carrasco 2002) mentions that some of these companies have also social motivations to invest, related to raising interest of local people in biomass, towards building networks for resource supply. Another demonstration line involves the testing of the circulating fluidized-bed combustion design (of the direct-combustion technological principle - see Section 4.4), and testing of the gasification principle. Almost all these projects benefited of investment subsidies from the government, EU programs or/and regional administration.

In addition, this group of developers also built commercial plants using organic wastes or biogas in conventional direct combustion technologies. The number of commercial plants developed by them increased after 1998, with the adoption of the new support system, when the terms of contracts and price have become clearer. These projects could reach profitability closer to large developers' business requirements, that is 10-12%, and qualify for project finance due to the use of low-cost organic wastes, generally below 1,2 €c/kg (Vitales 2001), from industrial/agricultural applications. But their commercial plants also have a clear strategic component. The strategic driver to invest is given by the expectation that government would approve the budgets envisaged in the 1999 policy plan for subsidies and fiscal advantages (see Tables 8.22 and 8.23). This would considerablly enlarge the segment of economically feasible resource potential. In addition, it is expected that the special price based on the 2818/1998 Royal Decree would also increase, because otherwise the fulfillment of the 12% target would be compromised. It is important therefore that when the market gets momentum, this can find companies with the necessary expertise in-house and business networks consolidated on the main pillars: equipment, financing, public authorities and resources[23]. Secondly, waste

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market playing an important role in diffusion, we do not deem anymore the necessity of the three preconditions. Both the financial burdens from investments and the socio-economic-industrial benefits from investments are in this case shared by small developers and large developers, expected to become equally interested to invest. Consequently, we do not consider necessary to inquire empirically for the extent to which the three preconditions of Hypothesis 3 are met in this specific case study.

[21] Of the four large energy utilities, only Endesa Cogeneracion y Renovables and Sinae had interest in biomass, in 2002 (the subsidiaries of first and the fourth largest electricity companies). Union Fenosa Energias Especiales had just some minor interest in biogas, especially from animal wastes. Iberdrola, through its new renewables arm IberRenova considered that given the current economic performances, it would be more realistic to make investment plans somewhere after 2004-2005 (Mendiluce 2001). The other, older and stronger investment arm of Iberdrola, Energia Hidraulica Navarra has always been more independent in its investment strategies and had actually a very strong interest in biomass. In 2001 it was commissioning a landmark plant in the Spanish landscape, a 25 MW straw based plant in Navarra (http://www.ehn.es), meant to demonstrate not only the technology and the new resource but also the fact that current price support was not sufficient to make such plants profitable. The plant was financed based on debt-corporate finance, with an investment subsidy from the EU and has been an appraised example of politically-strategic biomass electricity plant.

[22] The testing of energy crops cultivation was taking place in 2001 for two plants that were already approved (see Appendix 8.1) and for several more under study.

[23] Foreign companies are also interested to move inside Spain, based on the expectation that financial support for biomass will increase. As an example the German company Inergetic AC opened a branch in the Technology Park of Andalucia. From here it aims to expand first in Andalucia where regional government announced extra subsidies and clear targets for biomass electricity technologies, and later in Spain and in Latin America. Its strategic partner for equipment in Spain is Siemens, already an important player in the Spanish wind technology industry (Las Energias Renovables, 10 May 2001).

management companies became increasingly involved in biogas projects, exploiting the landfill gas at the sites they own. As Appendix 8,1[24] shows 25 of the total 73 projects registed at the end of 2001 in the Idae database for the special regime were using biogas.

Thirdly, the picture of developers has been enriched by the involvement of institutional and financial actors as equity contributors in the capital structure of biomass plants: Idae, regional energy agencies, public companies of regional government aiming to promote regional economic development, banks and capital venture funds. Investments of financing agents are focused on commercial plants with conventional technologies and low-risk resources. Their presence has been so far, in 2002, modest in terms of number of projects but significant in terms of the positive signals launched to other potential developers and financing agents that the market for biomass would be soon getting momentus. Institutional agents invest both in commercial and in demonstration plants, supporting the testing of new technologies and new types of biomass resources. But in the same time their projects have two (other) strategic components. On the one hand, they try to build confidence in biomass electricity technologies serving as example of sucessful developers. On the other hand, they try to create employment in the region and raise the interest of local people in biomass production and use.

Fourthly, industrial production and food companies generating organic wastes move away from self-generation and start investing in commercial projects[25]. Few of their new projects work in the regime of partly-self-generation (see Appendix 8.2), especially when plants are based on co-generation and the main demand is for heat[26]. But the projects of this group of developers have also two main strategic components - the advantage of zero fuel costs, and financially attractive way of eliminating wastes. However, in the future the role of industrial production companies in the picture of project developers is likely to shrink, because the potential for industrial organic wastes will be exhaused (see Tables 8.6 and 8.8). In contrast, the role of crop and farming cooperatives is likely to increase fast and substantially, as resources are large and at hand. Social reasons related to employment are considered an important driver of farming cooperations to become involved in biomass-for-energy projects. Based on these considerations Table 8.7 summarises the situation regarding the types of developers and their drivers to invest after 1995.

Table 8.7 *The main types of developers and drivers to invest after 1995*

Main types of developers	Main drivers to invest
energy utilities	commercial and/or strategic (technology / resource demonstration; first movers; raising local social interest)
industrial engineering groups	
institutional agents	commercial and/or strategic (confidence building; demonstration; social reasons)
financial agents	commercial
industrial production & food companies; waste management firms	commercial; self-generation; strategic (waste elimination; zero/low fuel cost advantage; social reasons);
agricultural cooperatives	

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[24] Appendix 8.1 lists all projects benefiting from the special regime that were still in operation by 2001, no matter the year when they were commissioned. The entries into the database appear only with the years 1999, 2000 and 2001 because registration was done according to the year when the owner shifted to the 2818/1998 Royal Decree.

[25] A first step was done through the bold investment activity of the large agricultural cooperative Oleicola de Tejar, which developed and has plans totalling around 75 MW (in 2001) using its wastes from olive-oil production. Oleicola El Tejar supplies 20% of the domestic olive-oil market. The cooperative Aceite Pina also had an 18 MW plant under development (in co-ownership) and plans for several more.

[26] Most projects are co-financed by Idae under the third party finance formula (see Appendix 8.2; Ministerio de Ciencia y Tecnologia, 2000).

Table 8.8 *Total installed capacity and the share of self-generation plants*

Biomes	1995	1996	1997	1998	1999	2000	2001
MW cumulative	152	182,8	183,6	187,8	202,4	217,2	240
MW selling to grid (commercial plants)	39,5	39,7	40,5	64,2	74,4	118	n.a
% self-generation	74%	78%	78%	66%	63%	46%	decrease

Based on Idae 2000 and REE website[27]

During interviews[28] it was mentioned that there were only very few new (partly-)self-generation plants. Scattered information from various written sources mention several (partly-)self-generation projects, listed in Appendix 8.2[29]. But looking at data in Table 8.8 it seems that there was actually no new self-generation capacity installed between 1995 and 2000. There were 112 MW functioning for self-generation purposes in 1995, while in 2000 this lowered to around 100 MW. In this context, it can be argued that there was a *very small capacity increase of self-generation* during these years, while this was accompanied by some shut-down in self-generation capacity operating before 1996.

Consequently, empirical findings indicate that investments were driven in the period 1996-1998 by a mixture of commercial, strategic and, to a smaller extent, self-generation reasons to invest. Some projects had the aim to demonstrate new technologies and resources, while many projects had specific strategic reasons to invest, as secondary drivers. But since 1999 the number of commercially motivated projects increased. The largest share of the new capacity put into operation since 1999 was represented by commercial plants. Throughout the entire period, 1996-2001, there was only a small new capacity dedicated for (partly-)self-generation.

These findings *confirm to a large extent* the theoretical expectations regarding the drivers to invest in biomass electricity technologies plants after 1995. We make this assessment because the self-generation capacity was much smaller than expected. We notice that there was a very fast shift from the overwhelming dominance of (partly-)self-generation before 1995 and their very small representation in projects built since 1996. The diversity of strategic reasons to invest was as rich as theoretically expected.

As regards the types of developers, the empirical data summarized in Table 8.7 suggest again a confirmation to large extent of expectations. This assessment is caused by the very limited presence of small developers. Their presence lowerd since 1999 as compared to the previous years, being mainly represented by few agricultural cooperatives and small/medium-size industrial production companies. The next sub-section discusses the types of financing schemes used for biomass electricity technologies projects since 1996.

8.3.1.2 Types of financing schemes

The hypothesis predicts that during the diffusion period when a political investment context applies, internal financing schemes would be predominantly used. When high profitability projects become possible, external financing schemes would also become available, possibly even dominating when the niche of high profitability projects is larger.

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[27] "The Special Regime in Spain - Statistical information regarding the grid-purchase of renewable electricity under the special regime" at http://www.ree.es, printed at 27 August 2002.

[28] Carrasco [Ciemat]; Fernandez [Idae], Fernandez [Adabe] April 2002.

[29] For the period 1999-2001 we drew up an inventory of all plants on which information could be found in various conference presentations, the articles of the journal Las Energias Renovables, interviews, and Idae publications discussing examples of individual projects with direct financial involvement of Idae or governmental investments subsidies.

Empirical data indicate that in the period before the adoption of the 2818/1998 Royal Decree, projects were overwhelmingly financed based on internal financing schemes, especially in-house corporate finance, debt-corporate finance and multi-contribution finance. Project finance was used only in some isolated cases in this period, but after 1998 it has started to be more frequently used (Sancho 2002). Banks have been conditioning however their loans on the participation of a large company known to them, usually an energy utility or the governmental agency[30] Idae (Fernando [Idae] 2002). Besides, when the biomass resource supplier is (co)owner, banks are also willing to give project finance. But in many cases the debt maturity is lower than in the case of wind projects, only 7-8 years, since banks consider biomass projects more risky and want to recover their loans faster (del Pozo 2001). Also the loan contribution is smaller than in 'normal' projects, in some cases being as low as 40% or 25% (see Table 8.9). For some plants project finance loans were given based on the agreement between Idae and Official Credit Institute for governmentally subsidized soft-loans (see Chapter 6). The projects benefiting from this credit line in 2000-2001 are mentioned in Table 8.9. Appendix 8.2 mentions the biomass electricity plants for which we could identify that the project finance scheme was used[31].

Table 8.9 *Projects with soft loans from the Idea-ICO line for biomass and biogas electricity plants*

Projects with soft loans Idae-ICO line 2000 and 2001			Share of loans
Biomes projects	Installed capacity	Developer	
2 projects biomass electricity	2,7 MW & 2,7 MW	drink industry	25%
2 projects biomass electricity	16 MW & 16 MW	olive-oil wastes	
2 projects biomass electricity	13 MW & 13 MW	paper industry	
1 project cogeneration	21,3 MW	paper industry	28%
Total 7 projects biomass	84,7 MW		
6 projects biogas	n.a	n.a	41,3%
1 project biomass soft loan Idae-PYMES line[32] (1997-2001) with 7 MW			

Source: Fernandez [Idae] 2002

The increase in the use of project finance at industry level for biomass was facilitated by the governmental agency Idae (as in the case of wind projects), who adopted a strategy to provide equity in the capital structure of several projects. Their equity contribution can be seen in Table 8.10. This increased the confidence of financiers in the commercial feasibility of biomass electricity technologies.

Third-party financing of biomass electricity projects has been used so far, by 2002, only in two cases - one by Idae (Idae 2000) and one by a renewables' utility subsidiary, Sinae (2001). The destination of electricity in both cases is mainly for self-generation, selling the surplus to the grid. For both plants, the would-be owners are industrial production companies. The

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[30] Caja Madrid (with interests in Sinae renewables specialised developer) and BCH Bank provide project finance loans when Idae is involved (Fernandez [Sinae] 2001).

[31] Looking at the types of companies involved in the ownership of biomass electricity plants (as listed in the more comprehensive list in Appendix 8.1) it is likely that project finance was used for more other plants, but we could not check this empirically.

[32] In 1997 Idae started the soft-loan program Idae-Pymes 1997-2001 to stimulate self-generation by small and medium size companies using renewables, as well as promote energy efficiency. By 2000 there was only 1 biomass electricity project of 7 MW benefiting of this scheme (Oleoliva SA). The largest share of funds in the Idae-Pymes line between 1997-1999 went to wind projects (38%) followed by co-generation projects (26,6%) and by energy saving and efficiency projects (23,2%) (Idae April 2001). Biomass projects including heat applications counted for only around 8% of the funds (Idae personal communication International Department).

agency Idae plans to use this scheme more often in the future to encourage more investments. These empirical findings *confirm* the expectations regarding types of financing schemes under this hypothesis. The next sub-section tests the expectations for project sizes and technological design choice.

Table 8.10 *Biomass electricity projects with direct financial contribution from Idae*

Project	Size MW	In function	Biomass resources	Contribution (equity) Idae
Allarluz	2,35	04. 1998	wastes: forestry and industrial wood	8%
EHN Navarra	25	09. 2002	straw; forestry wastes	10%
Idae-Dacsa	2	02. 2002	rice shells	85%
Taim-Tfg	0,6	In construction	wastes wood industry	27%
Biomap	12		energy crops, straw, forestry wastes	20%
Cecsa	12			20%
Pastguren	10,5	10. 2001	black liqueur and bark	100% (3rd party-finance)

Source: MCT, 2000; Fernandez [Idae] 2002

8.3.1.3 Sizes of projects and technological designs

The hypothesis predicts that during the diffusion period when a political investment context applies, there would be a predominance of small size projects using conventional technology designs. When high profitability projects become possible, an increase in project sizes is possible towards the dominance of medium and large size projects, while a slow increase in the investment interest in diffusion-optimal design may also be observed.

Like in the previous period, the testing of the project size indicator necessitated some calculations and inferences. Governmental statistics in the form of MW capacity for each project installed after 1995 were not available. For this reason, the analysis of project sizes was split in two parts. For the period 1996-1998 we used the same approach as for the period before 1996, explained in Section 8.2.1.2. Data were available in terms of tones of oil equivalent of each biomass plant, and we transformed the tons-of-oil-equivalent (toe) sizes in likely ranges of MW. The resulting approximations, shown in Table 8.11, suggest that no matter which and how many of these projects were generating electricity, the sizes of projects constructed in the period 1996-1998 were ‘small’ and ‘very small’.

Table 8.11 *Sizes the biomass projects developed in the period 1996-1998 in Spain*

toe	MWh	MW	no projects	qualitative
< 1000 toe	< 389	< 0,44	49	very small
< 5000 toe	< 1 945	< 2,22	14	small
< 10 000 toe	< 3 890	< 4,44	1	small
> 10 000 toe	> 3 890	> 4,44	1	small[33]

Based on Idae 1997 in Era Solar No 87, Madrid

For the years 1999-2001, we looked at the likely project sizes based on the data of the Idae register[34] for special regime plants. This lists all plants selling electricity to the grid, which have shifted to the payment method of the 2818/1998 Royal Decree - the new tariffs or the premium price (Appendix 8.1). This database contains both the projects already operating in

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[33] This was the 7,5 MW biomass electricity project of the large industrial company for pulp and paper ENCE (Idae 1999; Fernandez [Idea] 2002 personal communication).

[34] Available at the website of the high voltage transport company Red Electrica Española on 27 August 2001 (Appendix 8.1, http://www.ree.es).

1998 and the projects being commissioned and obtaining authorisation since 1999. But because for the first group the years of commissioning are not mentioned, a clear-cut analysis only for the projects installed or approved since 1999 could not be made.

As Table 8.12 shows almost half of projects listed in the Idae register at the end of 2001 are *small* size, while the other half consisted of *very small* - mostly biogas - and *modest* size projects. These empirical data can be considered to *confirm to large extent* our theoretical expectations. Although numerically modest and large size project did not dominate yet at the end of 2001 (mainly given the short period of time available for study when the support system offered high profitability) the tendency was clear towards larger size projects. All 19 medium-size plants were operating or approved only since 1999. Interviewees (Carrasco [Ciemat] 2002; Fernandez [Adabe] 2002) also explained that most of biomass power projects being commissioned have installed capacities of 18-25 MW or even higher in order to exploit the large economies of scale of biomass technology. Temporarily the main constraint for plants' size increase is related to the availability of biomass resources, as the infra-structural and institutional frameworks needed for large-scale resource availability are not yet in place. However, the investment interest into large power plants has been awaken, which is what our theoretical expectations refer to.

Table 8.12 *Sizes of biomass electricity projects in Idae register for special regime in 2001*

Sizes of projects in 2001	number of projects	% in all projects
<1 MW (very small)	17[35]	23 %
< 10 MW (small)	36	49 %
< 30 MW (medium)	19	26 %
>30 MW (large)	1	~2 %
total number projects	73	100 %

As concerns technological design, the biomass electricity plants entering in operation and approved up to 2001 used mainly conventional technological designs, namely engines (for small-scale plants), direct combustion technologies and anaerobic digestion. Some of these are in the form of co-generation plants (Carrasco [Ciemat]; Fernandez [Idae] 2002).

In this period, the new combustion technology called 'circulating fluidized bed' started to be used as well. Appendix 8.2 lists the only five projects using this technology that we could identify based on our own inquiry, since governmental statistics on this aspect are not available. But it is likely that there were more projects using it. In Section 4.4, we considered the fluidized bed combustion as design (based on the combustion principle) with the potential to bring improvements in conversion efficiency and cost performances, compared to the other designs.

As regards plants using the potentially diffusion optimal gasification and pyrolysis principles, we could identify only two small demonstration projects based on gasification registered in the special regime of Idae, and no plant using pyrolysis[36]. However, based on

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[35] Of these, twelve projects used biogas.

[36] Research on pyrolysis for electricity generation was introduced in late 1990s in several universities and public research centers. However, by 2001 this application seemed still ignored by the technology groups and energy companies. Several private companies started research and built some demonstration installations. Some envisage the use of organic wastes, while an increasing number focus on the pyrolysis of energy crops. However, so far all applications of bio-oil are in the form of transport fuel for car-engines. The political support and financial incentives for the use of bio-oil in the transportation sector seems to increase at a higher speed than the support for biomass-electricity. In 2001 the Spanish government adopted a scheme for fiscal exemption of bio-fuels, while the European Union was preparing a Directive

other sources it was possible to identify several more other projects testing gasification (Arauzo 2000; Vitales 2002; Oleicola El Tejar 2002) Most of them were owned by large technology corporations[37]. Information was not available however regarding the results of these development and demonstration works in terms of the five indicators that we chose as reference for diffusion-optimal design analysis: conversion efficiency, flexibility in resources, equipment costs, environmental performances, and integration with electricity generation unit. Having in view that there is a clear tendency for a shift in preference of large industrial corporations towards diffusion-optimal designs, although the number of already operating plants using such designs is not high, we conclude that practical developments *confirm* the theoretical expectations for this indicator. The next sub-section summarizes the empirical findings regarding biomass technology diffusion in 1996-2001.

8.3.1.4 Conclusion over the confirmation of theoretical expectations for the diffusion patterns of biomass electricity technology in Spain 1995-2001

Section 8.3.2 looked at the diffusion patterns for biomass electricity technology in Spain in the period 1995-2001. The five indicators for diffusion patterns took in practice some forms that are very close to those predicted under the expansion from political investment contexts towards optimal investment contexts. They are summarised in Table 8.13. For the indicators of types of financing schemes, project sizes and technological designs, empirical developments confirmed the theoretical expectations. The expectations for the indicators of types of project developers and drivers to invest were confirmed to large extent.

Empirical data revealed that in the period 1996-1998 diffusion patterns matched quite well the theoretical expectations under political investment contexts. In the period 1999-2001 they started to take values expected under optimal investment contexts. Nevertheless, small developers with self-generation or commercial projects *did not* emerge to the extent expected. There are two aspects that could explain why. The first reason is related to the business culture of financing agents. The financing obstacle of small developers in Spain is high. Even when small companies propose projects with profitability levels that in principle qualify for non-recourse loans (generally 10%), banks do not agree to give them loans unless a large or old-business-partner company or public agency takes a share in project's ownership (Carrasco [Ciemat] 2002, Fernandez [Sinae] 2001).

The second reason is related to the techno-economic particularities of biomass electricity technologies, namely the fact that they are very complex, and have too large economies of

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envisaging the compulsory use of biofuels to a certain extent. This could explain why the application of pyrolysis for electricity received so little attention so far, and creates expectations that this situation would persist in the near future.

[37] For example the company Taim-Tfg invested in two very small projects in order to test the conversion efficiency for the gasification of clean forestry wastes (interview 2001). Energia Natural de Mora was testing, since 1997, a down-draft design in a 0,5 MW plant. The company Gasbi developed its own down-draft design and was testing it for various types of biomass resources, using an engine as electricity generation unit. The technology group Abengoa built in 1997-1998 several installations of different sizes to test the fluidized-bed and down-draft designs. Further, Cadagua was planning for 2001 the demonstration of technical and economic feasibility to gasify various types of biomass resources. Gamesa Energia was planning in the same year a 1,5 MW plant (Vitales, February 2002) using the gasification technology provided by one of its parent companies Grupo Guascor. It is not clear however whether this was its own design or an imported technology. And finally, the large cooperative for olive oil production Oleicola El Tejar, was engaged in R&D for the gasification of as many types as possible of by-products from this food sector. Grupo Guascor was in 2002 one of the most comprehensive suppliers of equipment for biomass plants in Spain, offering equipment and services for gasification, direct-combustion, biochemical conversion systems, as well as pyrolysis of organic wastes for bio-oil with application in car engines.

scale for this group. The economics of biomass electricity plants show that the production costs per kWh are often higher than for other renewable technologies and they have a lower elasticity to plant size up to a certain level. In the case of direct-combustion and gasification technologies, costs start to lower only after sizes larger than 30 MW. Low-cost biomass electricity projects can only be developed using engines with capacities below 1 MW (Carrasco 1996). Table 8.11 shows that there were 17 projects smaller than 1 MW[38], and 36 projects below 10 MW since 1996. The fact that small developers have still entered the market to a small explained could be seen as a consequence of the availability of higher investment subsidies for this category, 40% after 1998, and the advantage of some small companies of having organic wastes available.

Table 8.13 *Diffusion patterns for biomass electricity technologies in Spain 1996-2001*

Empirical developments	Theoretical expectations
Drivers to invest in wind projects	
very few self-generation projects; many projects had also some strategic elements (low fuel costs, demonstration; wastes elimination); since 1999 commercial plants;	balance of self-generation projects, strategic and commercial drivers to invest; later dominance commercial projects (confirmed to large extent)
Types of project developers	
first years: mainly industrial production companies of different sizes, cooperatives; since 1999 mainly energy utilities, technology groups, public agencies; public development companies.	predominantly small developers, but also industrial companies, energy utilities to limited extent; later predominance large developers (confirmed to large extent)
Type of financing schemes	
first dominance of internal financing schemes; later project finance also available especially for large developers and public agencies / companies	internal financing schemes predominate; later use of external financing schemes increasing (confirmed)
Project sizes	
almost half were small size; the rest very small (mostly biogas projects) and medium size	likely dominance of small size projects; later increase to medium and large size likely (confirmed)
Technological designs	
direct-combustion dominated; several projects identified as testing new technologies: gasification and fluidized bed combustion	mainly conventional technology designs with slow introduction of diffusion-optimal designs (confirmed)

The complexity of biomass electricity projects seems to have led to the predominance of an ownership model for biomass electricity commercial plants in Spain whereby each co-owner contributes to the plant with something more than financial resources. Many companies are constituted around the following model:

- one energy company providing the link with the electricity industry;
- one technology group taking care of plant construction and/or operation;
- one public agency/company helping with the administrative approval processes and local-social acceptance/engagement,
- one company that supplies biomass resources, and sometimes
- one financial institution, taking care of a good loan arrangement.

Small developers are likely to enter a commercial company-ownership when they can provide something, most often biomass resources. When a small developer disposes of resources, but

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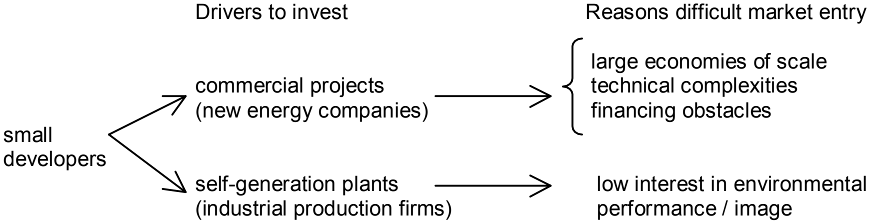
[38] Of these, twelve plants used biogas developed by technology groups and waste management companies.

because of grid-remoteness prefers a self-generation plant, the technical complexity and large economies of scale are often discouraging for acting alone. Besides, if financial governmental support increases, it becomes less likely that self-generation projects by small industrial production companies will have an important presence, because of the still low importance attached to the (voluntary) environmental performances and image. To encourage self-generation among this group of actors, special governmental policies are needed that condition the extra financial support on the use of electricity for self-generation. These instruments have already been used in the form of soft-loans (see Chapter 6) but their budgets for biomass-electricity need to increase to allow a more significant presence of small developers with self-generation projects. Figure 8.2 summarises the main reasons for the poor market presence of small developers and of self-generation plants.

Figure 8.2 *Difficulties for market entry of small developers with biomass electricity projects*



In conclusion, the extent of confirmation of the expectations with regard to diffusion patterns can be overall assessed as *good*. This supports the continuation of empirical analysis regarding the dependent variables of the analytical framework, which is done in Section 8.3.2.

8.3.2 Installed capacity increase and prospects for sustainable diffuison processes in 2001

This section tests the expectations on installed capacity increase and looks at the prospects for the sustainability of market diffusion processes as they looked like by 2001.

8.3.2.1 Installed capacity increase, 1996-2001

The hypothesis predicts the support system may lead to *modest* capacity increase in short medium term. In Chapter 5 we operationalised a 'modest' capacity increase as in the range of 500-1000 MW. Further, we expected that in this case the features of the social-economic-industrial context of diffusion would rather have the characteristics expected under political investment contexts. This case study covered a period of six years, 1996-2001 during which only 90 MW (see Table 8.14) entered into operation.

Appendix 8.1 lists all commercial projects that entered the register for special regime renewable plants of the governmental renewable agency Idae after the entry into force of the 2818/1998 Royal Decree for the new payment system. The database does not mention the year when they were commissioned but only when they were placed on the 1998 payment method (either new tariffs or premiums). For this reason, it is not clear which projects were developed/approved after 1995. But, taking into account that:

- at the end of 1995 there were 152 MW already operating, of which only 40 MW were selling electricity to the grid (commercial plants);
- in 2001 there were 473 MW in the Idae register of commercial plants;
- during 1995-2000 there were projects totalling around 100 MW functioning in self-generation regime (and therefore not included in the Idae register listing the projects selling electricity to the grid);

- between 1995-2001 there were only very few projects totalling a small capacity dedicated for self-generation projects; and assuming that
- none of the projects installed or approved during 2001 were self-generation plants,

it could be estimated that the capacity installed and approved between 1996-2001 was slightly above 433 MW[39] (no matter if they were mainly for commercial or self-generation or strategic purposes). But at the end of 2001 there were only 90 MW producing biomass electricity, while around 343 MW were not operating yet.

Table 8.14 *Annual cumulated installed capacity of biomass electricity*

Biomass	1995	1996	1997	1998	1999[40]	2000	2001
MW	152	182,8	183,6	187,8	202,4	217,2	242

Source: Idae 2002, Bulletin No.3

The 433 MW number of capacity increase goes quite close to the range of modest market share increase, which was considered between 500-1000 MW. In Chapter 5, we mentioned that this operationalisation would be orientative and that the tendency behind the number is important. The market entry of diverse categories of large developers after 1999, the improved availability of project finance loans and the tendency for power plants' increase in size indicate a tendency for faster annual increase in installed capacity.

The period we studied empirically extended to only six years. Looking at the changes in diffusion patterns it may be expected that within five more years the installed capacity would perhaps double. The governmental target is to reach 1708 MW of biomass power by 2010. The rate of market growth and the achievement of the target will depend on the extent to which there is sufficient biomass resource potential that allows profitable projects under the available price support. The government promised investors in the 1998 renewable policy plan a series of financial support mechanisms for biomass electricity. But by 2001 the government failed to implement the policies announced. The diffusion patterns observed since 1999 suggest that the market - both a large diversity of economic actors and financing agents - is ready to implement substantial investment plans, provided that the economics of biomass power plants allow them to book the required profitability for projects. Based on these (tendency-oriented) considerations, we incline to *partly confirm* the expectation of the part of the hypothesis with regard to capacity increase.

8.3.2.2 The prospects for sustainable diffusion processes

This sub-section looks at the prospects for the continuation of market diffusion processes after 2001. In Chapter 6 we considered that in this case the features of the social-economic-industrial context of diffusion would rather have the characteristics expected under political investment contexts. The prospects of diffusion continuity are strongly dependent on the availability of biomass resources at costs that would still enable projects with high or at least modest profitability.

We start this sub-section by looking at the issue of cost performances (production costs per kWh) and factors affecting this. They are discussed in relation to the domestic potential and price of different types of biomass resources, and after that in relation to the types of

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[39] This number was calculated as 473 MW (commercial projects installed or approved by 2001) minus 40 MW (commercial capacity already operating in 1995) = 433 MW; to this one can add the very small new self-generation capacity (which is however not known exactly).

[40] In 1999 the biomass electricity (including biogas) represented 0,6% of total electricity generation in Spain and 13% of total renewable electricity production, excluding large scale hydropower (Idae, April 2001).

technological designs. These are the perspectives on diffusion sustainability that we argued need to be analysed just empirically. Following this, we test the theoretical expectations with regard to the features of the socio-economic-industrial diffusion context in 2001. At the end of this section, we discuss the obstacles facing diffusion continuation in 2001 and make some reflections on potentials, targets and expectations for the role of biomass in electricity supply. Finally, Section 8.3.3 summarises and concludes on the confirmation of theoretical expectations formulated in the hypothesis for this case study.

Cost performances and biomass resource potential

From the perspective of cost-performances, some cost reductions were booked by biomass technologies in Spain in 2001. In mid 1990s biomass electricity incurred production costs that had the lower range between 5,7 - 7,5 €c/kWh (Carrasco 1996), depending on the biomass-feedstock technological principle, the size of power plant used, as well as the characteristics and location of resources (see Section 4.4). In 2001, the lower range was starting from 5,2 €c/kWh (Alonzo Gonzalez 2001). But the average pool price of electricity in 2002 was 4,5 €c/kWh, which shows still a cost gap compared to fossil-fuel-electricity. Market experts suggest that price support should increase by 1 - 2 €c/kWh in order to make a larger part of the clean resource potential economically feasible and initiate the spin-offs for costs reduction (Vitales 2002; APPA 2001). Only biogas and certain types of organic wastes used at their production place could be employed for biomass electricity generation at production costs in the range of average market prices, 3 - 4 €c/kWh.

Table 8.15 summarises our assessments on how did the categories of factors influence production costs for biomass electricity since mid 1990. We briefly discussed each of them separately, in continuation, with emphasis on biomass resources potential and prices.

Table 8.15 *Cost performances of biomass technologies in Spain during the 1990s*

Evolution cost sources	biomass in Spain mid 1990s-2001
technology-specific	very high and only small decrease
technology-complementary	still low but on the increase since 1999
context induced	high and little change
quality / price resource exploited	increasing, but resource costs also increase
lowest (per kWh) production costs	3-4 €c/kWh biogas; 5,2 €c/kWh for conventional biomass designs

Factory costs of biomass technology in mid 1990s accessible to the Spanish market of investors were very high. They could vary between 1200 €/kW – 2400 €/kW, depending on the combination of biomass-to-feedstock technology and electricity generation technology, and depending on the size of the power plant for which they were used (Carrasco 1996). By 2001 the range of technology costs lowered to 960 €/kW (Alonzo Gonzalez 2001). As it will be explained in more detail in the paragraph regarding the industrial basis, Spain did not have in 2001 its own biomass technology industry for design and manufacturing. There were companies concerned with research and demonstration operating small prototypes. There were other companies concerned with the manufacturing of pieces of equipment under technology transfer agreements with foreign companies. But overall, the technology cost reductions were imported rather than owed to the domestic industry activity. With only 90 MW of biomass power plants put into operation between 1996-2001, a domestic industry would not have achieved any reduction in technology costs.

Regarding technology complementary costs, we did not find information on their share and evolution. However, looking at the types of resources used before and after mid 1990s some inferences could be made. Up to 1995, the main resources were industrial-agricultural organic wastes (secondary resources). Electricity plants were located close to or even at the sites where organic wastes were produced. The output was often consumed also close to the site in industrial production activities or sold to the grid to which the industrial company was connected. This may support the assumption that technology complementary costs had a small weight in production costs.

After 1996, the use of organic wastes for electricity generation started to take place outside the sites of wastes' production, incurring hence technology complementary costs for the transport, storage and handling of them. Later, clean biomass resources have also started to be used, which assume in addition also costs for collection and logistics of wastes gathering. In 2002, only 26% of resources were in the clean (or primary resource) category. Hence, one can as well assume that the costs in this category started to slowly increase as clean biomass resources have begun to be used in 1998/1999. If governmental price support increases so that the very large potential in this resource category can be exploited, technology complementary costs will continue to increase accordingly.

In the context-induced cost category we differentiated in Chapter 2 among: financing/trade cost factors; costs incurred during project life-cycle stages; and administrative(social) consent/tax expenses. We cannot make any statement with regard to the third group of costs because we could not find empirical information regarding this topic. However, regarding the first two cost groups it can be argued that these costs were still high in 2001.

In Section 8.2.1.2, it was already mentioned that when project finance loans are available, banks require shorter debt maturity, higher equity contribution and higher interest rates. These kept the costs associated to financing at high level, compared to financing costs of traditional business areas or technologies. Further, the costs incurred during project life-cycle stages could be inferred as high. The size and dynamics of the industry appeared large from the governmental statistics. But there was in fact little investment activity and as we explain below many companies did not seem to have had yet any background in biomass technology activities. The large numbers do not suggest to us automatically high competition among product and service suppliers in the manufacturing and support industry (and consequently low costs in this group).

Finally, as regards the relationship quality/price of resources exploited, a clear tendency could be seen for an increase in the role that biomass costs play in production costs. Before 1995 the only resources used were zero-costs organic wastes and biogas, as they were used by their producers or by companies working in (relation with) biogas generation sites. By 2001, data in Appendix 8.1 show that 26% of the capacity was using clean biomass resources such as forestry wastes and straw. The use of these resources comes at higher costs because, on the one hand, they often assume purchasing costs while on the other hand they may incur also higher costs for transport, collection and processing. In addition, 5% of resources used in 2001 was represented by dedicated energy crops, which assume even higher costs than clean biomass wastes. In Table 8.17 further below the ranges of costs for different types of biomass resources can be observed.

The assessments of biomass resources indicate that the potential for agricultural and industrial organic wastes and for biogas is very small as compared to dedicated cultivation and clean biomass wastes. This means that unless financial support from the government increases, the rate of installed capacity increase would reach a ceiling and then diffusion would stagnate. The remaining potential that can be economically exploited (annually) based on the 2000 price support was very limited (see Table 8.16).

The sustainability of market diffusion processes depends on the availability and costs of resources. When biomass resources result in production costs that are higher than the available price support, diffusion continuity would be restricted to the repowering of the installed capacity operating at affordable biomass costs. We look in the frame of the following paragraphs at the relationship between diffusion potential and biomass costs.

Biomass resource costs, resource potential and diffusion continuity

Governmental assessment of the potential for different types of biomass resources changed during the 1990s. Estimations at the end of 1996 suggested a potential of 37,2 Mtoe (million tons of oil equivalent) split per resources as in Table 8.16. However, in the preparation of the 1998 policy plan for renewables new assessments were made. They suggested a lower potential, respectively 16,6 Mtoe for biomass and 0,546 Mtoe for biogas.

Table 8.16 *The biomass resource potential in Spain, uses in 2000 and targets for 2010*

Type of biomass resources		Million tons of oil equivalent (Mtoe / year)	
		Potential per year (Idae, 1999)	Potential per year (Idae 1997)
Dedicated cultivation	Energy crops	4,0	19,6
	Forest cultivation	1,7	
Clean biomass wastes	Forestry wastes	1,4	13,8
	Woody-agricultural wastes	1,0	
	Crop-agricultural wastes	7,9	
Secondary biomass	Agricultural organic waste	0,25	2,2
	Industrial organic wastes	0,25	
Biogas		0,546[41]	1,6
Total biomass		17,146	37,2

Sources: Idae 1997; Idae[1] 1999

The estimations in the 1998 renewable policy plan show a large technical availability of biomass resources. If the total estimated 17,14 Mtoe energy stored in the various forms of organic matter was to be transformed in electricity this would mean a potential of 7620 MW[42]. We are not aware of technical studies indicating limits above which diffusion benefits of economies of scales and/or learning. But if diffusion would go so far to reach almost 8000 MW, it is reasonable to expect substantial improvements in production costs and technical performances of biomass electricity technologies.

Nevertheless, in contrast to wind and solar energy, this potential is often costly to exploit. In the policy plan, it appears that the remaining potentials of secondary biomass wastes (organic industrial and agricultural) and biogas are very limited. These are the only types of resources that usually come at ‘no’ or ‘low’ costs. Together they are not expected to contribute to more than 465 MW electricity plants[43].

The technical potential for dedicated energy cultivation and clean biomass wastes is clearly large. The estimation for dedicated cultivation, of 5,7 Mtoe (see Table 8.16) was made only for 10% of the total area considered in that year as available for non-food cultivation (Idae[1] 1999: 57). The theoretical potential for forestry wastes is also in practice much higher than the technically feasible estimate of 1,4 Mtoe. Menendez (1997: 163) explains that Spain disposes of 11 million ha of forest that can generate clean forestry wastes equivalent to 4 Mtoe. Not all of this might be recoverable, due to reasons such as dispersal, difficult topography, or

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[41] Biogas resources are expected to come mainly from sewage treatment plants, followed by solid waste sites, industrial wastes, and livestock manure (Idae[1] 1999: 148).

[42] We made this rough estimate based on the transformation 1 MW = 2250 toe that we used in Section 8.2.1.2 to get an idea about the likely sizes of projects developed before 1995.

[43] This is again a rough estimate of us, considering that 2250 toe is needed for each MW and having in view that the total estimation for these resources is 1146 Mtoe.

poor infrastructure. In addition there is the problem of competing uses, as forestry wastes have also applications in the industrial sectors of paper and furniture. But the theoretical potential can still be considered high having in view that many large areas of Spain would need to be submitted to afforestration, to avoid the fast advancing desertification, or reforestation to replace the pine forests losing their function of CO_2 storage (Menendez 1997: 165). Clean agricultural wastes have by far the largest potential. Although exposed to some use-competition from the paper industries and some traditional applications of straw in farming, it is estimated that there is a remaining potential of 8,9 Mtoe for energy applications.

The availability of these potentials comes at different costs. The financial support for biomass power projects, available up to 2002, has been too small to make these technical potentials also economically feasible. Menendez (1997: 139) mentions that the cost for clean forest wastes supply is between 3 - 4,8 €c/kg. For clean agricultural wastes prices have an even much larger variation. For example for straw they can vary between 1,2-9 €c/kg. For woody agricultural wastes costs are above 3 €c/kg (Menendez 1997: 128). Biomass-electricity plants using such resources can only be profitable - under the price support per kWh electricity available in late 1990s - if biomass is available at 1,8 €c/kg biomass. Interested developers (Vitales 2001) estimate that only a price increase of 1,8 €c/kWh for electricity sold to the grid (compared to the 2001 tariffs/premiums) can make plants using clean biomass resources profitable on a larger scale.

But beside costs, developers intending to use clean biomass have to face substantial price risks too. For energy crops and clean forestry wastes, price risks are mainly related to the limited experience with using these types of resources and to the fact that a resource-market did not emerged yet by 2002. For some clean agricultural wastes such as straw there are long-established markets. But their prices are also exposed to large fluctuations. The main reasons are their seasonal availability, climate influence and competing uses of such wastes. In late 1990s the phenomenon of price speculation was also reported, as farmers noticed the increasing interest of energy developers. The last column of Table 8.17 summarises the situation on costs and risks for the types of biomass resources included in the 1998 potential estimation.

But the exploitation of the technically available potential is restricted not only by costs and price risks. A series of other obstacles were highlighted both by the government, in the 1998 policy plan, and by market players. Many of them are inherent to the beginning phase of any new technology. They regard issues such as:

1. learning needs among different groups of actors needed to be involved[44];
2. improvements still needed in the technical and logistic aspects of resource collection, transport, storage and processing[45];
3. the hesitance of farmers to switch to a completely new type of cultivation, in the case of dedicated energy crops, for which costs and profits are yet not known;
4. building business relations / networks between actors who did not have such contacts before: farmers / rural population and energy companies.

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[44] For example the use of forest wastes requires an improved understanding of forest ecology that needs to be traced in a clear schedule. The processes to prepare clean agricultural/forest wastes in usable feedstocks are technically complex. Special machinery needs to be used and there is limited experience with such equipment, except in the wood industry.

[45] For example, there is a need to improve the use of the traditional equipment from wood industry and agriculture in order to increase the density of material to be transported and reduce costs. The storage method influences the energy quality of resources in time, impacting this way also on price.

5. poor coordination of agricultural, forestry, waste management and energy policies, that can locate and organize the use of biomass.

Table 8.17 *The costs and risks of biomass resources in Spain*

Types of biomass	Price	Other obstacles	Availability
forestry wastes	high and risky (3-4,8 €c/kg)	needs for: learning and logistic-technical improvements; uncertainty on demand; poor / lack of awareness; markets need organization; lack of policy integration	technically large but mostly not yet economically feasible without extra price support
agricultural woody wastes	high and risky (> 3 €c/kg)		
energy crops	high and risky		
herbaceous agricultural waste	high and risky (1,2-9 €c/kg)		
industrial wastes	zero / convenient	no significant restrictions	technically small
biogas			

Therefore, biomass resource potential in Spain, considered as technically available in late 1990s, is large. This could support the installation of at least 7620 MW. However, only a small part of it is also economically feasible to exploit. This is mainly formed by biogas and organic wastes. Governmental financial support for biomass electricity production available in 2001 did not make possible (or attractive) the use of clean biomass resources (forestry wastes; agricultural waste sand energy crops), except for niche sectors such as agricultural cooperatives[46]. Even if financial support increases, there are a series of other obstacles confronting the market introduction of these resources. Consequently the long term continuity of diffusion depends on the willingness of the government to increase price support, which needs to be accompanied by institutional intervention and coordination for the supply of biomass resources.

Technical performances, costs and biomass resources

In Section 4.4, we discussed that there is a tight relationship between cost performances, technological design, plant sizes and types of biomass resources. Direct combustion technologies are however cheaper for a wider range of plant sizes than gasification technologies. Besides, they can be used for any type of biomass resources, unlike gasification technologies for which different designs assume different requirements for biomass resources. Given the limited price support offered by the support system in Spain, by 2001 direct combustion technologies dominated market adoption.

Seen from the perspective of diffusion expansion potential, they have lower efficiency ranges than those already achieved by gasification technologies. However, gasification designs are limited in terms of the biomass resources types that each of it is compatible with. Reductions of investment costs and improvements in the resource base technically compatible for each gasification technological design are important developments necessary for the long-term expansion of the diffusion potential. However, the immediate expansion of the diffusion potential is also problematic as the limited extent of price support does not stimulate the large-scale market adoption of these diffusion-optimal designs, which would in its turn stimulate technology-specific cost reductions and more research for the enlargement of the technically compatible resource base.

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[46] It is estimated that in 2002 only 10% of the clean-waste biomass were used.

The next part of this subsection regarding the prospects for the sustainability of market diffuison processes tests the theoretical expectations regarding the features of the socio-economic-industrial context of diffusion in 2001.

Table 8.18 *Diffusion results of biomass electricity technologies in Spain, in 2001*

Diffusion context likely to emerge		Theoretical expectations	Biomass in Spain 1996-2001
Socio-economic benefits		modest	partly confirmed
Local	Direct: ownership	likely	not confirmed
	Indirect: more attractive (than usual) benefits from ~ land rents; ~ local taxes; or ~ local economic or social welfare investments	not likely	not confirmed (important benefits are available)
	Indirect ~ local employment	technology specific	increasing
National	Ownership individuals (shares)	likely	not confirmed
	Employment in industry	likely modest	confirmed
Industrial basis and dynamics		modest	confirmed large extent
Number companies offering products / services for renewable electricity plants		modest	confirmed
Types of companies involved in industry		mostly industrial companies active for conventional energy technologies	confirmed
Degree of specialisation in renewables		modest	confirmed

The features of the socio-economic-industrial context of diffusion in 2001

Table 8.18 presents the theoretical expectations regarding the socio-economic-industrial context likely to be created by a political investment context on which we hypothesised a modest installed capacity increase. Besides, it presents the empirical findings regarding these features after a six-year period of diffusion for biomass power technologies in Spain.

Our overall assessment is that the socio-economic benefits from diffusion so far are small. But they have the potential to be very large given the labour intensity of biomass power technologies. The industrial basis and dynamics appear at first sight large, looking only at the numbers of companies listed as involved in the business. However, a closer look reveals that due to the limited demand the de facto size of the manufacturing and service industry is small. It has, however, a large potential to expand quickly, when demand for technology increases. Overall we assess the expectations on socio-economic benefits as *partly confirmed* and those regarding the industrial basis as *confirmed to large extent*.

Socio-economic benefits

As regards the first channel, of local socio-economic benefits, we could not identify cases of biomass electricity plants where local population is directly participating with equity, as co-owners in projects built in the region. However, an increasing number of plants are being built, where biomass resource suppliers contribute to the capital formation of project-oriented companies[47], or even companies specialised in biomass power commercial plants[48]. In some

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[47] Examples here are the biomass electricity plants built with the participation of the cooperatives Oleicola El Tejar or Aceites Pineda, which are supplying the residues from the industrial process of olive oil production.

[48] An example here is a new company specialized in the electricity conversion of pig manure. It is formed by four large corporations: the energy company Iberdrola, the engineering group Sener, the bank Caja España

cases, local people are share-holders or members of the entities that supply biomass resources. This is especially the case of agricultural cooperatives, and of the associations for animal farming. This way, indirectly, they become interest-holders in biomass power plants. This model is expected to expand in the future, as both project developers and financing agents view the capital participation of resource suppliers as an important factor in risk reduction. An indirect local economic benefit from biomass power plants investment is formed by the participation of an increasing number of local municipalities or energy agencies as co-owners of biomass plants.

The use of clean biomass resources in only 26% (or 123 MW) of the capacity approved by 2001 suggests, on the one hand, that the progress along these three channels of local socio-economic embeddness has been small so far at sector level. But, on the other hand, the fact that this market share increase took place in basically only 3-4 years (after 1998), suggests that the prospects of continuing progress on these aspects are quite good.

Local employment through biomass supply is the channel with the highest potential for socio-economic embeddness. Local people need to be involved in all processes preceding the use of biomass in the energy plant: collection, transport, storage and pre-treatment. In the case of energy cultivation, growing crops is also needed. It has not only the benefit of creating employment but also that of avoiding the migration of rural population towards cities. As more land is removed from EU subsidies for food crops production, energy crops are the only alternative that can offer similar economic benefits, since they still qualify for EU subsidies.

After 1998/1999 an increasing number of energy companies and technology corporations entered in contact with agricultural cooperatives and local associations in rural areas. Long-term contracts emerged for the supply of clean agricultural wastes and clean forestry wastes. The first contracts for the long-term supply of dedicated energy crops have also been concluded in Castilla y Leon and Aragon. Hence, one can expect an increasing interest of farmers to sign long-term contracts for energy crops supply, in the near future, since the cooperatives which played the role of prime movers already reported good business results[49]. The governmental renewable agency Idae estimated that if the target for biomass use for 2010 is reached (1780 MW), around 1000 companies would function in the industrial sector of biomass supply[50].

In addition to employment, local benefits can also be measured in terms of opportunities to establish new types of companies, focusing on activities such as storage of biomass resources, pre-treatment of biomass, production or trade of fertilizers for energy crops, repairment and maintenance of equipment for biomass handling and storage, biomass trading and so on.

As regards the national level employment and potential for trade union political lobby, biomass power plants create high employment also in the phases of construction, operation and maintenance. Menendez (2000) estimated that, in 2000, there were around 3000 people benefiting of direct jobs related to resource supply, commissioning and operation of biomass energy plants). If the 2010 governmental target of 1780 MW new capacity is reached, direct-biomass employment could raise to 30.000 people. The 1998 renewable energy policy plan does not make estimations on this issue.

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and the cooperative Calporc for pig farming. In 2001 these companies were planning four plants of 15 MW each for the anaerobic digestion of pig manure (Las Energias Renovables, 7 January 2001).

[49] "New energy crops" in *Las Energias Renovables* of 18 October 2001, Madrid.

[50] "The government wishes to increase the energy consumption based on biomass" in *Las Energias Renovables,* 12 November 2001.

Industrial basis and dynamics

From the standpoint of industrial capacity and dynamics, progress was achieved by 2001. In mid 1990s only around 60 companies were offering equipment and services for biomass electricity technologies plants, of which only a few were covering biomass-to-feedstock equipment and biomass/biogas collection-supply systems. The Idae (2001) statistics for the biomass industrial capacity in 2001 mentioned 130 companies with activities in the field of forest wastes based plants and 140 firms covering technologies that used agricultural wastes. This suggests very large industry size, which is striking having in view the limited internal demand and that the Spanish industry does not serve a (large) foreign market. Hence, we investigated further into the size of the industrial basis.

Beside the published statistics, the governmental renewable agency Idae administers also a database on-line where, voluntarily, companies are registered on three main criteria: technological areas covered; commercialized products; and activities/services performed[51]. A first search of the database selecting, in turn, each of the two resource types for the option 'technological area' and nothing for the other two options available results in different but also high numbers: 113 companies for forestry wastes, and 114 companies for agricultural wastes. Table 8.19 presents the number of companies offering some types of activities/services, as differentiated by Idae[52].

Table 8.19 *Companies offering services and products related to biomass power*[53]

Activities and services	Companies for agricultural wastes	Companies for forestry wastes
financial services	23	21
manufacture equipment	28	32
equipment import	25	24
equipment repair	29	30
consultancy	53	49
equipment maintenance	53	50
equipment installation	62	very many
feasibility studies	71	very many
technical assistance	79	very many
project development	93	almost all
Total number companies	113	114

Based on Idae company-database, http://www.idae.es, analysed at 30 May 2001

These data suggest that there was a very intense competition for services in the sphere of engineering and advising/consulting. For activities dealing with equipment import, manufacturing and repair there were fewer companies registered. Their number was also significant, but looking only at numbers does not tell what kind of equipment companies offer. As discussed in Section 4.4, biomass power plants involve 3 types of systems: biomass supply, biomass-to-feedstock and electricity conversion equipment.

Table 8.20 presents the results of a different search in the Idae company-database, looking at the number of companies that commercialised one of the technological systems and designs

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[51] The Idae company-database is available on line at http://www.Idae.es.

[52] These are the results of the extended search, when the activities/services presented in the first column of Table 8.19 were added to the searching task.

[53] The searche was organized by selecting simultaneously the 'technology area' of agricultural wastes and one of the activities mentioned in Table 8.19. The same operation was done for the technology area of forestry wastes.

mentioned in the first colom of the same table. These data show that only 25 companies were offering (importing or manufacturing) equipment for one or more technologies the first two groups of systems[54]. The competition per type of technological design was much smaller, with biogas and direct combustion systems being the best supplied. As regards gasification only Taim-Tfg had an original Spanish design, although in testing - not yet commercially available. The other companies were importing or ready to import. Similarly, for pyrolysis the industrial equipment capacity was rather ‘potential’, in terms of readiness to supply. There were no plants built or under construction using this design in 2001.

Table 8.20 *Industrial capacity for specialized biomass equipment in 2001*

Industrial capacity per type of technology design[55]	Manufacture	Imports
Equipment for the pre-treatment of wastes	4	3
Equipment for treatment of biomass	3	3
Biogas production plants	4	6
Systems for biomass manipulation	4	7
Systems for anaerobic digestion	4	4
Gasification installations	6	5
Pyrolysis installations	4	2
Direct combustion installations	9	9
Total number of companies on Search [2]	25 companies	

Based on Idae website database http://www.idae.es

Table 8.21 *Degree of specialization on biomass electricity technologies technology*

Number of technology areas of specialization of biomass electricity technologies-core companies	Number of companies
only biomass electricity technologies	-
biomass electricity technologies + 1 RET	4
biomass electricity technologies + 2 RET	11
biomass electricity technologies + 3 RET	2
biomass electricity technologies + 4 RET	4
biomass electricity technologies + > 4 RET	4

In order to get a glimpse at the degree of specialization of companies in biomass power plants, we only looked at how many other types of renewable technologies were covered by the 25 firms offering equipment for biomass. The results, based also on Idae database search are presented in Table 8.21. They indicate that, although there was no firm working exclusively on biomass technology, there were 15 companies that had in their portfolio 1 or 2 other types of renewables. Most of them were working with technologies for urban solid wastes and/or biofuels - the closest related to biomass electricity technologies. Only 4 companies in this group dispersed their activities over more than 4 other RETs. A random check among the rest of companies - around 100 - suggested that most of them were actually integrated with more than 4 other RETs. These results suggest:

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[54] Based on Idae database we identified actually only 22 companies. To these, we added 3 large technology corporations that were not registered at all in the database. But their involvement as equipment manufacturers appeared clear form interviews with market experts and specialized journal articles. These large technology corporations are: Taim-Tfg, Grupo Guascor and Standardkassel.

[55] No selection was made for the other two main searching criteria - technological area and activity/product offered.

- the tendency of a handful of companies to specialize in equipment and services using wastes and organic biomass; these companies are often coming from related technological backgrounds, such as fossil fuel combustion, and various types of industrial equipment;
- the majority of companies look for business risk-pooling in their technological portfolios, by offering more general services, such as engineering and feasibility studies, for a larger set of RETs.

With regard to the very high number of companies registered in Idae database it needs to be explained that by 2001 only few of them had actually been involved in commissioning and operation works for biomass electricity plants. They were generally large technology corporations or energy companies that set up new departments or subsidiaries for renewable energy projects. Many companies registered rather their willingness to become involved in this new business area. But by 2001 some of them did not have actually departments or even specialized personnel that could work in biomass projects[56]. It is not clear how fast could 'willingness' be eventually transformed in 'readiness', since this requires skilled personnel. The Spanish government (Idae[1] 1999) and industry agree that this was still in shortage in 2001. Therefore, we interpret the large numbers as 'potential' industrial basis and dynamics.

Interviews with several market experts and publications of Idae[57] do not consider the industrial capacity a problem for biomass electricity diffusion in Spain. There is a common view that this "does not pose limitations" since the equipment needed does not assume a too high degree of specificity (Idae[1] 1999: 142). It is believed that the existing manufacturing capacity for industrial equipment could respond fast to an eventual increase in demand for direct combustion and biogas-based technologies. Besides, the interest of multinational corporations that own already designs for the innovative technologies of gasification and pyrolysis, combined with the manufacturing capacity of Spain, could ensure that demand would be served for these technologies too. Although strongly stressed in the section of 'obstacles' for biomass projects in the 1998 policy plan, the shortage of specialized personnel, and the need for equipment adjustments to fit requirements of biomass use seem to be downplayed when taking about an "industrial capacity with no limitations". At the time of analysis diffusion still relied, partly, on imported technology - mostly from Nordic countries (Carrasco 2002).

In conclusion, we consider that the industrial capacity for biomass electricity technologies and the degree of competition for each activity and service needed, as well as for each technological design was in practice still small, in 2001 - in terms of experienced companies ready to respond to business orders[58]. However, there was a potentially large capacity in terms of willingness of industrial companies to increase their specialization in biomass electricity technologies plants once demand justifies (extra) investments in specialized personnel and sunk investments in manufacturing or supportive equipment. We incline, hence to characterize the indicator of industrial embeddness and dynamics of biomass electricity technologies technology by 2001 as partly favourable for the continuation of diffusion processes.

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[56] The 'working-profile' of these companies was known to us from previous interviews - either directly with companies or with market experts, from journals and governmental publications, and in some cases from companies' own website. Some of them have only worked in wind area, by 2001, or only in hydropower.

[57] Carrasco [Ciemat], Fernandez [Idae], Fernandez [Adabe] May 2002; Idae ([1] 1999; 2002).

[58] Given the slow rhythm of developments, some Spanish equipment companies and potential developers drafted investment plans abroad. For example, the Guascor Group will invest in biomass projects in Brazil where biomass resources are abundant and the government announced to introduce premiums for woody wastes based electricity (Las Energias Renovables, 2 June 2001).

It can be concluded, hence, that the expectations of this hypothesis were *partly confirmed* with regard to the socio-economic benefits and *confirmed to large extent* with regard to the industrial basis and dynamics. In the following paragraphs, we make an overview of the main obstacles facing diffusion continuation in 2001.

Obstacles facing diffusion in 2001

We would like to differentiate between obstacles and difficulties. There are issues that make the use of certain types of biomass resources difficult but one cannot interfere to change the situation for the better. For example the use of many types of resources, such as forestry wastes and animal manure faces the inconvenient that resources are very dispersed. Collection remains labour intensive and time consuming even when logistics are optimized. Another example is the seasonal availability of agricultural and forestry resources, and the influence of climate on their quality. These are difficulties that one can find ways to accept or, when possible, predict and minimize negative effects.

Drawing on governmental analyses in the 1998 policy plan, and on the opinion of market experts we differentiate among the following groups of obstacles:

- economic: insufficient financial support to exploit all types of resources, and to use more efficient, new technologies;
- financing, mainly due to price risks, resource availability risks; and technology risk-(perceptions);
- resource markets not ready, both in terms of volume and continuity of supply, and of price certainty and stability;
- technical: demonstration and technical improvements needed for supply systems and especially for biomass-to-feedstock systems;
- competing applications of certain types of resources and technologies (pyrolysis);
- training, communication and awareness;
- institutional coordination and cross-sector policy integration.

The *main obstacle for a meaningful diffusion is economic*, due to the insufficient financial support in the economic-policy support system. As Table 8.16 showed, the potential for the currently economically feasible resources - organic wastes and biogas - is limited. Perhaps no more than around 465 MW could be installed by 2010 using these resources. A very small part of the clean biomass resources theoretically available by 2010 could be economically exploitable without extra financial support. The main causes are the unsuitable price system in the 2818/1998 Royal Decree and the very long delay - now four years - in the implementation of the financial schemes envisaged in the 1998 policy plan.

The 40/1994 Electricity Law placed all types of biomass-electricity used in one technology group, together with urban solid wastes. But there are large production costs differences, depending on the biomass resources and technologies used. The 2818/1998 Royal Decree placed plants using dedicated energy crops in one separate technology group. But it mixes again a large variety of resources in the same group: wastes from a primary use of biomass, especially manure, sludge from residual water treatment, forestry and agricultural wastes, biofuels and biogas. The 1998 Decree and those that followed it so far for price-updates, failed to compensate this resource mixing by means of higher price per kWh support. Additional financial support was envisaged in the 1998 policy plan. But in 2002 budgets were still not approved by the government. The investment subsidies for collection, processing and supply of biomass resources[59] proposed in the 1998 policy plan are shown in Table 8.22.

Table. 8.22 *The financial support for the supply of primary biomass resources (Idae[1] 1999)*

Types of clean biomass resources	Collection of resources	Equipment processing fuel for energy uses	Production subsidy for fuel delivered
Forestry wastes	production subsidy (300 €/ha)	investment subsidy (20%)	24 €/toe, based on long-term contracts with electricity generators
Woody- agriculture wastes	-		
Grassy agriculture wastes	-	-	
Dedicated energy cultivation	63 €/ha (EU)	investment subsidy (20%)	36 €/toe, for contracts minim 10 yr

In order to improve the profitability of biomass electricity plants the plan proposed a series of financial and fiscal support systems for generators of biomass electricity, as represented in columns 2-4 of Table 8.23. These are additional to the legal price support annually revised through Royal Decree and refer to investment subsidies of maximum 10% except for organic industrial wastes; subsidies for interest rates; and fiscal incentives. The budgets for these schemes were also not adopted in 2002. There was no political will to increase the level of the premium/tariffs, in spite of the legal provision, in the 1997 electricity law, that price support for the different RET would have to be set at levels that enable the achievement of the governmental target of 12%.

Table 8.23 *Financial support for biomass electricity generators, in the 1998 renewables policy plan*

Types of biomass resources	investment subsidy	soft-loan subsidy	fiscal incentive	kWh price support
energy crops	10 %	yes	yes	6,7 (in 1999, annually adjustable)
forestry wastes				
woody agricultural wastes				
herbaceous agricultural wastes				
forestry industrial wastes	no	no	yes	6,3
agricultural industrial wastes				

Based on Idae[1] 1999

The persistence of the economic obstacle is partly responsible for the other obstacles. The financing barrier is an immediate example. When projects' profitability is low, the same legal price risks are perceived differently, because they affect not only the project's profit but also its economic feasibility. Financiers are more hesitant when they are expected to cumulate price risks with the already perceived resource risks and technology risks. Further, because of both the economic and financing obstacles, there is very slow progress in the organisation of the resource market and in the expected technological improvements. If there are not sufficiently strong signs that there is a steady demand for clean biomass resources, potential resource suppliers would not invest in organising and co-ordinating their activities. In the absence of

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[59] Only forestry wastes may receive subsidies for resource collection. The collection subsidy in the case of energy crops should be given actually as a premium for the voluntary choice of the land producer to shift to dedicated energy cultivation. Further, companies getting involved in the transformation of certain biomass resources into fuels usable for energy purposes are considered eligible for 20% investment subsidies on equipment. These resources are forestry wastes, woody agricultural wastes and dedicated energy cultivation. In addition, companies that distribute primary energy resources can also receive a production subsidy per ton of oil equivalent of fuel supplied to electricity generators based on long-term contract. This was meant to reduce fuel risks and costs.

sufficient incentives for private initiatives, the government needs to intervene in preparing the resource supply segment[60]. Technological improvements on the areas identified as necessary in Section 4.4 are also in delay because of the financing difficulty and economic uncertainty to use anything else but direct-combustion and biochemical technologies[61].

The economic obstacle is also responsible to some extent for the risks induced by competing applications of biomass resources. When other sectors can pay better for resources such as forestry wastes or straw - for example the paper and furniture/wood industries, the electricity sector will not manage to attract steady supply of resources. Similarly, the economic obstacle is a major cause in the fact that pyrolysis technology did not manage to capture even the small attention that gasification captured for companies willing to try demonstration installations. The Spanish financial and institutional support seems to consolidate for the application of pyrolysis bio-oil in transport sector applications. The support increases at EU level too, with the likely introduction of compulsory consumption of bio-oil. Therefore, the economic obstacle seems to be central to the chain of obstacles challenging the market diffusion of biomass electricity technologies. But in order to eliminate all obstacles various types of institutional interventions would be necessary as well. Table 8.24 summarises the main proposals to reduce obstacles from the governmental side.

Table.8.24 *Governmental policy proposals to overcome the obstacles of biomass technologies*

Proposals	Forms of support for biomass	Forms of support for biogas
economic	investment and production subsidies for biomass supply; soft loans; fiscal incentives	fiscal incentives;
research	subsidies for R&D	
institutional	a) training local farmers / companies on processing of biomass resources; b) integration of biomass energy plans with forest and agricultural policies; c) diffusion and awareness raising campaigns among potential developers and in the agricultural sector; d) public education campaigns	a) drawing-up waste management plans; b) job training for construction/operation of plants; c) clarity in regulations regarding ceiling of organic matter in dumping solid wastes; d) regional inventories on sources for biogas; e) clarity on technical rules for anaerobic digestion; f) awareness programs for public authorities to enhance resource base: agriculture; fisheries, food, industries.

As regards proposals from interested developers they revolve around the issue of financial support. Besides the need to implement the financial schemes promised in the 1998 policy plan, they emphasise the need to change the payment system of the 1998 Decree. Developers require (Vitales 2001) the elimination of the classification in secondary and primary biomass[62] and propose to introduce a classification based on a combination of resource, technological[63]

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[60] A regional government initiative was underway in 2001 for the constitution of several Biomass Supply Centers in Andalucia, where suppliers and interested users could meet and trade (Nieto, Madrid 2000). These are expected to reduce financing obstacles and speed up the development of projects.

[61] For gasification, these areas are: investment costs, efficiency, emissions, resource flexibility, and better integration with the electricity conversion systems. The first three are also the improvements needed for direct conversion technologies.

[62] According to the 1998 Royal Decree, primary biomass resources are those which did not suffer any previous use, whereas secondary biomass is that which already offered a benefit or was subjected to a transformation. However in the same decree it is indicated that agricultural and forestry wastes are 'secondary biomass', while they are in fact primary biomass resources - should the government be consistent with its own definition. On the other hand, as Vitales (2001) further explains, Autonomous Communities are interpreting these concepts differently introducing additional uncertainty and complexity.

[63] It is suggested to split biomass for electricity production in four technologies: combustion, gasification, bio-digestion, and bio-fuels (Vitales 2001).

and plant-size criteria. The main reasons that recommend this classification are related to the need to account for the: large differences in resource costs and risks; particularities in the technical problems of each technological line; and differences in production costs for different plant sizes when various technological lines are used.

Policy proposals envisage also the support of research and demonstration works. The priority is to improve the performances of fluidized bed combustion and gasification technologies. There are three technology areas considered as Priority I: the increase in efficiency for biomass gasification; the reduction of atmospheric emissions from all technology versions; and the improvement of conversion efficiency. Among Priority II areas are the improvement of fluidized bed combustion and the adaptation of gas turbines and motors to gas produced in biomass gasifiers. These are all areas where substantial innovation needs were underlined in the technology analysis made in Section 4.4. But improvement needs were also signalled with regard to the equipment for the collection and pre-processing of resources. In the case of dedicated energy cultivation, the need for innovation extends to the increase of the energy content and productivity of species, and the diversity of species that can be used. Several interviewed experts stressed that if extra financial support for clean biomass resources delays, improvements in the biomass supply systems should be given priority to reduce biomass costs and increase the range of economically available potential (Carrasco [Ciemat] and Fernandez [Adabe] 2002).

Final considerations on diffusion prospects

Given the delay in the implementation of most of the 1998 policy proposals, several regional governments developed support programs for their own Communities. Among them are also the regions where the largest potentials exploitable by 2010 were identified in the 1998 plan: Andalucia[64], Castilla y Leon, Castilla La Mancha, Aragon[65] and Extremadura. But others, such as Asturias and Navarra, are also ambitious in biomass supply. Regional support ranges from giving extra financial support to taking care that an institutional frame is put in place to stimulate energy crops production and collection of biomass wastes.

The 2010 biomass target envisages the use of 6,0 Mtoe resources, of which around 5,1 Mtoe should be used for electricity generation. This would be a major shift in biomass application, since in 2000 only 5,9% of resources were used for electricity, that is 0,22 Mtoe (Idae April 2001). Without increased financial support and a serious multilateral tackling of the other obstacles at central level, even if regional governments are doing their best, it is possible that the national target will not be achieved.

It seems that the government has a different logic as regards the mutual relations among obstacles and the diffusion success factors. The agency Idae argues that “the issue of projects’ profitability should be studied more carefully” because the fact that there is already some 100 MW capacity installed since 1995 suggests that current support is sufficient to build profitable

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[64] Andalucia has a special policy plan called Probiomassa, 2001-2006, which places a 250 MW target for new capacity by 2010. For this, special investment subsidies have been made available. In 2001 there were 50 MW in operation, 75 MW in building, and 160 MW in development (Sodean 2001).

[65] Aragon regional government aims to stimulate energy crops cultivation. Asturias offers generous investment subsidies (see Chapter 5) and opened in 2002 its Asturian Energy Agency which aims to investigate the potential and be active developer of biomass energy based on agricultural and forestry wastes. In both regions, cooperation with university has been initiated to reach the goals. Experimental crops were being tested in several Communities such as Castilla Y Leon, Aragon, Castilla La Mancha (Las Energias Renovables, 30.03; 18.10 2001).

projects”. The problem is however that these are mostly niche market projects, where special circumstances resulted in acceptable profitability levels, as discussed in one section above.

In 2001 Idae formulated the expectation that technical improvements in the combustion and gasification processes would increase plants’ effciency above 30% which will increase the profitability of projects under the available price support (Idae 2001). In addition research in energy crops would also contribute to the increase in the energy content of biomass resources, improving also the profitability. The government expects that progress in these areas will help fulfill the governmental target for 2010.

Interested developers suggest that an increase of 1,8 €c/kWh would be needed to bring substantial biomass capacity in the market to create the necessary spin-offs for market growth, of the type and scale that Idae believes would somehow happen (APPA 2001; Vitales 2001). Technical and resource quality improvements would come sooner when there are higher industrial dynamics and more operating experience. As our analysis suggested the potentials for socio-economic embedness and industrial dynamics are very large and some small/modest progress was achieved in the six-year period studied. However the capacity increase and sustainability of market diffusion processes are dependent on the extent of financial support. This needs to be sufficient and constant for some medium-term horizon, in order to allow the expansion of the technically available resource base with some tangible results in terms of technical-cost performances, creation of jobs, and of industrial and agricultural companies specialized in the biomass electricity business.

8.3.3 Summary and conclusion regarding hypothesis confirmation

In Section 8.3, we tested the theoretical expectations of a hypothesis specified in Chapter 6 for the case when the support system results in a mixture of (and transition from) a political investment context and an optimal investment context. The case-study regarded the period 1996-2001. The hypothesis formulated the following expectations regarding to diffusion patterns:

- diffusion patterns will take the forms expected under political investment contexts in the period 1996-1998 (forms under Hypothesis 3); and
- a transition towards the forms of diffusion patterns expected under optimal investment contexts (according to Hypothesis 1) may be seen after 1999.

As regards the potential for installed capacity increase, we hypothesised it to be ‘modest’ in short-medium term of diffusion, because of the limited opportunities to build high profitability projects. Further, we considered that in this case the features of the social-economic-industrial context of diffusion would rather have the characteristics expected under political investment contexts.

Diffusion patterns

The predictability of diffusion patterns under both the political investment context and the optimal investment context for this case study can be assessed as *good*. For three indicators of diffusion patterns expectations were ‘confirmed’ - types of financing schemes, project sizes and choice of technological design. For two indicators - types of developers and drivers to invest - predictions were ‘confirmed to large extent’. The situation regarding the extent of confirmation of these two indicators is hence similar to that in the case study for Hypothesis 4. We summarise here the main findings regarding the indicators for which the expectations were not fully confirmed.

As regards the *drivers to invest*, the expectations were ‘confirmed to large extent’ because of the very restricted presence of (partly-)self-generation projects. Biomass power projects were either solely commercial or were co-motivated by various strategic reasons. Since 1999, increasingly more projects could be built with profitability between 8-10% (optimal investment context). Partly-self-generation projects for biomass electricity were in process of disappearance already since 1995 in Spain. Increased financial support made more new investments profitable, and hence preferable in the form of commercial projects, selling all output to the grid. As the indicator of *types of project developers* is concerned, the expectations were ‘confirmed to large extent’. The reason is the decreasing presence of economic actors categorised in the group of small developers.

Diffusion results

For the *installed capacity*, we hypothesised that this would be ‘modest’ in short-medium term of diffusion. In practice, between 1996-2001, the capacity installed and approved was slightly above 433 MW. But at the end of 2001, there were only 90 MW operating and selling biomass electricity to local grid companies. This development was considered to *partly confirm* the expectation (see discussion Section 8.3.2.1).

The expectations of the hypothesis with regard to the socio-economic benefits emerging from diffusion were only partly confirmed, while those with regard to the industrial basis and dynamics were assessed as confirmed to large extent. Our assessment was that the socio-economic benefits from diffusion so far are still small. But they have the potential to be very large given the labour intensity of biomass power technologies. The industrial basis and dynamics also has the potential to become very large in short term. Many industrial companies stand ready to serve an increase in demand for technology and related services. By 2001, the de-facto size of the manufacturing and service industry was still small taking into account only the companies with an operational background in the field of biomass power plants. But the number of companies recorded in the database of the governmental renewable energy agency as part of the industrial infrastructure of biomass electricity is high.

As regards the *cost performances*, the continuity of diffusion processes is threatened by the limited governmental price support. This only enabled by 2001 the use of a restricted resource niche and mostly the use of the conventional type of technology - direct combustion of biomass. The assessments of biomass resources indicate that the potential for agricultural and industrial organic wastes and for biogas - currently dominating the investment preference - is very small as compared to dedicated cultivation and clean biomass wastes. This means that unless financial support from the government increases, the rate of installed capacity increase would reach a ceiling and then diffusion would stagnate. The insufficient availability of price support also de-favours progress in *technical performances*. By 2001, diffusion still took place mainly by means of import of biomass technology. There was only a handful of corporations doing research and demonstration on the diffusion optimal technological principles - gasification and pyrolysis.

Exogenous factors and alternative specifications

Summarising the findings of empirical research, we assess that the following factors may be playing a role in the forms observed for diffusion patterns and results:

- business requirement on profitability of economic actors, especially here - energy utilities (influencing the installed capacity achieved);
- perception regarding the stage of technical development of the respective renewable technology (influencing the installed capacity achieved);

- business culture of financing agents with regard to small (unfamiliar) developers (influencing the presence of small developers);
- the techno-economic particularities of biomass power plants, namely the fact that they are very complex, and too expensive (have too large economies of scale) for small developers; (influencing the presence of small developers and investments in self-generation plants by them); besides, the complexity of biomass projects seems to have led to the predominance of an ownership model where each co-owner contributes to the plant with something more than financial resources, in terms of expertise or implementation/operation support;
- low importance attached to the (voluntary) environmental performances and image by production companies beyond the interest of wastes elimination (influencing the extent of investments in self-generation; whenever price support improves, production companies switch from self-generation to commercial projects);
- (biomass) resource availability for the extent of price support that the system enables (influencing the installed capacity achieved); here comes the issue of the operationalisation of the dependent variable: small, modest, large installed capacity; we discuss this issue in Chapter 14 that draws the conclusion of the study regarding the analytical framework.

The next section makes a summary of the main findings of this chapter from the perspective of the analytical framework.

8.4 Summary

In Chapter 6, we specified the hypotheses to be tested in the framework of empirical research in Spain regarding the diffusion of renewable electricity technologies. In this chapter we tested, in Section 8.2, Hypothesis 4 for the case study of biomass electricity technology market introduction in the period 1980-1995. Further, in Section 8.3 we tested a hypothesis specified for the case when the support system results in a transition from a political investment context to an optimal investment context. The testing of this hypothesis was done for the case study defined by biomass electricity technology diffusion in the period 1996-2001.

In the case study for the testing of Hypothesis 4, the independent variables of economic-policy risks and ranges of project profitability *appeared to have a strong explanatory powe*r with regard to the diffusion patterns and diffusion results of the supported technology. The extent of confirmation of the theoretical expectations under Hypothesis 4 could be assessed as ‘good’ for both diffusion patterns and diffusion results. We observed the influence of two factors on the empirical developments recorded, which also emerged as influencing factors in the second case study – biomass diffusion since 1996. These factors are:

- the business requirement on profitability of economic actors;
- perception of regarding the stage of technical development of the respective renewable technology.

In the case study for testing the specified hypothesis for the political-optimal investment context, the independent variables *appeared to have a strong explanatory powe*r with regard to the diffusion patterns *but not with regard to diffusion results* of the supported technology. The extent of confirmation of the theoretical expectations under this hypothesis could be assessed as ‘good’ for diffusion patterns and as ‘partly satisfactory’ for diffusion results.

Beside the influence of the two independent variables, we identified a set of six factors and resource availability; factors related to business perception/culture profitability preferences; and technology specific factors.

The next chapter tests Hypotheses 2 and 1, for the case studies of small hydropower technology diffusion in the periods 1980-1994, respectively, 1995-2000 in Spain.

Appendix 8.1

Biomass electricity projects registered in the special regime in Spain in 2001 (REE website http://www.ree.es 27 August 2001)

Capacity	Year register	Resource	Company
0,96	1999	biogas	Bioartigas
2,5	1999	biogas	Biosanmarcos
7,32	1999	biogas	Bioastur
2	1999	woody industry wastes	Tableros Tradema
16	1999	organic industrial wastes	Enemasa
9,5	1999	clean wastes biomass	Endesa ECYR
5,97	1999	co-firing paper wastes	Papelera Guipuzcoana
5	1999	clean agricultural biomass	Agroenergetica Algodonales (El Tejar)
8,05	1999	organic industrial wastes	Bioreciclaje de Cadiz
9,2	1999	biogas	SINAE
2,3	1999	woody industrial wastes	Maderas Jose Saiz
Total projects entering Idae register in 1999 = 69 MW			
25	2000	straw	EHN
12,9	2000	olive wastes	Vetejar El Tejar
2	2000	biogas	Compania Aborgase
1	2000	biogas	Ingenieria Ambiental
0,45	2000	biogas	EMSSA-Gava
1,43	2000	organic industrial wastes	Oleicola El Tejar
5,27	2000	organic industrial wastes	Hermanos Santa Maria
0,95	2000	biogas	Biomeruelo Energia
2	2000	biogas	Inventem Mediteranea
25	2000	olive wastes	Agroenergetica Baena[66]
25	2000	olive wastes	Oleoenergia Jimana
0,55	2000	clean biomass wastes	Romero Alvarez
1,032	2000	co-fire with gas	Cadagua
3	2000	organic industrial wastes	Biomasa Extremadura
4,5	2000	organic industrial wastes	Energias Alcoholeras
0,24	2000	biogas	EDAR Sewage Comp.
10	2000	clean biomass wastes	Alvaro Espuny
0,61	2000	biogas	Aprovechamiento Vertedero Municipal
3,55	2000	biogas	Planta Biomasa Alvensa
1,33	2000	biogas	Tractamient Juneda
2,012	2000	biogas	Ingenieria Urbana
1,3	2000	organic industrial wastes	Metarnhel
8	2000	clean biomass wastes	n.a
16	2000	clean biomass wastes	Energia La Loma
4,25	2000	organic industrial wastes	Tableros Tradema
32,4	2000	organic industrial wastes	Cellulosa Energia ENCE - CENER II
12	2000	energy crops & clean agricultural wastes	Biomasa del Pirineo (with SINAE)
0,6	2000	biogas	Empresa Municipal Sanemiento Emasagra

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[66] This is also a company of Oleicola El Tejar, the largest cooperative for olive oil producer in Spain, with 20% of the market.

10,3	2000	biogas	Biogas y Energia SA
0,24	2000	biogas	Ayntamiento Lerida
12	2000	organic industrial wastes	SINAE
Total projects approved in 2000 = 229 MW			
9,31	2001	waste pulp & paper	Papelera Navarra
1,06	2001	biogas	Cespa Gestion Residuos
1,05	2001	biogas	Ecoenergia Canmata
3,34	2001	fruit wastes	El Mañan Cooperativa
0,67	2001	biogas	Endesa ECYR
2,35	2001	woody industrial wastes	D.T.M 96 S.A.
3,8	2001	biogas	Coll Cardes Gas
6	2001	biogas	Ecopark Barcelona
3,58	2001	organic industrial wastes	Uniener
2,11	2001	organic industrial wastes	Agua Residuales Bilbao
8,93	2001	organic industrial wastes	Becosa
7,8	2001	organic industrial wastes	Termica AFAP
2	2001	biogas	Combined Landfill
0,66	2001	biogas	Torre Paduco
20	n.a	landfill gas	Consortium: Sufi, Cespa, Vertesa
0,6	n.a	forestry wastes	Taim & Idae
0,35	n.a	forestry wastes	Taim Tfg
2,35	n.a	clean biomass wastes	Allarluz
10	2001	anaerobic digestion	SINAE
3,5	2001	wood wastes	SINAE - UNIARTE
2	n.a	rice hulls	Idae - Dacsa
12	n.a	energy crops and straw	Idae-Cecsa
12	n.a	straw & wood wastes	Cecsa
12	n.a	energy crops; straw & wood wastes	Biomap
10,6	n.a	black liqueurs	Pastguren
15; 15.	n.a	pig manure biogas	Biogas Company (with Iberdrola)
5,6	n.a	agricultural-industrial wastes	Oleicola El Tejar
1	n.a	biogas	Biosasiesta
Total projects entering Idae register in 2001 = 175 MW			
Total projects entering Idae register[67] in 1999-2001 for payment under the 3rd economic governance structure = 473 MW			

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[67] The last 22 plants mentioned in this table were not included in December 2001 in the Idae register but information was found in the Journal Las Energias Renovables, during interviews, several conference papers and Idae Reports.

Appendix 8.2

Investment characteristics for some projects developed, beginning with 1996

Projects developed beginning with 1996 (most of them after 1998)					
Developer/Co-owner	Plant size	Resource	Financing	Technology	Driver to invest
with Grupo Sufi as co-owner	12 MW	energy crops	project finance	combustion	demonstration (&commercial)
	20 MW	landfill gas	project finance & subsidies	combustion	commercial
	small projects using biogas		project finance	combustion	commercial
Taim-Tfg & Idae (in construction)	0,6 MW	forestry wastes	with Idae equity 27 %	gasification	demonstration
Taim-Tfg	0,35 MW	forestry wastes	in-house finan; Idae subsidy	gasification	demonstration
Sevillana Electricidad	small	biogas	n.a.	combustion	commercial
Esmarsa	1,5 MW	biogas	n.a.	combustion	commercial
Esmarsa	2,5 MW	landfill gas	n.a.	co-generation	commercial
Biomasa de Extremadura[68]	2,5 MW	olive waste	n.a	co-generation	commercial
Allarluz[69]	2,35 MW	forestry & agricultural wastes	project finance (loan 46,6%) subsidy 16,2%	n.a.	demonstration & commercial
EHN	25 MW	straw	debt-corporate fin.; EU subsidy	fluidized bed combustion	demonstration & commercial
co-ownership of Endesa ECYR with other companies	16 MW; 16 MW	olive-wastes	project finance	combustion fluidized bed	commercial
	12 MW	n.a.	project finance	combustion	commercial
	2 small plants	biogas	1: in-house fin. 1: project fin.		commercial
SINAE	10 MW	n.a.	n.a.	anaerobic digestion	n.a
Sinae-Uniarte	3,5 MW	industrial wood wastes	project finance (Ferrando 2000)	combustion	partly self-generation
Idae-Dacsa joint venture	2 MW	rice shell	Idae 85 % joint venture	n.a.	partly self generation (70%)
CECSA with Idae vehicle company	12 MW	energy crops; straw	with Idae 20 % equity	n.a.	partly self generation
BIOMAP (Aragon)	12 MW	straw and wood waste	with Idae 20 % equity	n.a	n.a
Pastguren (Idae for industrial company)	10,6 MW	black liquer y corteza	TPF 100 % (2001)	n.a.	partly self generation
Biomasa del Pirineo (with SINAE)	12 MW	energy crops; clean waste	project finance	combustion.	demonstration-commercial
CENER (paper ind. company ENCE)	36 MW	forest & organic wastes	n.a.	combustion	partly self-generation

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[68] This is a vehicle company constituted by four large firms.

[69] This is a vehicle company constituted with 9% Idae equity and five large companies.

ENCE (paper company)	7,5 MW	cortezas	n.a	fluidized bed combustion	n.a.
Company specialized in biogas (with Iberdrola)	2 of 15 MW	pig manure biogas	project finance (bank also gives equity)	combustion	commercial
Oleicola Tejar[70] 1995	12,5 MW	orujillo	project finance (Sancho Ghesa)	fluidized bed combustion	commercial
Oleicola Tejar 1999	5,6 MW	orujillo	project finance	co-generation	commercial
Oleicola Tejar	25 MW; 25 MW; 5 MW	olive wastes	project finance with subsidies	co-generation	commercial
Biosasiesta (with energy agency)	1 MW	landfill gas	n.a.	combustion	n.a.
La Fontanilla	1,5 MW	organic wastes	n.a.	combustion	n.a.
Tafisa (wood factory)	1,5 MW	wood wastes	n.a.	combustion	n.a.
Gamesa	1,5 MW	n.a.	project finance	gasification	demonstration-commercial;

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[70] This plant is built by the olive processing cooperative Oleicola el Tejar with the regional grid company Sevilana and the large technology corporation Abengoa.

9

Diffusion of small hydropower technology in Spain

9.1 Introduction

This chapter analyses the market diffusion patterns and processes for small hydropower technology in Spain during the 1980s and the 1990s. The purpose of the analysis is to test Hypotheses 1 and 2, developed in Chapter 6. Section 9.1.1 makes a short historical overview of hydropower use in Spain in the form of small plants for electricity production.

Section 9.2 is dedicated to the testing of Hypothesis 2. Section 9.2.1 investigates the forms of the five indicators for diffusion patterns of small hydropower technology in the period 1980-1994. Section 9.2.2 discusses the diffusion results at the end of 1994, in terms of level of installed capacity increase and the main features of the investment context created, in order to get an idea if and how diffusion processes would have continued without a change in the economic governance structure. Section 9.2.3 will draw the conclusion regarding the overall confirmation of Hypothesis 2.

Further, Section 9.3 tests Hypothesis 1 for small hydropower diffusion in Spain during the period 1995-2000. Section 9.3.1 investigates the forms taken by the five selected indicators for diffusion patterns in this period. Section 9.3.2 tests the expectation on installed capacity increase and discusses to what extent a context has been created, at the end of 2000, for sustainable processes of market diffusion. Section 9.3.3 draws the conclusion regarding the overall confirmation of the theoretical expectations formulated in Hypothesis 1. Finally, Section 9.4 summarises and concludes this chapter.

9.1.1 Historical overview of small hydropower use in Spain

The use of hydropower in Spain in the form of small electricity systems goes back to the end of the 19th century. Very small run-of-river installations (see Section 4.3) were the first to offer electricity to industrial companies and residential use. During the first decades of the 20th century electricity generation was almost entirely based on small hydropower plants, located close to consumption points. During the 1920s, the political objective was set to exploit the entire hydropower potential of all river basins in Spain (Idae 1992). Initially, small hydropower installations were mostly developed by industrial companies located in the proximity of rivers, for self-generation purposes (Bustos 2001). Later, with the discovery of alternative current, the transport of electricity became possible and stand-alone small distribution grids emerged around small hydropower systems, delivering electricity for nearby local communities (Bustos 2001; Torez 2001). Some villages along river flows developed their own small hydropower installations. Beside energy needs, self-generation was an attractive option also because in the first decades of the century developers had the right to use river-waters for private interests (Ocharan 2001).

Beginning with the 1950s, with advances in dam and reservoirs' technology, numerous large-size hydropower plants started to be built too. Distribution networks expanded and reached more consumption points and cities. Small electricity companies replaced industrial companies as main generators of electricity, but they all emerged as exploiters of water energy. In 1965, more than 70% of electricity generated in Spain was based on hydropower (Gonzalez Martin 2001).

During the 1960s and 1970s, fossil fuels started to dominate the electricity sector. Fossil fuels were used in much larger power plants with increasingly wider-coverage networks for high voltage transmission. These plants could reach many industrial companies, cities, as well as many villages. The interest of both industrial companies and energy utilities in hydropower decreased substantially with the lowering of fossil fuel prices during the 1960s. The hardest hit were small hydropower installations because they assumed higher operation costs. They could not compete anymore with large hydropower and especially with fossil-based technologies. Consequently, since mid 1960s no new investments were done and numerous shut-downs were registered. From 1748 small hydropower plants functioning in 1964, the number of operating systems continued to drop to 576 in 1982. In terms of installed capacity this means a 50% decrease, from 689 MW to 327 MW in 1982.

After the two oil crises in the 1970s, the Spanish government decided to foster the domestic and renewable energy resources. A complex economic-policy support system was put in place for this purpose. It mainly consisted of the 82/1980 Energy Conservation Law, which traced the protective economic governance structure, and a series of policy support mechanism traced in the national policy plans adopted in 1983, 1986 and 1991. Both commercial and self-generation projects were encouraged in order to revive the interest in small hydropower technology. Small hydropower enjoyed the largest variety of policy schemes and the most substantial financial support, as compared to other renewable technologies. Besides, in 1981 the government concluded an agreement with energy utilities to rehabilitate 100 small hydropower installations (Idae 1992).

But the re-introduction of small hydropower in the Spanish electricity system was much more difficult than one could have expected. The former developers who started or flourished their economic activities with the help of small hydropower installations were in many cases not interested in them anymore. Industrial companies returned to small hydropower self-generation only in isolated cases and energy utilities were, with few exceptions, not enthusiastic to go back to the old small-scale technology. Financing barriers were also experienced, in spite of being a traditional technology line in Spain, with an established domestic industry. Project finance was not available during the entire decade of 1980s. Later, when the first loans based on project finance finally became available in early 1990s, powerful social local opposition based on environmental grounds emerged, accompanied by administrative opposition or extremely slow bureaucratic processes. Consequently, the story of small hydropower diffusion in Spain is different from that of the other technology-cases studied in this book. This is not a case of market introduction but market revival, and of capacity re-powering taking place in parallel with capacity expansion.

9.2 Testing Hypothesis 2 for small hydropower diffusion in Spain, 1980-1994

9.2.1 Testing theoretical expectations on diffusion patterns 1980-1994

This sub-section looks at the forms of the five selected indicators for diffusion patterns for small hydropower investments in Spain during the period 1980-1994. The theoretical expectation for the indicator of *project sizes* cannot be tested, since the definition of small hydropower plants as projects with below 10 MW is politically decided.

9.2.1.1 Types of project developers

Hypothesis 2 predicted that, although smaller developers are also expected to invest, large and financially self-reliant companies would dominate the developers' picture under entrepreneurial type of investment context. In practice our investigation revealed that the group of dominant developers was indeed formed by companies that can be described as large or financially self-reliant. In the period 1986-1994, for which governmental statistics are available, projects were commissioned by the following types of developers:

- 75% of the projects were built by large companies or financially strong companies, of which 39% were owned either by energy utilities or by independent companies specialised in the commercial generation of hydropower;
- 17% of the projects were built by public authorities - local municipalities, regional authorities and the renewable agency - and by water boards and confederations; and
- 8% of the projects were built by individuals and farming associations.

These empirical findings *confirm* our theoretical expectations regarding project developers under Hypothesis 2. The next paragraphs explain how we analysed empirical data to arrive at these findings.

One publication of the governmental renewable agency Idae (1996) mentioned that, up to 1995, the owners of small hydropower were generally "private entities who posses a single small installation, companies whose activities are centred on the construction and operation of small hydropower plants, or electric utilities of different sizes, for which this constitutes a part of their commercial activities." The numbers in Table 9.1 confirm this statement. The table is made on the basis of the lists of projects mentioned in two publications of the governmental renewable agency[1].

Table 9.1 *Types of developers of small hydropower plants during 1980-1994 (Based on Idae 1986)*

Types of developers	1986 - 1990	1991	1992	1993	1994
developers with more than 1 plant (during years)					
energy utilities and companies specialised in small hydropower or electricity[2]	61	12	37	25	10
Idae					
developers with only 1 plant					
project-vehicle companies[3] (mainly) and industrial companies	73	14	26	16	7
local municipalities; regional governments	12	4	8	3	-
water boards	21	5	5	2	3
individuals / agricultural farms	19	3	2	2	2

We processed the empirical data on these information brochures, differentiating between two groups of dominant developers. One the one hand, there were the private entities owning a single installation - envisaged in the above-mentioned governmental publication. They could be grouped in their turn in two types: companies especially constituted for the development and operation of one plant, also referred to as 'project-vehicle companies', and industrial companies. On the other hand, there was a second group of main developers, which was formed by energy utilities and specialised commercial electricity companies. Up to 1991 this first group developed slightly more projects as compared to this second group. Energy utilities

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[1] For the years 1986-1994 we used data from the CADER database of Idae - Commission for Energy Saving, Diversification and Renewables - and published in the "Manual of small hydropower plants", Idae, 1992. For the years after 1991 we used data published in "Renewable Energy in Spain - Balance and Perspectives 2000", Idae 1999.

[2] The small hydropower installations counted in this group were developed by companies whose name was known by the author as a (former) public utility or specialized small hydropower firm from empirical literature, from interviews and by observing that the names of companies recur during the years in the governmental lists of projects. These companies accumulated more small hydropower plants.

[3] These are companies that have only one small hydropower plant. But this does not mean that some of the owners do not have ownership shares in other projects too. But this is not transparent in the available documentation.

were investing either on their own or through subsidiary companies to which regional authorities and industrial companies from various sectors were sometimes also participating in the capital. The independent specialised electricity companies were either focused only on small hydropower production or were concerned more generally with the commercial generation of electricity, using more types of resources and technologies (Gonzalez Velez 2002). In the last case, they had also other types of industrial activities in their portfolio. But like energy utilities they owned more small hydropower generation plants. In terms of industrial background, these specialised companies emerged from traditional industrial sectors in Spain, such as construction, engineering, industrial equipment maintenance, or equipment and components manufacturing industries (Idae 1996). Many of them stood also behind project-vehicle companies (Fages 2002).

Consequently, it can be ascertained that the dominant types of developers in this period were indeed large, financially self-reliant, companies able to invest based on internal financing schemes, as theoretically expected. Hence, it can be stated that the part of Hypothesis 2 regarding the indicator of project developers' types has been *confirmed*. Beside these dominant developers, small hydropower projects were also built by water boards, local and regional authorities, agricultural farms and individuals. The cumulated share of all these types of developers was around 30% in the years up to 1991. The next paragraphs discuss the reasons to invest in small hydropower of developers in Spain.

9.2.1.2 Drivers to invest

Hypothesis 2 predicted a balanced presence of (partly-)self-generation, strategic and commercial projects under entrepreneurial investment contexts. Interviewed developers[4] explained that around 90% of the small hydropower plants developed in Spain since the revival of the market in early 1980s were commercial projects. The rest 10% were either self-generation only systems or installations which were used both for auto-consumption by the owner and selling output from time to time to the grid. This means that the part of Hypothesis 2 regarding reasons to invest has *not been confirmed*.

Three potential explanations for the predominance of commercial projects could be formulated. The first is that special stimulation was given to such projects through the governmental support system. In the 82/1980 Energy Conservation Law small hydropower was the only technology for which the special economic governance structure extended also to commercial plants. For the other RET the legal text only referred to self-generation and R&D projects. Later, in the 1986 Plan for Renewable Energy investment subsidies were specifically targeted at companies specialised in the commercial generation of electricity based on small hydropower installations. The objective was to make small hydropower production a new, self-standing industrial-business activity in Spain (Lopez 2000: 173). This objective was re-iterated in the later energy policy plans.

The second explanation has a cultural-business nature. In Spain self-generation of electricity has been traditionally driven by energy demand. Private investments for electricity self-generation by small consumers are only made when the tentacles of public distribution grids do not reach the sites where demand arises. But similarly un-attractive is self-generation also at the level of industrial companies, with some exceptions of energy intensive industries, such as textile companies. On the one hand, the low environmental concern of consumers in

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[4] Jose Maria Gonzalez Velez, President Small Hydropower Section of the Association of Renewable Energy Producers (APPA), and Manuel Bustos, Public Relations Service of APPA; Ocharan Camara, Ministry of Economy; interviews February 2002 and April 2001.

Spain does not give incentives to industrial production firms to build renewable energy plants for green image. On the other hand, perhaps even if there were industrial companies with opportunities to use water energy of the nearby rivers, this might have been discouraged by the growing local environmental opposition to small hydropower that emerged in early 1990s. Environmental opposition could have worked against the public image of industrial production companies. And this is linked to the third likely reason why self-generation plants were so rare in Spain.

Beginning with the first years of the 1990s the social and administrative opposition on environmental grounds and the slowing down of the administrative approval processes implied higher risks, higher costs and longer waiting times for developers. There were increasingly higher risks that projects would be refused, meaning that all the costs for project preparation and application could be lost. Besides, the detailed environmental impact studies required, and the investments asked in order to minimise the environmental consequences claimed by various parties led in many cases to the substantial escalation of investment costs. Further, as project approval started to claim at least 4-5 years in the waiting line, self-generators were the least likely to be willing to wait for so long. If they were indeed motivated to produce their own electricity, it was more convenient to shift to other types of resources. Consequently, self-generators were less likely to accept these risks, extra costs, and waiting times. These arguments, together, could explain why small hydropower plants were so seldom build as self-generation projects in Spain.

Governmental statistics on the small hydropower capacity operating annually and selling electricity to the grid (commercial plants) are not complete. The publications of the governmental renewable energy that appeared during the 1990s mention the annual capacities only since 1986. In some publications, the capacity installed before 1986 is included (without specifying this apart, though), while in others this is not included, creating confusion regarding the rates of market growth. In Table 9.2 we reproduced the numbers mentioned as operating small hydropower capacity and installed capacity used as commercial projects. So it appears that only in 1993 and 1994 the commercial capacity was smaller then the installed capacity, creating the assumption that 6% - 8% of the installed capacity was used for self-generation purposes. Taking into account the information from interviewees and looking at this data, the general idea is that the share of self-generation plants was indeed very low, which does not confirm the theoretical expectation for this indicator.

Table 9.2 *The annual cumulative capacity of small hydropower, 1986-1994*

Year / Installed capacity annually	1990	1991	1992	1993	1994
MW cumulative (only since 1986)	214,4	276,5	392,2	486,2	547
MW selling to grid[5] in each year	274	357,5	399,4	454,5	501
% self-generation	-	-	-	6,5 %	8 %

Based on Idae, 1999[2]

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[5] The capacity of small hydropower plants selling to the grid is higher for some years (1990-1992) than the annual cumulative capacity because statistics on this last indicator could be found only for the period beginning with 1986. As it is explained later, there are reasons to believe that several tens of MW entered into function (rehabilitated) before 1986. The increase in the numbers for cumulative capacity in 1993 and 1994 as compared to the capacity selling to the grid can be explained by the fact that some of the early small power plants were shut down by that time.

9.2.1.3 Types of financing schemes

The theoretical expectation of Hypothesis 2 for this indicator was that investments will be predominantly based on internal financing schemes under entrepreneurial investment contexts. Interviews with several developers and market experts revealed that during the 1980s investments were exclusively done based on internal financing schemes. Most of them also benefited of investment subsidies (see Section 6.7). After 1991, project finance started to slowly become available. However it did not become dominant and it was mostly approved when certain actors were involved such as a large utility, the governmental agency Idae, a regional authority or a public company. These summarised empirical findings *confirm* our theoretical expectation to observe an overwhelming dominance of investments based on internal financing schemes. The next paragraphs explain in more detail the particularities of the financing schemes used in this period, and the circumstances surrounding their use.

In the category of internal financing schemes, the most frequently used were in-house corporate finance and debt-corporate finance. These were the schemes used by the dominant developers - energy utilities, specialised commercial generators, industrial companies and project-vehicle companies[6]. The multi-contribution corporate finance was also used, but not as often as in the case of wind technology. This scheme was generally resorted to when investments were done in the form of project-vehicle companies. In the first years, the governmental agency Idae was equity contributor in some of these companies. The reason was to attract as many types of potential developers as possible in the small hydropower sector in order to revive it and to encourage the financing community to re-open this technology file in their portfolio of conventional investments. Between 1989 and 1994, six small hydropower projects were financed with Idae contribution under this approach (Idae 1993 and 1996).

Third party finance was another internal financing scheme used by the governmental agency Idae with the same purpose. The projects were built for a wide diversity of 'would be' owners, such as irrigation associations, water boards, municipalities, energy utilities, as well as private industrial companies. Between 1988 and 1994, a number of 17 small hydropower plants were built based on this scheme by Idae, representing 29 MW. In these projects, Idae financing accounted for 75% of total investment costs. Finally, private finance was also one of the schemes used in this period, and this was typical for projects commissioned by individuals and agricultural cooperations.

In 1991, the first project finance loan is recorded (Gonzalez Velez 2001). But only some companies can receive such loans. The developers that were the most frequent beneficiaries of project finance loans were Endesa[7] and Energia Hidraulica Navarra - as subsidiaries of the first, respectively second, largest electricity companies. The use of project finance becomes more widespread only beginning with 1995. Some financing parameters also change in time. For example the average loan maturity was initially 8 years. In late 1990s this increased however reaching 10-12 years (Fages 2002). Consequently, the theoretical expectations of Hypothesis 2 regarding types of financing schemes were *confirmed*. The internal financing

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[6] For example the two main utilities investing in small hydropower - Endesa and Iberdrola, through their subsidiaries specialised in hydropower investments, were using these two schemes during the 1980s. During 1991/1992, they also had to use them more frequently than project finance (del Pozo and Arbalan 2002). Specialised commercial generators had also to offer as first loan guarantee the internal financial resources and the non-hydropower assets of the company, such as other types of energy technology plants or production facilities from different industrial branches. The small hydropower project itself was often taken only as a last-option guarantee for loans (Gonzalez Velez 2002).

[7] All the small hydropower projects commissioned by the largest energy utility Endesa, and for which investment costs were still not fully recovered in 2001, were financed based on project finance (del Pozo 2001).

schemes were the only ones available during the 1980s, while project finance started to be used to a small extent after 1991.

The case of small hydropower in Spain has to be seen from the perspective of long-established technology attempting market revival. Leaving aside our theoretical considerations, which regarded the situation of market introduction of new technologies, one would have expected to see the project finance scheme as dominant, actually, after the technology enjoyed market dominance in the first half of the 19th century. The interviewed developers and the empirical literature[8] suggest four main reasons for the delayed use of project finance.

Firstly, it is pointed towards the high contract and price risks associated with the 82/1980 Energy Conservation Law. As discussed in Chapter 5, contracts were guaranteed but their length was not specified in the law. Also the price was guaranteed but it had to be annually decided by the Ministry of Industry and Energy. The financing community did not have confidence in the legal support framework.

Secondly, it is pointed out that the disinterested attitude of many energy utilities and industrial companies towards this technology did not help financing agents to regain interest in small hydropower projects (Gonzalez Velez. 2000). The increased and more complex patterns of electricity requirement by industrial companies were not compatible anymore with the small run-of-river electricity systems. Further, energy utilities were not very enthusiastic about the new policies for renewables' governmental support. Only two utilities appeared interested in new investments and rehabilitation of small hydropower plants - Endesa and Iberduero. The last one has founded two companies specialised on such investments - Energia Hidraulica Navarra and Sofoensa. Other utilities were not attracted to invest but were holding water use concessions and did not want to loose them. They considered more attractive to lease the water concessions to any interested developer. This was the policy of Union Fenosa, for example, for many years. And finally another group of utilities abandoned their concessions or sold their small hydropower installations, some of which were still in operation (Gonzalez Velez 2000). Utilities and industrial companies were actually in the group of dominant developers, but they were not numerous. There was rather a restricted number of companies who had many project proposals, and in the end a larger number of projects approved. But there was no industry-wide interest and harmony in strategies, which would have been more likely to raise the interest of banks to start approving project finance.

Thirdly, the size of more than half of installations was very small, that is below 1 MW. Although the legal limit was 5 MW based on the 1980 Law, the majority of investments were done in order to rehabilitate older systems that already had water concessions. As these were initially developed a long time before, when the most used technology was run-of-river applied in very small systems, this was reflected in the plants put into operation during the 1980s. In the period 1986-1990, 82% of the small hydropower put into operation had capacities smaller than 1 MW. Later this percentage lowered and in the period 1991-1994, only 57% of the systems built were smaller than 1 MW (based on Idae 1992 and 1998). Therefore, during the 1980s projects were far too small to be financed based on project finance loans.

A fourth argument invoked is that project developers themselves were not very enthusiastic to use project finance, due to the extra costs that such a scheme attracts. On the one hand, there are all kind of risk premiums and extra feasibility study costs that project finance requires. One the other hand, the size of projects was too small, especially during the

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[8] By empirical literature is meant here mainly a series of articles presented by developers and market experts at various conferences and seminars organized during the 1990s and governmental publications addressing the issue of small hydropower. They are listed in the correspondent section of the bibliography list.

1980s. When total financing costs were spread over total investment costs, the extra costs per kW were too high. Therefore many financially self-sufficient companies preferred actually to increase the profitability of their projects by using one of the two corporate finance schemes. The first use of project finance was signalled in 1991 when the share of new constructions in the total number of plants put into operation increased and, correspondingly the size of plants started to increase too[9]. The increased use of project finance is signalled after 1995 when the legal limit of plant-sizes was lifted to 10 MW.

In Chapter 10, we discuss the consequences of these observations and factors from the perspective of the analytical framework, together with observations from the other chapters of Part II. The next subsection tests the theoretical expectations with regard to the technology design choice of investors.

9.2.1.4 Technological designs

Hypothesis 2 predicted that under entrepreneurial investment contexts conventional technological designs would dominate, but the adoption of diffusion-optimal designs is also likely to a small extent. We discussed in Section 4.3 that for small hydropower technology, the analysis of diffusion expansion potential of technological designs needs to be made from the following performance-perspectives:

- the ability to improve cost performances as compared to conventional technologies, and to reach economic feasibility in exploiting sites with very low water head - below 3 m - in particular;
- the ability to bring substantial reductions in the environmental impacts of civil works of small hydropower plants.

We considered that when a new technology brings substantial progress in one of these performance-areas, it can be viewed as diffusion-optimal. During the 1980s when, small hydropower technology was re-introduced in Spain, its technical performances were superior to those during the 1960s when most of the Spanish small hydropower plants were closed. The main technical advances booked world-wide were in the areas of 1) the range of exploitable water heads and water flows, 2) control and adjustability of power quality, and 3) flexibility in matching supply and demand profiles. The turbine efficiencies had already reached their maximal performances in early 1930s.

The technology designs adopted in Spain in early 1980s were based on state-of-the-art design of the small hydropower technology in that period world-wide. If we consider these as ‘conventional designs’, we can say that during the first decade of market revival, up to mid 1990s, some more technical and cost improvements were brought to the small hydropower designs adopted by project developers in Spain. They mainly regarded technical optimisations in the areas of complementary equipment such as the speed regulator, which allowed an improved control of power quality - voltage and frequency levels (Idae 1996).

From the perspective of the ability of technical innovations to improve cost-performances, some progress was achieved. This came, on the one hand, from reductions in technology-specific costs, through the introduction of automatisation or remote control equipment. On the other hand, it also came from technology-complementary cost components, through the use of lighter construction materials and improved plant design (Idae 1996; Gonzalez Martin 2001).

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[9] Nine plants were actually with capacities higher than 5 MW and were given special individual approval for eligibility to the special regime protection.

From the standpoint of environmental impacts' reductions through technical improvements, the main implemented measures regarded the reduction of impacts on river fauna and flora. The reduction of impacts related to the civil works was just starting to get attention after more projects were blocked in impact studies at local level. The need to come with some technical solutions for this went up on the research agendas in Spain especially after 1990 when more new small hydropower plants started to be built and the share of rehabilitated plants in the annually approved projects lowered.

Overall, empirical data and information indicate that most of the small hydropower plants constructed or rehabilitated in Spain in the period mid 1980s - mid 1990s were based on conventional technological designs. But some plants incorporated also new technical features bringing technical optimisations and improvements in environmental and cost performances. Their effect on diffusion expansion potential is not the same comfortable to assess as in the case of technical features of wind technologies. However, the empirical literature suggests that the new improved designs made investors' task of project development and implementation easier, smoothing this way the diffusion processes. Therefore, we consider that the expectations for this diffusion indicator were *confirmed*.

9.2.1.5 Conclusion regarding the extent of confirmation of theoretical expectations for diffusion patterns under Hypothesis 2

Section 9.3.1 looked at the diffusion patterns of small hydropower technology in Spain in the period 1980-1994. The indicator of project sizes could not be tested. The assumption that there are no direct constraints on decisions of developers over project sizes was not confirmed, since the sizes of small hydropower plants are generally defined by legal rules.

Table 9.3 *The theoretically expected and the empirically registered diffusion patterns for small hydropower technology in Spain, 1980-1994*

Practical developments	Theoretical expectations
Drivers to invest	
Dominance of commercial projects	Balanced presence of self-generation, strategic, and commercial drivers (not confirmed)
Types of project developers	
Dominant developers: energy utilities; companies specialised in small hydropower commercial generation; project vehicle companies; industrial / technology companies.	Predominantly large developers (confirmed)
Type of financing schemes	
Dominance of 'in-house corporate finance' and debt-corporate finance'; but other types of internal financing schemes also present. After 1990 few projects based on 'project finance'.	Predominantly internal financing schemes (confirmed)
Project sizes	
All installations below 5 MW, according to definition of small hydropower plant in Law 82/1980 => assumption of 'no legal constrains' was not confirmed	possible dominance of small/medium size projects (cannot be tested)
The degree of innovativeness of the technological designs adopted in the market	
Conventional technological designs used, but designs with modest improvements from the standpoint of diffusion expansion potential were also often adopted	Conventional technology designs will dominate market; the adoption of some incrementally improved models possible (confirmed)

The expectations regarding three indicators were ‘confirmed’ - the types of developers, types of financing schemes, and technological designs. But the expectation for the indicator of drivers to invest was ‘not confirmed’. Self-generation plants had only a small share in the capacity developed. The empirical forms are summarised in Table 9.3.

Overall, we consider the extent of confirmation of the expectations regarding diffusion patterns as *satisfactory*. This enables the continuation of empirical investigation regarding whether diffusion processes could have been expected to be sustainable.

9.2.2 Installed capacity increase and the prospects for sustainable diffusion by mid 1990s

Hypothesis 2 predicted that under entrepreneurial investment contexts a *modest increase in installed capacity* could be observed in short-medium term. Further, the continuity of market diffusion processes was considered as dependent on the business culture of the traditional financing community who may or may not become willing to approve project finance loans. It was considered that *market diffusion processes could be sustainable*, in the long-term, if financing agents are flexible in terms of willingness to accept economic-policy risks, as result of observing investment interest from large companies. However, if the investment interest of large developers is substantial, given the available resource potential, diffusion processes have also good prospects of being sustainable in the absence of external financing schemes.

9.2.2.1 Increase in installed capacity, 1980-1994

Based on our operationalisation in Chapter 5, a capacity increase can be described as modest if it is located in the range of 500-1000 MW, and achieved in a short-medium time span, of 5 to 10 years. There are no governmental published statistics regarding small hydropower plants put into operation annually in the years up to 1986. The publications of the governmental agency Idae only mention that investments started slowly in 1983/1984 and got more speed after 1986 (Idae 1992 and 1996).

This view was also expressed by all interviewed developers and market experts. According to direct governmental statistics (Idae[2] 1999), in the period 1986-1994, a total of 547 MW small hydropower capacity were installed in Spain, in the form of rehabilitation works, extensions and new constructions. Cumulated to the capacity of perhaps few tens of MW that might have been put into operation in the misty period up to 1985, this can be considered a *modest capacity increase.*

But around 700 MW more were mostly blocked in administrative/social approval processes or already received refusal of construction permits or water concessions. This suggests an investment interest that would have led to a large capacity increase, had administrative and social obstacles not been present[10]. Nevertheless, having in view the long period of 15 years covered by this case study we assess that - in terms of rhythm of market growth - this expectation was *confirmed.* The investment interest was substantial, having in view that:

- this was a technology with a substantial historical background in Spain among economic actors of various types, and

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[10] One governmental publication (Idae 1992) mentions that in 1990 there were 550 applications for water concession, representing 1047 MW of small hydropower capacity. Between 1991 and 1994 the capacity increase was of only 326 MW. These obstacles emerged actually in early 1990s as a result of too many applications that took by surprise local administration and populations.

- many sites needed just rehabilitation investments and were very profitable under the available price support.

Table 9.4 *The number of projects and annual capacity increase, in MW, based on small hydropower technology in Spain, 1986-1994*

Yr	1986	1987	1988	1989	1990	1991	1992	1993	1994
Number	40	39	33	35	52	38	78	48	22
MW	30,62	29,3	33,4	49,4	71,7	62,1	115,7	93,9	54,6

Source: Idae, 1999[2]

9.2.2.2. The prospects for sustainability of market diffusion in mid 1990s

The expectations under Hypothesis 2 was that market diffusion processes could be sustainable if the business culture of the traditional financing community is characterised by flexibility in terms of willingness to accept risk and enable external financing schemes. A sustainable diffusion process could be then seen on a long-term, through a gradual change in diffusion patterns towards those expected under optimal investment contexts. However, if the investment interest of large developers is substantial, compared to the resource potential, diffusion processes have also good prospects of being sustainable in the absence of external financing schemes.

In Spain, at the end of 1994, internal financing schemes were the dominant financing approach for small hydropower plants. The business culture of the traditional financing community did not facilitate the widespread use of project finance. Only few large utilities were privileged with loans based on project finance. When other developers were refused project finance, one of the reasons invoked was that the technology was not sufficiently reliable[11]. But the uncertainty on cash flows due to the risks embedded in the price mechanism and contract was also often openly given as reason for refusing project finance loans. As discussed also in the case of wind technology, Spanish banks are quite risk adverse, especially with regard to uncertainties on regulations. They were therefore not very likely to generalise the issue of project finance types of loans unless legal guarantees were offered for minimum contract length and/or a minimum guaranteed price.

However having in view a) the size of the available hydropower potential and b) the interest of many large developers with good accessibility to financing resources to invest, it can be argued that diffusion would have continued even without a change in the economic governance structure for lower risks. In 1998 the Spanish renewable agency Idae estimated the maximum theoretical potential at 2419 MW. The Association of Renewable Energy Producers estimated the technically exploitable potential at 1000-1250 MW. This is not such a large capacity, taking into account that for example (by comparison) the estimation of technical potential for wind energy is 15.100 MW in Spain (Idae[1] 1999). A potential of 1000-1250 MW may be possible to finance based 100% internal financing schemes. Nevertheless, it is necessary that the risk-profitability context is sufficiently attractive for many types of large developers who would create the necessary financial pool at industry level.

Given the fact that in 1990 there were applications awaiting administrative processing that summed up 1047 MW, it could be argued that at industry level there was a large interest to

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[11] This in strong contrast with the attitude regarding loans for wind projects. Although wind technology was younger than small hydropower, the involvement of manufactures as equity shareholders in wind projects determined bankers to accept more easily technology risks. But since manufacturers of small hydropower systems were not involved as equity investors, banks continued to assign important technology risks to small hydropower.

invest. The investment interest could have probably reached the technical potential even without a change in the risk level of the economic governance structure. It appears that the very limited access to ‘project finance’ was perhaps for many (potential) developers an inconvenient but not a key diffusion obstacle. In Spain, the largest obstacles for small hydropower technology diffusion were local administrative and social opposition obstacles. Consequently, as it was envisaged under Hypothesis 2, diffusion processes seem to have had indeed good prospects to be sustainable, from the financing availability standpoint, because there was sufficient investment interest from large developers willing to use internal financing schemes and the resource potential was not that large.

Leaving aside the issue of administrative and social obstacles, diffusion remained in mid 1990s under the challenge of the extent of price support. In the period 1980s-1994 price support was very attractive, enabling very high profitability (see Section 6.9.3). But reductions in price support were expected, and they actually took place in 1995 through lower investment subsidies. When the reductions in governmental price support are larger than the achieved reductions in cost performances, this comes at the expense of lowering the economically exploitable resource potential (see Section 2.8). When this potential remains very low, while the technically exploitable potential is still significant (and economically worthy to lobby for, from investors’ standpoint) the issue of the lobby potential of stakeholders becomes important.

The following paragraphs look at way the cost-factors discussed in Section 2.8 have influenced cost performances for small hydropower plants up to mid 1994. After that it looks at the features of the socio-economic-industrial context for diffusion and compares them to those expected under Hypothesis 2 for entrepreneurial investment contexts. In the last part of the sub-section, the obstacles for diffusion in mid 1990s are discussed.

Cost performances

The progress in cost performances of small hydropower in Spain by mid 1990s was quite modest. In Chapter 2 we differentiated among four categories of costs: technology-specific, context-induced, technology-complementary and resource quality/availability. In Spain, interviewees explained that, while technical improvements brought about small decreases in the first and second category, the costs associated with the third and fourth mentioned category increased. These changes are mentioned in Table 9.5.

Table 9.5 *Cost performances of small hydropower technologies in Spain in mid 1990s*

Evolution cost sources	SHP in Spain, 1980s – mid 1990s
technology specific	only small cost decrease
technology- complementary	high levels; small cost decrease
context induced	increasing costs
quality / price resource exploited	decreasing quality & availability; increasing production costs
average (per kWh) production costs	around 6 - 6,6 €c/kWh in mid 1990s

Automatisation and remote-control lowered production slightly but the cost reduction potential in the technology specific category is limited. Technology-complementary costs also led to some cost decrease through technical improvements such as lighter construction materials and improved plant design aimed at the reduction of environmental impacts. The increase in context induced costs was mainly due the obligations to make supplementary environmental impact studies to lower such impacts as well as the extra costs induced by having projects blocked for sometimes more than five years in administrative processes, including campaigns for gaining local public support. But, as diffusion advances, the resource quality decreases. Most of the remaining sites have low water heads and highly variable seasonable availability in contrast to the already exploited water courses. In mid 1990s the average production costs were around 6 - 6,6 €c/kWh (Gonzalez Velez 2002) and the prospects for sustained cost reductions were small.

The features of the socio-economic-industrial context for diffusion

Table 9.6 presents the features of the socio-economic-industrial context for diffusion as they were assessed in empirical research and compares them with the forms that were theoretically discussed. The general assessment is that this framework was only partly favourable towards sustained diffusion in mid 1990. The size of the industrial basis and dynamics did not appear satisfactory to serve increasing levels of domestic demand. Besides, the patterns of market adoption to that point did not bring about the theoretically expected socio-economic benefits. Part of the reason for this is related to technology specific factors. We discuss first the aspect of socio-economic benefits and, after that, the developments in the field of manufacturing and service support industry.

Table 9.6 *Diffusion results of small hydropower technology in Spain, in mid 1990s*

Diffusion context likely to emerge		Small hydropower in Spain mid 1990s	Area 2- theoretically expected
Socio-economic benefits		very small	modest
Local	Direct: ownership	confirmed	likely small
	Indirect: more attractive (than usual) benefits from ~ land rents; ~ local taxes; or ~ local economic or social welfare investments	not confirmed	likely modest
	Indirect ~ local employment	small	technology specific
National	Ownership individuals (shares)	confirmed	not likely
	Employment in industry	not available	likely modest
Industrial basis and dynamics		small / modest	modest
Number companies offering products / services for renewable electricity plants		confirmed	modest
Types of companies involved in industry		long-established industrial branch	large presence of corporations from diversity of industrial sectors
Degree of specialisation in renewables		confirmed	modest

Socio-economic benefits

The local socio-economic benefits were *very small* both for local people and for public agencies and private agents. Firstly, in contrast to wind projects, the sizes of small hydropower installations were too small, mostly below 1 MW, meaning that local taxes, fees for public land renting and royalties were quite low. If local taxes and fees at local/regional level increased too much, projects would have lost their economic viability. Because of this, they could not boost regional development and social welfare as in the case of wind energy, through extra investments in various types of production factories, entertainment centres, educational and research units, or social welfare projects[12].

Secondly, the mechanisms that supported the boom in wind energy regional employment and enthusiasm by regional administrative authorities could not function to the same extent for small hydropower technology. In the case of wind systems, the manufacturing and service

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[12] The embeddness channel under this indicator for diffusion results is actually less likely to function for the case of small hydropower technology at all.

industry was being established and growing, finding production sites in accordance to the location of wind resources. If a region was rich in wind resources, many large wind farms were being built there, and the manufacturing and service industry was being located inside that region - indeed at the request of regional authorities. This contributed to employment creation, and regional economic-industrial development. In the case of small hydropower, the manufacturing and service industry had a long industrial background in Spain, and companies were mostly long-established than new entrants driven by a new industrial market segment. In the same time, water resources for small hydropower plants are in Spain lower and more dispersed than wind resources. This does not enable numerous local investments that would make a difference for the local economy. Actually larger or more numerous small hydropower plants are likely to be more opposed locally on environmental grounds. These factors did not help inducing local social-economic benefits from small hydropower investments through regional/local employment, as they helped in the case of wind energy.

Thirdly, direct economic benefits through ownership by local population or substantial long-term fees for land renting were missing or very low. The number of projects developed by local groups, cooperatives or individuals was lower than that built by large companies, which did not help towards the improvement of local social interest and acceptability of small hydropower plants.

Local employment for small hydropower technologies depends on the extent of automatisation of the power station. Having in view that most plants did have automatisation equipment, it is not likely that local jobs for operation and maintenance made an important economic impact locally.

As concerns national employment and potential for trade union lobby, the domestic demand for small hydropower technology manufacturing, plant construction and operation did create an important number of jobs in Spain. Studies over the labour intensity of small hydropower technology (Gonzalez Velez 2000), suggest that 18,6 employers - considered as 1800 hours-work per year - are needed for the commissioning of 1 MW. Of this, 40% is needed as direct employment, while 0,4% jobs are needed for operation and maintenance works. This means that the 547 MW installed between 1986-1994 involved 10.174 temporary jobs, of which 4.070 were direct jobs for plant construction works. In addition, 407 permanent jobs were created for the operation and maintenance works.

This size of temporary employment could be considered, in principle, as able to exert some lobby in favour of the preservation of the support system for small hydropower technology. But the jobs supporting small hydropower investments were not exclusively dependent on the domestic technology demand. The Spanish small hydropower industrial sector has been already for few decades strongly dependent on exports. Besides, many of its companies are horizontally integrated with other industrial sectors, as well, offering them alternative industrial activities. It is therefore uncertain if trade unions representing the employees of companies offering temporary and indirect jobs could have formed a potentially strong lobbying group, arguing in favour of a more attractive support system or governmental intervention for the removal of its diffusion obstacles. In conclusion, diffusion patterns did not result in socio-economic embeddness through direct and indirect economic benefits for local population, private agents and public bodies.

Industrial basis and dynamics

As regards the size of the industrial basis, this can be assessed as between *small and modest*. In Table 9.7, we showed the numbers of companies offering technology equipment and services for small hydropower installations. These numbers suggest a very limited price competition for certain products and services that are essential in the economics of small hydropower plants, such as those highlighted on dark background in the table. Only for products and services that normally are more often requested also in other energy/industrial areas was competition slightly higher.

In terms of the industrial background, hydropower is an old technology, which has had in Spain its own place in the industrial sector. This indicator is more interesting to observe in the case of new technological principles such as wind technology, biomass gasification and pyrolysis technologies, or solar photovoltaic systems. The governmental renewable agency Idae assessed the Spanish industrial basis in 1996 in the following terms: "Small hydropower in Spain enjoys a solid base of industrial rooting. As a result of many years of continuous activity, and being a classical sector of electricity generation, there are important numbers of engineering, equipment and construction companies with wide experience and specialisation." (Idae 1996: 19). Throughout decades, the Spanish small hydropower industrial sector was able to ensure its continuity during the decades of domestic investment stoppage, with the help of demand from foreign markets, and domestic demand from related industries and applications.

Table 9.7 *The industrial basis for the manufacturing and construction of small hydropower systems in mid 1990s (based on Idae 1996)*

Companies offering products or services for small hydropower	Companies
Suppliers of electrical equipment	17
Engineering	16
Mechanical equipment	16
Turn-key installations	11
Turbine manufacturing	11
Civil works	10
Manufacturing of transformers	2
Steel pipes	7
Regulation and control equipment	5
Generators manufacturing	4
Operation and maintenance	4

From the perspective of the degree of specialisation of involved industrial companies, the industrial basis was to a large extent horizontally integrated with other industrial sectors (Idae 1996). We considered this to indicate a low potential for political lobby towards smoother small hydropower diffusion. One favorable spin-off of horizontal industrial integration from the cost-perspective is in the better chances for price reductions in equipment parts and services that are offered to other industrial sectors as well - as a result of economies of scale.

In conclusion, the theoretical expectations with regard to the socio-economic benefits emerging from diffusion were *not confirmed*, while those regarding the industrial basis and dynamics were *partly confirmed*. The following paragraphs look at the main obstacles for diffusion in mid 1990s.

Obstacles for diffusion[13]

Developers and publications of governmental authorities refer to three groups of obstacles. Firstly, there was the local social opposition that was often enshroud in environmental reasons. The governmental agency explains (Idae[1] 1999: 84) that this has to do with lack of awareness on the side of local population regarding the positive environmental effects of this type of energy. In addition, there is a strong negative influence on them from conservative ecological groups. They condition agreement on tough and arbitrary requirements on the ecologically usable water flow that lack a serious technical analysis.

Secondly, there were obstacles at the administrative level. In Spain, the administrative procedure has to be carried out through the Water Commissary of the Hydrographic Confederation or the relevant department in the Autonomous Communities - when these enjoy such competencies[14]. After a water concession license it awarded, the Hydrographic Confederation carries on further the administrative approval process. This requires the advice of various regional departments such as Agriculture, Industry, Environment, and Territorial Planning. Although these advises do not have the legal position of rejecting a project, this is what they lead to in practice. In Spain the culture of administrative solidarity is widely present. This means that when a certain department issued a negative advice on a project proposal, the authority that has the right to take the final decision becomes solidair to the negative advice and rejects the project. Especially the negative advises from the environmental departments are politically dangerous to ignore.

One line of criticism from developers and interested investors is that bureaucrats lack the technical expertise to be able to conduct thorough studies and often negative advises are arbitrary. Developers are not consulted in the processes and in the end the only legal instrument they have to contest the refusal is via the general law of public administration. But this is mainly focused on administrative procedures and not on the content and technicalities of problems at hand, rending developers one more time helpless.

A second line of criticism is that when projects do receive positive advice, it happens normally after many years of delay. This adds to the ‘context-induced’ costs of small hydropower projects, reducing the range of profitability the economic-policy support system would have enabled. The legal framework for administrative approval of small hydropower plants is complex but it traces very clear ‘approval routes’ and tight timetables. The process should take one year, or at most two years, if all identifiable delays occur. But in practice these rules are ignored, while some claim that they do not even exist. The process of approval takes in practice between five to ten years (Fages 2002).

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[13] These paragraphs are mainly based on two papers 1) “Actual and potential exploitation of hydropower resources in Spain”, presented by Jose Maria Gonzalez Velez, Vice-president APPA at the Enernova Congress, February 1998, Madrid (in Spanish) and 2) “State of the art and future evolution of small hydropower” presented by Miguel Angel Gonzalez Martin, director general Energia Navarro Generracion S.A. at the Genera Congress - Markets and Regulatory Framework for Renewable Energy, Madrid, 1 March 2001 (in Spanish).

[14] In Spain, water resources - surface or underground - are in public ownership and their use is considered of general interest. In order to make private use of water resources, a special concession right has to be granted, specifying the purpose and period of time for water use, the maximum flow granted, as well as the technical characteristics of the equipment. The Water Act (Act 29/1985) establishes that concessions must be granted according to the provisions of the National Hydrological Plans. They have to be temporary in nature and be issued for maximum 75 years. In practice authorisations are generally issued for 25 years with the possibility to extent them for 15 years. If the type of water use implies risks to the environment, an impact study is also required preliminarily.

A third important criticism regards the weakness of general regulations, leading to administrative discretion of regional bodies and extreme easiness for local population to obstruct projects. Developers argue that the technical and environmental criteria used by administrative authorities to decide on whether a project should be approved are arbitrary and not transparent. There are also strong disagreements on the issue of the 'ecologically feasible' water flow approved for energy harnessing[15]. Local groups of ecologists often interfere with the assessments of public administration on this issue having the opportunity to carry the negative message of the local population already injected with ideas of environmental harm from small hydropower. Regulations allow the rejection of project proposals very easily. Often a letter with signatures is sufficient (Gonzalez Velez 2002). Open discussions are missing from the administrative procedures and often there are no 'mediators' around. Usually the involved actors are either strongly pro or strongly against small hydropower plants. This attitude has been often seen in the process of wind power market introduction in many industrialised countries, but more rarely so acute with regard to small hydropower at a country level.

A third type of obstacle invoked by non-utility developers is that of grid-connection difficulties. Although this is a basic right of developers, guaranteed by law already since 1980, electricity companies owning distribution networks have been frequently invoking technical problems for the grid connection of independent developers, contributing to the delays in project approval (Velez 2001[16]; Fages 2002; Bustos 2001).

In conclusion, there was little positive spin-off towards a more favourable context for diffusion processes that could be related to the characteristics of the economic-policy support system. The investment patterns under the discussed support system were not able to help reduce or remove the financing, nor the social-administrative obstacles of small hydropower technology. Project finance was scarcely available, 15 years after the launch of the support system, and part of the reason was in the contract and price risks harboured in the support system. As regards local opposition, the main arguments were related to the environmental impacts of plants, and the conflict with use of water resources for fishing and recreational activities. But the support system did manage to produce some reductions in production costs and improve some aspects of technical performances.

In this context, it can be argued that the installed capacity of small hydropower technology might have continued to increase based on internal financing schemes. The types of developers involved in investments - large and financially self-reliant companies - would have supported more investments. But the analysis of the indicators for diffusion results and obstacles facing the continuity of diffusion in mid 1990s suggests that market diffusion processes would not have been sustainable for too long.

9.2.3 Summary and conclusions for Hypothesis 2

In Section 9.2 we tested empirically Hypothesis 2 for the case of small hydropower technology diffusion in Spain, in the period 1980-1994. During this long period, the economic-policy support system put in place for the market revival of small hydropower technology created an

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[15] A certain portion of the river flow needs indeed to remain in its initial river-bed to preserve the ecology of the river. But the larger this ecological flow is the smaller is the water flow available for energy exploitation. And this has direct strong impacts on the economics of the small hydropower plant, up to the point that it can make a project no more economically feasible.

[16] Gonzalez Velez, "Minihidraulica, una energia estancada" in *Las Energias Renovables*, 3 November 2001, Madrid.

entrepreneurial investment context. For such contexts, we formulated in Chapter 3 the following hypothesis.

A support system leading to a national investment environment of high to very high economic-policy risk and high to very high levels of project profitability will induce *diffusion patterns* that are characterised by:

- predominantly large developers, and only to a reduced extent small developers, with
- diverse motivations to invest - commercial, strategic and partly-self-generation, using
- predominantly internal financing schemes, in
- mainly medium and small size projects, based on the use of
- all types of technological designs of which new and/or existing diffusion-optimal technological designs are likely to be used to a small extent.

Such diffusion patterns will result in:

- a *modest installed capacity* increase in short-medium term; and
- *possibly sustainable* market diffusion processes in the long term for the renewable technology envisaged.

Market diffusion processes could be sustainable if the business culture of the traditional financing community is characterised by flexibility in terms of willingness to accept risk and enable external financing schemes. A sustainable diffusion process could be then seen on a long-term, through a gradual change in diffusion patterns towards those expected under optimal investment contexts. However, if the investment interest of large developers is substantial, given the available resource potential, diffusion processes have also good prospects of being sustainable in the absence of external financing schemes.

Diffusion patterns

The extent of confirmation of the expectations regarding diffusion patterns under the entrepreneurial investment context applicable in Spain for small hydropower technologies up to 1994 can be assessed as only *satisfactory*. For three indicators of diffusion patterns expectations were ‘confirmed’ - types of developers, types of financing schemes and technological designs. For the indicator of drivers to invest, the expectations were ‘not confirmed’. Further, the indicator of project sizes could not be tested because the political definition of small hydropower assumes restrictions on investors’ decision regarding this aspect of investment. We summarise here the main findings regarding the indicator for which the expectation was not fully confirmed.

Small hydropower was an established technology, with an established technical track record and clear economic record. This was once dominating electricity generation in Spain and the 82/1980 Energy Conservation Law was mainly put in place for its market revival, especially by means of commercial projects. The projects built incorporated new features bringing improved technical and cost performances. But they cannot be regarded as demonstration plants in the generally understood meaning. Other strategic motivations were also not perceived in empirical research. Only around 10% of projects put in operation up to 1994 were partly self-generation plants, while the rest were commercial projects. The formerly dominant owners up to mid 1950s - small developers and industrial production companies - did not choose to return to self-generation.

Diffusion results

As for the dependent variable of installed capacity increase the theoretical expectation was 'confirmed'. We expected to observe a 'modest' installed capacity increase on a short/medium term - i.e. 5 to 10 years. In practice, during the 15 years of support system application around 600 MW or more capacity was installed. In the same time around 700 MW more were either blocked in the administrative/social approval procedure or already refused license.

The prospects of sustainable diffusion were regarded as good from the standpoint of financial resources. In spite of the very limited availability of external financing schemes, a high number of economic actors were interested to invest and willing to do so based on internal financing schemes. There was only a limited resource potential available for exploitation - between 1000 and 1250 MW - which would have been possible to exploit based internal financing schemes.

As regards the three perspectives for the discussion of long-term diffusion prospects, improvements were booked in terms of cost and technical performances. There were some reductions in technology-complementary costs and technology-specific costs. However, some factors in the group of context-induced costs together with the decrease in the quality of available hydropower resources cancelled to some extent the progress booked in the first two mentioned categories. Improvements in technology performances were mainly in the areas of automatisation, remote-control, plant design and construction materials for lower environmental impacts. The theoretical expectations with regard to the socio-economic benefits emerging from diffusion were *not confirmed*, while those regarding the industrial basis and dynamics were *partly confirmed*.

These empirical findings lead to the assessment that the extent of confirmation of theoretical expectations for diffusion results is only *partly satisfactory* for this case study.

Exogenous factors and alternative specifications

The main factors identified as playing a role in the non-confirmation of the indicator driver to invest (in particular the reduced presence of self-generation projects) are:

- the low environmental concern of consumers in Spain does not give incentives to industrial production firms to build renewable energy plants for green image;
- low structural concern of industrial production companies for environmentally friendly technology;
- environmental social opposition could have worked against the public image of industrial production companies;
- the very long and costly administrative and social approval processes led to the situation that self-generators lost interest to invest due to: 1) the high risks that project development expenses would be in vain; 2) the high extra costs when they were eventually approved; 3) and long waiting times frustrating the self-generation plans.

In addition to this, technology-specific factors appeared to play an important role in the extent possible of local indirect socio-economic benefits. These factors are:

- the (by definition) small sizes of plants;
- the fact that a manufacturing and service support industry is established, and it does not follow the investment locations on new power plants which would have strengthened local embeddness of technology.

The next section tests Hypothesis 1 for the case study defined by small hydropower technology diffusion in Spain in the period 1995-2000. In this six-year period, two economic governance structure were applied for the support of small hydro energy. But as we discussed in Chapter 6 their risk-profitability profiles did not differ very much. Together with the policy support mechanisms that were used in this period, both support systems that emerged were placed in the category of optimal investment contexts.

9.3 Testing Hypothesis 1 for small hydropower diffusion in Spain, 1995-2000

In this section we test the theoretical expectations formulated under Hypothesis 1 regarding optimal investment contexts, for the case study of small hydropower technology diffusion in Spain, between 1995-2000. The discussion of this case study starts in sub-section 9.3.1, which focuses on testing the expectations for diffusion patterns. Further, Section 9.3.2 looks at the effectiveness of the support system in terms of capacity installed by 2000 and at the prospects for sustainable market diffusion processes in long term. Subsection 9.3.3 summarises and concludes this case study.

9.3.1 Testing theoretical expectations on diffusion patterns, 1995-2000

This sub-section discusses the empirical findings relevant for the first part of Hypothesis 1. Sections 9.3.1.1 to 9.3.1.4 describe the forms of diffusion patterns for four indicators. In Section 9.3.1.5 we summarise the main findings regarding the predictability of diffusion patterns.

9.3.1.1 Types of project developers

Hypothesis 1 predicted that under optimal investment contexts all types of project developers could be observed entering the market. It was expected that the picture of project developers would have a higher diversity, as compared to the other three categories of support systems differentiated. In practice, the investigation revealed that the group of dominant developers was still formed by companies that can be described as large or financially self-reliant. This was stressed, on the one hand, during interviews with market experts[17]. On the other hand, this appeared also based on our analysis of one governmental publication listing the companies that developed small hydropower plants, the sizes of projects and their names (Idae[2] 1999). In the period 1995-1998, for which governmental statistics are available, projects were commissioned by the following types of developers:

- 70% of the projects were built by large firms or financially self-reliant companies, of which 38% were owned either by energy utilities or by companies specialised in the commercial generation of hydropower;
- 11% of the projects were built by public bodies - local municipalities, regional authorities and Idae - and by water boards;
- 19% of the projects were built by individuals and farming associations.

These shares were calculated based on the numbers presented in Table 9.8. The table is made based on a list of projects published by the governmental renewable agency[18].

Although the categories of developers remained the same, the picture of developers changed slightly, compared to the previous period. One important change is that financing

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[17] Interviews with Manuel Bustos (APPA April 2001), Joan Fages (Hidrowatt, February 2002), Jose Maria Gonzalez Velez (February, Hidro Norte, 2002).

[18] "Renewable Energy in Spain - Balance and Perspectives 2000", Idae 1999.

groups - banks and insurance companies - started also to be directly involved in the constitution of companies for the commercial generation of electricity based on small hydropower. After 1995 financing groups started to contribute with equity to project-vehicle companies, as well as older and new independent companies for electricity generation based on hydropower (del Pozo 2001 and Fages 2002). Another change is the increase in the number of projects developed by small economic actors - that is individuals and agricultural farms. If these developers built only 8% of the projects in the period before 1994, their market share increased to 19% in the period 1995-1998.

Based on these arguments we assess that the diversity of project developers is larger than during the period of the first support system up to 1994. This leads us to consider that empirical information *confirms* our theoretical expectations regarding project developers under Hypothesis 2.

Table 9.8 *Types of project developers of small hydropower plants in Spain, 1995-2000*

Types of developers	1995	1996	1997	1998
developers with more than 1 plant (during years)				
energy utilities and companies specialised in small hydropower or electricity[19];	11	9	10	9
Idae	1	-	-	1
developers with 1 project				
project-vehicle companies (mainly) and industrial companies[20].	6	8	15	6
local municipalities; regional governments	2	3	1	-
water boards	2	1	1	2
individuals / agricultural farms	9	4	3	4

Based on Idae[2] 1999

9.3.1.2 Drivers to invest, 1995-2000

For this indicator, Hypothesis 1 predicted that commercial projects will predominate but strategic. All interviewed developers and market experts stated that the overwhelming majority of the small hydropower installations built in Spain were commercial projects selling all the electricity produced to the grid. Only a small number of projects were conceived as partly-self-generation and there were also few self-generation-only projects. Table 9.9 presents the only available data from the statistics of the renewable agency.

Table 9.9 *The annual cumulative capacity in MW and the share of self-generation projects, based on small hydropower*

Year	1995	1996	1997	1998	2000	2001
MW cumulative (since 1986)	612	652	682	717	754	784
MW selling to grid	535	562	605	n.a.	n.a.	n.a.
% self-generation	12,6 %	13,6 %	11,3 %	n.a.	n.a.	n.a.

Based on Idae[3] 1999

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[19] The small hydropower installations counted in this group were developed by companies whose name was known by the author as a (former) public utility or specialized small hydropower firm from empirical literature, from interviews and by observing that the names of companies recur during the years. These companies accumulated more small hydropower plants.

[20] These are companies that have only one small hydropower plant. This does not mean that some of the owners do not have ownership shares in other projects too. But this is not transparent and also not relevant for our analysis.

For the years 1995-1998, it can be observed that commercial projects accounted for around 86-89% of plants in operation. However, these statistics do not include the small hydropower investments built before 1986. The available empirical information *confirms* our theoretical expectations for the indicator of drivers to invest.

9.3.1.3 Types of financing schemes, 1995-2000

The part of Hypothesis 1 regarding this diffusion indicator expects that external financing schemes are likely to be predominantly used for investments.

Interviews with developers revealed that project finance started to be more frequently approved for small hydropower installations after 1995/1996. But it seems that some developers benefited more from project finance loans[21] than others, who had to continue using internal financing schemes. Of these, debt-corporate loans and in-house financing were actually the most often used, which actually remained the dominant types of financing schemes, as in the previous period (Gonzalez Velez 2002). Beside them, the use of multi-contribution financing and third-party financing[22] was also signalled. The last was used by the governmental agency Idae for a large diversity of developers, just as in the previous diffusion period. This empirical information does *not confirm* the expectations under Hypothesis 1.

We could identify three main reasons why project finance for small hydropower after 1995 did not become the dominant type of financing scheme. Firstly, due to the social and administration opposition to new constructions that emerged in early 1990s, developers had to reduce the sizes of proposed plants in order to minimise environmental impacts and receive final approval. This has made project finance unattractive both for financing agents and for developers. Between 1995 and 1998, 73% of the plants put into operation were smaller than 2 MW (based on Idae[2] 1999). Such plants are in principle too small to use the project finance scheme (see comment Section 9.2.1.3).

However, in 2002, some developers with less strong financial capacity would like to shift already operating small hydropower plants, commissioned based on internal financing schemes, to project finance. This way they would get faster cash for other projects. Legally, it is possible to transfer the water use concession, but administratively this is very difficult and bureaucratic process. This way they experience cash shortage and their investment plans have to be postponed (Gonzalez Velez 2002).

Secondly, the difficulties in obtaining social consent and administrative approval from the many regional departments involved the risk of substantial financial deviation from proposed budgets. Extra costs proved to be often claimed in order to evaluate and to minimise environmental impacts. But also the administrative delays in themselves led to costs' escalation. The risks on budget overrun diminishes the chances for project finance.

Thirdly, the dramatic increase in the duration of administrative approval processes also contributed to the reduced interest of the traditional financing agents in small hydropower plants. Instead of waiting for five to ten years for a project to be approved, financiers were understandably more attracted to invest in wind energy, for which administrative procedures were faster and smother. These three reasons could explain why project finance for small

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[21] For example, all the small hydropower plants of the first largest utility Endesa that did not recover their investment at the end of 2000 were financed based on project finance (del Pozo 2002). Another large developer owning 25 small hydropower installations - Energia Hidraulica Navarra - used also project finance for most of its projects (Arlaban 2001). But other developers continued to use internal financing schemes.

[22] Various Idae publications refer to 7 such projects put into operation between 1995 and 1999 (Idae 1996, 1998 and 1999).

hydropower did not become the dominant financing scheme after 1995 when the investment context improved in terms of economic-policy risks.

The consequence of this empirical explanation for our theoretical framework is that the pecking order theory of finance seems again to be backed up when project sizes are small and seemingly may also hold in optimal investment contexts. We come back to this lesson when we discuss the financing of wind technology in the United Kingdom.

9.3.1.4 Technological design, 1995-2000

The part of Hypothesis 1 regarding technological designs predicted the developers will be likely to adopt diffusion-optimal designs quite habitually. As discussed in Section 4.3, small hydropower technology was in late 1970s already technically advanced form the perspectives of ability to exploit a wide range of resource sites, with high efficiency and to offer high quality power output both for grid-connected and stand-alone applications. But, since then, it was confronted with expectations for substantial improvements in its economic and environmental performances. The technical improvements recorded in the period after 1995 where mostly of the same nature as those in the previous period.

The main recent technical advances mentioned in the governmental Policy Plan for the Promotion of Renewable Energy Technologies of 1998 are:

- technical optimisation for improved control of power quality and partial or even integral automatisation and remote control of small hydropower installations;
- small cost reductions, mainly as a result of implementing the measures for technical optimisation; but in the last years more new plants were introducing and increasing the role of polymers as construction materials, especially for pipes; this also contributed to some small reductions in the construction costs component. On average, production costs at the end of 2000 lowered to 5,4 €c/kWh (Gonzalez Velez 2000), from around 6 - 6,6 €c/kWh in mid 1990s;
- reduction environmental impacts, through plant design and technical measures to protect river flora and fauna.

Having in view the limited potential remaining for technical improvements, we assess these achievements as *substantial* in terms of diffusion expansion potential, taking also into account the large range of progress-areas covered and the relatively short period of time when they were achieved. Consequently, this empirical indicator to *confirms* the expectations in Hypothesis 1.

9.3.2.5 Conclusion on the overall confirmation of Hypothesis 1 for diffusion patterns of small hydropower technology is Spain

Section 9.3.2 looked at the diffusion patterns of small hydropower technology in Spain in the period 1995-2000. Three out of the four testable indicators for diffusion patterns were confirmed - the types of developers, drivers to invest and technological designs. Their empirical forms are summarised in Table 9.10.

The expectation for the indicator of types of financing schemes was not confirmed. Project finance started to be increasingly more used after 1995, but internal financing schemes continued to dominate the investment picture. The indicator of project sizes could not be tested. The assumption that there are no direct constraints on the decisions of developers regarding project sizes was not confirmed, since the sizes of small hydropower plants are generally defined by legal rules.

The overall extent of confirmation of the theoretical expectations regarding diffusion patterns can be assessed as satisfactory. This enables the continuation of the empirical investigation regarding the sustainability of diffusion processes. Section 9.3.2 looks at the effectiveness of the support system, in terms of installed capacity increase by 2000 and the prospects created for sustainable diffusion processes.

Table 9.10 *The theoretically expected and the empirically registered diffusion patterns for small hydropower technology in Spain, 1995-2000*

Practical developments	Theoretical expectations
Drivers to invest	
Dominance of commercial projects, around 90 %	likely predominance of commercial projects (confirmed)
Types of project developers	
- 70 % projects = by large / financially self-reliant companies energy; - 11 % projects = public authorities, water authorities - 19 % projects = individuals, farming associations.	all types of developers (confirmed)
Type of financing schemes	
- Still dominance of 'in-house corporate finance' and debt-corporate finance'; But increasing presence of 'project finance' - Other types of internal financing schemes also present.	predominance of external financing schemes, (not confirmed)
Project sizes	
All installations below 10 MW, according to definition of small hydropower plant in Royal Decrees => assumption of 'no legal constrains' was not confirmed	large variety of sizes (cannot be tested)
Technological designs	
Technological designs with diffusion-optimal features adopted frequently	diffusion-optimal technological designs adopted frequently (confirmed)

9.3.2 Installed capacity increase and prospects of sustainable diffusion in 2000

This section tests the expectations on installed capacity increase and looks at the prospects for the sustainability of market diffusion processes as they looked like at the end of 2000.

9.3.2.1 Increase in the installed capacity, 1995-2000

In Chapter 3 we hypothesised that an optimal investment context would be able to induce a *large increase in installed capacity,* operationalised as at least 1000 MW, if the support system retains its characteristics for at least a short-medium term period, of 5-10 years. This case study covered a period of six years, 1995-2000.

Summing up the annual capacities mentioned in Table 9.11, it results that 237,3 MW were installed during this period. This is only a *small* increase, since we considered as ‘small’ any installed capacity below 500 MW. If we add the 246 MW[23] capacity in construction works in 2000, this would still result in a small capacity increase. Figure 9.1 offers a general picture of small hydropower installed capacity during the 1990s.

Nevertheless, the investment interest manifested in the number of applications was still very large. In 1995 there were 690 projects already awarded water concessions and in process of administrative approval (Idae 1996: 22). But statistics show that between 1995-2000, only 155 projects were put into operation (see Table 9.11) due to administrative and social

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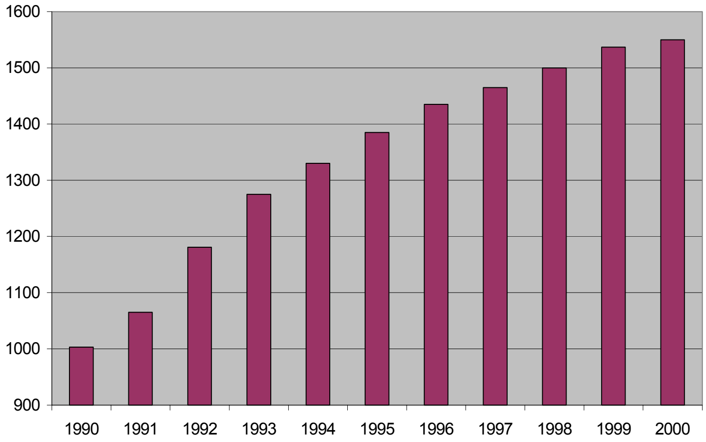
[23] The 1998 policy plan (Idae[1] 1999:56) mentions that in 1998 there were 314 MW small hydropower in construction. During 1999 and 2000 only 67,3 MW new appeared.

obstacles. At the end of 1998 there were 505 projects waiting for administrative approval, with a total of 1036 MW (Idae 1999: 86).

Table 9.11 *Annual capacity increase of small hydropower in Spain*

Year	1995	1996	1997	1998	1999	2000	total
No projects	32	25	30	27	17	24	155
MW	65	40	30	35	37	30,3	237,3

Figure 9.1 *Installed capacity increase of small hydropower during the 1990s in Spain*



Source: APPA, website, http:www.appa.es in August 2001

Interviewees explained that some projects were actually on the bureaucrats' desks even since mid 1980s (Fernandez [Sinae] 2001, Castillo [UFES] 2001). For 174 of the proposed projects, dams were already constructed and pressures from the renewables' generators representative association APPA were mounting for the immediate administrative approval of at least these projects[24] (APPA 2001). No type of developer seems to enjoy approval priority from administrative authorities. Both large developers - electricity and industrial companies, public companies, public authorities - and small developers had projects blocked in the approval process. Consequently, taking into account also the number of applications not yet approved by 2000, we assess that the expectation for this indicator was *confirmed* for this case study.

9.3.2.2 The prospects for sustainable diffusion processes in 2000

Hypothesis 1 predicted that under optimal investment contexts there are good prospects for the sustainability of market diffusion processes in the long term for the renewable technology envisaged. It assumed however that external financial schemes would be widely available.

In Spain, by 2000, external financing schemes were not yet the predominating investment tool, as expected under Hypothesis 1. Nevertheless, having in view the investment interest of many types of large developers with good access to financial resources, on the one hand, and the limited technically exploitable resource potential, on the other hand, it can be argued that

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[24] Manuel de Delas, "La minihidraulica, una energia para el desarollo sostenible" August 2001, APPA website http://www.appa.es.

diffusion continuity was not obstructed by financing availability. As in mid 1990s, the main obstacles to diffusion were the local administrative and social opposition.

This sub-section discusses first the topic of cost performances in relation to the resource potential in Spain in 2002. After that, it looks at the extent to which the features of the socio-economic-industrial context for investments changed as compared to those in mid 1990s and whether the empirical forms correspond to theoretical expectations in Chapter 3. We conclude by presenting some of the governmental proposals to eliminate remaining obstacles.

Cost performances and small hydropower resource potential

From the perspective of cost-performances, some cost reductions were booked by small hydropower technology in Spain. In mid 1990s, production costs were in the average range of 6 - 6,6 €c/kWh, while in 2000 the average was around 5,4 €c/kWh. But still these costs were 1,8 €c/kWh higher than the market price in the power pool. The changes in the factors affecting cost performances can be described for this period in a similar way as for the previous diffusion period differentiated (see Table 9.5).

The president of the small hydropower section of the Association of Renewable Energy Producers, Gonzalez Velez (2002), explained during an interview that with the 2002 level of governmental price support, the economically exploitable potential in Spain is between 700 - 1000 MW[25]. However, if price support decreases too much, as the trend seemed to be, many sites would become economically un-feasible or not sufficiently profitable. This would lower the economically exploitable potential accordingly. The governmental target set in the 1998 policy plan for renewables was to support the installation of 720 MW by 2010. This is achievable with the 2002 price support. But this would fail if cost reductions cannot keep the pace with reductions in price support. Some cost reductions could be still achieved but the highest potential is in the category of context-induced costs (see Section 9.2.2.2). This requires, however, institutional intervention in the local administrative approval procedures.

Assuming that only the 700-1000 MW remain economically feasible with price support from the government, this means that diffusion continuity after that point cannot take place anymore based on the expansion of installed capacity, but by means of re-powering of the already achieved capacity. Taking into account that in 2000, there were 1550 MW registered in the database of the renewable agency, this assumes a maximum installed capacity of 2250 MW - 2550 MW. But very importantly, the operation of this capacity assumes a range of production costs that starts at the level of variable costs and has to include the 2002 level of price support (that is 6,3 €c/kWh).

After some years power plants are able to operate only at variable costs (when they recovered their investment costs) and become competitive without price support[26]. But when the technical life-time is over and the plant has to be decommissioned, investors would need again price support to re-power the plant. These often are lower than investment costs because the infrastructure, foundation and construction works are already in place. They may need however works for rehabilitation. Overall, the re-powering costs may be lower than investment costs in a totally new similar power plant. But if technology-specific costs do not decrease

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[25] Regarding the environmental impacts, APPA (Genera 2001) considers that at least 450 MW capacity can be developed at present with minimum impacts. But the potential for 'environmentally-friendly' capacity is expected to increase soon, by means of technical progress in the field of civil works, construction materials, turbine design and positioning, and improved flow control through three-dimensional simulations.

[26] Maintenance and operation costs are between 1,2 - 1,8 €c/kWh (Idae[1] 1999: 83). The expected useful life-time of a small hydropower plant is around 25 years (Juan Antonio Alonso Gonzalez, IDAE, “Actual situation of renewable energy”, March 2001, Genera Conference, Madrid).

sufficiently by the time of re-powering the overall production costs may result in levels above the market price. This would necessitate again price support.

In section 2.7, we mentioned that the national potential of any renewable resource can be roughly divided into:

1) not technically feasible;
2) technically feasible but not economically feasible given the applicable support system;
3) both technically and economically feasible - given the support system; and
4) cost-competitive without any form of support instruments.

The cost competitive potential is often a very sensitive piece of information that owners of renewable projects are likely to know but would not inform about. The potential that is both technically and economically feasible was discussed above. As regards the technically exploitable potential which is however not economically feasible with the 2002 price support estimations differ depending on the barriers considered and the assumptions made. The assessments of the main actors are presented in Table 9.12.

The governmental agency assesses the theoretical potential at 2419 MW. Out of this potential it estimated that only between 600 MW and 800 MW could be installed by 2010, taking into account the existing restrictions faced by small hydropower, such as competing uses of water and the fact that many sites are situated in natural reservation areas. For this reason, it has placed a target of only 720 MW, around the middle of the expected interval[27] (Idae[1] 1999). But Idae considers, more generally, that the current level of technical development reached by small hydropower technology allows further investments of similar size with minimal environmental impacts.

Table 9.12 *Estimations regarding the exploitable small hydropower potential in Spain*

Source of estimation	Small hydropower potential estimation
Idae	theoretically exploitable 2419 MW; expectations: 600 - 800 MW by 2010
Governmental target	720 MW by 2010
Idae: Spanish industrial capacity	1200 MW by 2010
APPA	technically exploitable 1000 MW; other study: 1250 MW
Autonomous Communities	967 MW
Foundation Augustin de Betacourt	exploitable 610 MW
Menendez Perez (1997)	theoretical potential 7000 MW

The Association of Renewable Energy Producers quotes studies suggesting slightly higher exploitable potential levels - 1000 MW and 1250 MW (APPA 2001). The independent estimations of the regional governments of Autonomous Communities lead together to 967 MW at national level (Idae[1] 1999). But there are studies that indicate some higher figures. For example a study of Menèndez Pèrez over renewables diffusion in Spain mentions a theoretical potential of 7000 MW (1997: 160). Since the potential is limited and having in view that substantial progress was booked in ensuring high power quality from small hydropower plants, grid integration is not an obstacle for small hydropower diffusion. In conclusion, as argued in Section 2.8, the extent of long-term governmental price support is

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[27] In setting this target, the agency also took into account that at the end of 1998 there were 697 projects, totalling 1350 MW in Spain that already had water concessions. For 314 MW, works were already in construction stage, while the rest 1036 MW were in stage of administrative approval. Estimating the capacity for which proposals could be rejected, it chose a lower target that has more chances to be reached.

decisive for the market share that can be sustained by small hydropower technology in the national energy resource base.

The features of the socio-economic-industrial context of diffusion in 2000

Table 9.13 presents the theoretical expectations regarding the socio-economic-industrial context likely to be created by an optimal investment context on which we hypothesised a large installed capacity increase. Besides, it presents the empirical findings regarding these features after a six-year period of diffusion for small hydropower in Spain.

Table 9.13 *Diffusion results of biomass electricity technologies in Spain, in 2001*

Diffusion context likely to emerge		Small hydropower in Spain 1995-2000	Theoretical expectations optimal investment contexts
Socio-economic benefits		small	large
Local	Direct: ownership	likely present	confirmed
	Indirect: more attractive (than usual) benefits from ~ land rents; ~ local taxes; or ~ local economic or social welfare investments	likely high	not confirmed
	Indirect ~ local employment	technology specific	small
National	Ownership individuals (shares)	likely present	not confirmed
	Employment in industry	likely high	data not available
Industrial basis and dynamics		large	large
Number companies offering products / services for renewable electricity plants		large (confirmed)	large
Types of companies involved in industry		long-established industrial branch	large presence of corporations from a wide diversity of industrial sectors
Degree of specialisation in renewables		modest partly confirmed	high

We expected to see large socio-economic benefits from diffusion and in practice we assess them to be modest. The expectation to observe a large industrial basis and dynamics was confirmed by empirical observations. In these paragraphs we highlight only the differences as compared to what was presented in Section 9.2.2.2.

Socio-economic benefits

In terms of socio-economic benefits, they can be assessed as small. The arguments made in Section 9.2.2.2 with regard to local indirect benefits are also valid for these years of diffusion. As regards the direct benefits the difference is in higher local ownership, as the number of small developers increased to around 20% in this period. However, these owners are small and dispersed. The opportunity for political lobby through local politics is limited as long as local authorities have limited economic gains from increased small hydropower investments or prolonged governmental price support.

Another small difference as compared to the previous period is the slightly higher related employment. The new 237 MW small hydropower plants created only 176 permanent jobs for maintenance and operation tasks. Beside this, they contributed to 4408 temporary jobs, of which 1763 direct temporary jobs for plants' construction[28].

Industry size and dynamics

As regards the industry size and dynamics, these increased accommodating a larger number of companies. This is mainly due to the political commitment promulgated in the period 1997-1999 through the third economic-policy support system. However, statistics do not always agree on the extent of industry size. On the one hand, sources quoting the governmental agency Idae mention that, in 2001, there were 155 companies with operations in the field of small hydropower. They were offering services of engineering, and project development, equipment manufacturing, import and commercialisation[29]. On the other hand, the on-line Idae database listed in 2002 only 118 companies[30]. The fact that the number is lower might be because companies place themselves voluntarily on this database. In Table 9.14 the industry size is split per number of companies offering various types of technology products and services. The government estimated in the 1998 policy plan for renewables that the Spanish industrial capacity for small hydropower plants construction is around 1200 MW in the period 2000-2010.

From the standpoint of the degree of specialisation of industrial companies, not too much progress was achieved compared to the previous period. Most companies remained horizontally integrated with other industrial activities or with other types of renewable technologies. According to Idae, companies related to the small hydropower sector at the end of 1998 were coming from industrial sectors such as engineering, construction, and companies for the production operation and maintenance of industrial equipment (Idae 1999). The integration of small hydropower activities with other renewable technology areas is shown in Table 9.15.

Table 9.14 *Companies offering services and products for small hydropower developers registered in Idae database*

Services / products for small hydropower	Number companies
manufacture equipment	39
equipment sale	47
equipment import	21
equipment installation	63
equipment repair	41
technical assistance	75
maintenance	58
viability studies	60
project development	95
consultancy / feasibility studies	39
financial services	17
Total number companies	118

based on information at http://www.idae.es

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[28] These employment figures represent our estimations based on the numbers regarding the temporary and permanent employment per 1 MW of small hydropower. These numbers were obtained from the Association of Renewable Energy Producers (Gonzalez Velez 2002).

[29] *Las Energias Renovables*, "Minihidraulica una energia estancada", 3.11.2001, and "1573 MW of small hydropower electricity generation", 20.08.2001, Madrid.

[30] The on-line company database can be found at the agency's website: http://www.idae.es.

Table 9.15 *The degree of integration of small hydropower with other RET*

Technological areas addressed	Number companies
only small hydropower	22
small hydropower + 1 other RET	15
small hydropower + 2 other RET	18
small hydropower + 3 other RET	15
small hydropower + 4 other RET	16
small hydropower + more than 4 other RET	32
Number companies Idae database	118

Based on information at http://www.idae.es

The fact that only 22 companies are exclusively dedicated to small hydropower systems can be seen, on the one hand as a progress as compared to the previous period. But on the other hand, this represents a small proportion in the total number of companies listed as involved in the industry. This can be seen as an indicator that industrial companies perceive the future of this type of energy still as uncertain and prefer to diversify and minimise the risk of economic downfall in case of demand still-stand.

In conclusion, the new support system led to the expansion of the industrial basis, which can be assessed as large. Many companies stand ready to serve an increase in the demand for small hydropower technology and related services. But due to the limited de-facto successful investments, and a series of particularities related to the diffusion patterns of the technology, and specific aspects of this technology (small size by definition, not too much local ownership, longer established industry), the local socio-economic benefits remained small. These results only *partly confirm* the theoretical expectation with regard to the features of the socio-economic-industrial context for diffusion.

Proposals to eliminate remaining obstacles

In order to reduce the obstacles still facing small hydropower diffusion at the end of 2000, a series of possible measures were being discussed. On the one hand there were proposal from the governmental side, formulated on the 1999 policy plan for renewables (Idae[1] 1999). They were focused on three issues. Firstly, the need was signalled to harmonise the requirements for environmental protection at national level. The Ministry of Environment was put in charge to agree together with the relevant authorities of Autonomous Communities on a set of criteria for environmental impacts analysis. In addition, a Program for Environmental Surveillance was also requested in order to ensure that the corrective measures imposed on developers are implemented and to detect eventual residual or unexpected impacts. Secondly, it was requested that the administrative approval procedure be revised and speeded up. Thirdly, in order to deal with the still existent financing difficulties it was proposed to establish special soft-loan credit lines. This should be available either through the public Official Institute of Credit or through private banks. In addition, there is the plan to introduce an obligation for investment funds to invest a certain minimum percentage of the fund in small hydropower projects[31].

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[31] In addition to these, in order to make use of all available sites, it was required that holders of water concession licenses who stop operating their plants for more than 3 years have their license suspended.

9.3.3 Summary and conclusion Hypothesis 1

In Section 9.3 we tested empirically Hypothesis 1 for the case of small hydropower technology diffusion in Spain, in the period 1995-2000. During this period, the two economic-policy support systems valid for the small hydropower technology were both characterised by high/ very high levels of profitability and low/moderate economic-policy risks. The theoretical expectations under Hypothesis 1 were as follows.

A support system leading to a national investment environment of low to medium economic-policy risk and high to very high levels of project profitability will induce *diffusion patterns* that are characterised by:

- the involvement of all types of project developers, having
- predominantly commercial motivation to invest, using
- predominantly external financing schemes, in
- mainly medium and large size projects, based on
- the use of all types of technological designs of which new and/or existing diffusion-optimal technological designs are likely to be more frequent.

Such diffusion patterns will result in:

- a *large installed capacity* increase in short-medium term; and
- *good prospects for the sustainability* of market diffusion processes in the long term for the renewable technology envisaged.

Diffusion patterns

Section 9.3.1 analysed the diffusion patterns of small hydropower technology in Spain in the period 1995-2000. The extent of confirmation of the theoretical expectations regarding diffusion patterns can be assessed as *satisfactory*. For three indicators of diffusion patterns the expectations were ‘confirmed’ - the choice of technological design, types of developers and drivers to invest. For the indicator of project sizes, the expectations could not be tested because the political definition of small hydropower assumes restrictions on investors’ decision regarding this aspect of investment.

There was no confirmation for the indicator types of financing schemes. We observed a dominance of internal financing schemes and the prospects for a shift towards project finance were not very promising in 2001. Project finance started to be used in 1995/1996 after the change in the economic governance structure. Large developers, especially (subsidiaries of) energy utilities and industrial corporations benefited more often of project finance loans. But external financing schemes did not become predominant.

Diffusion results

For the first dependent variable, we expected to observe a ‘large’ installed capacity increase on a short/medium term - meaning 5 to 10 years. In practice the installed capacity increase was ‘small’ - 237,3 MW, or 483 MW if the capacity already under construction is included. At the end of 1998 there were 505 projects waiting for administrative approval, with a total of 1036 MW (Idae 1999: 86). Taking these into account, we assessed that the expectation for this indicator was *confirmed* for this case study.

As regard the prospects of sustainable diffusion processes, these were assessed as good by 2000, from the perspective of financing availability. Although external financing schemes were not (yet) the predominating investment tool, as expected under Hypothesis 1, there was a large investment interest from financially strong companies willing to use internal financing schemes. On the other hand there was a limited technically exploitable resource potential which enables the argument that diffusion continuity was not obstructed by financing availability. As in mid 1990s, the main obstacles to diffusion were the local administrative and social opposition.

From the cost performance perspective, the available price support enabled the economically feasible exploitation of around 700-1000 MW of the technically available potential estimated at 1000-1200 MW. Technical performances continued to record some small improvements, based on the same patterns as in the previous period studied. It was estimated by technical experts that some potential still remains for some reductions in costs and environmental impacts.

As regards the socio-economic-industrial context, the theoretically expected features were not observed. The socio-economic benefits remained small. However, the new support system led to the expansion of the industrial basis, which was assessed as large. These results only *partly confirm* the theoretical expectations with regard to the features of the socio-economic-industrial context for diffusion under optimal investment contexts. Overall, the extent of confirmation of the theoretical expectations regarding diffusion patterns can be assessed as *satisfactory*.

Exogenous factors and alternative specifications

The main factors identified as playing a role in the partial-/non-confirmation situations are as follows.

Firstly, there was the social and administration opposition to new constructions that emerged in early 1990s. This had effects on all five diffusion patterns indicators:

- type of financing scheme: it made project finance unattractive both for financing agents and for project developers;
- reducing project sizes to smaller than 1-2 MW; only very small sizes could generally pass the environmental impact test in the approval process;
- drivers to invest: making self-generation projects unlikely;
- types of developers: making it difficult for small developers to invest because of the extra costs and risks which they find more difficult to handle than large (hydro)power specialised companies;
- technological designs: project developers had no other choice than to look for innovations that would reduce environmental impacts; some of them were accompanied by cost reductions as positive spin-offs.

Secondly, there was competition for financial resources and investment interest from wind energy. In the period studied, banks were in the ‘wind-fever’. They were competing to finance the generally much larger wind plants whose approval came very fast. When interested to diversify investments, biomass electricity projects were more appealing due to their large economies of scale and expected market boom in the near future.

Thirdly, there was the assessment of financing agents that small hydropower in Spain cannot become ‘big business’. For example, the potential of biomass electricity plants is assessed to be in the order of thousands (around 8000 MW by 2010), while the theoretical potential of small hydropower is assessed at around 2400 MW. The technically available potential is assessed at 1000-1200 MW, while the target by 2010 for small hydropower was 720 MW.

9.4 Summary

In this chapter, we tested, in Section 9.2, Hypothesis 2 for the case study of small hydropower technology' market revival in the period 1980-1994. Further, in Section 9.3, we tested Hypothesis 1 for the case study defined by small hydropower technology' diffusion in the period 1995-2000.

In the case study for the testing of Hypothesis 2, the independent variables of economic-policy risks and ranges of project profitability *appeared to have a strong explanatory powe*r with regard to the diffusion patterns and diffusion results of small hydropower technology. Empirical findings lead to the assessment that the extent of confirmation of theoretical expectations for diffusion patterns was satisfactory, while those for diffusion results confirmations was only *partly satisfactory*. However, we still consider that the independent variables held in this case study an overall strong explanatory power because of the influence of several strong exogenous factors. From the diffusion results for which theoretical expectations were formulated, those regarding installed capacity and the industrial basis were confirmed. There was no confirmation regarding the socio-economic benefits from diffusion due to two technology-specific factors (see Section 9.2.3). As for the diffusion patterns, we observed the influence of four exogenous factors. A discussion on the factors that affected more systematically diffusion patterns and results for the three renewable technologies studied in Part II of the book, follows in Chapter 10.

In the case study for testing Hypothesis 1, the independent variables of economic-policy risks and ranges of project profitability *appeared to have also a strong explanatory powe*r with regard to the diffusion patterns and diffusion results. The extent of confirmation of the theoretical expectations under Hypothesis 1 was *satisfactory* for both diffusion patterns and diffusion results. Beside the influence of the two independent variables, we identified a set of three exogenous factors that influenced diffusion patterns and results. One of them - administrative and social opposition and delays - affected all forms of diffusion patterns, with consequences for diffusion results as well.

The next chapter concludes Part II of the book, which focused on theory testing for the diffusion of renewable electricity technologies in Spain. There we make a summary of the main issues discussed in Chapters 6, 7, 8 and 9, and make a comparison regarding the extent of confirmation of theoretical expectations for the six case studies, and the role of exogenous factors in the observed diffusion patterns and results.

Chapter 10

Concluding remarks regarding the diffusion of renewable electricity technologies in Spain

10.1 Introduction

This chapter concludes Part II of the book, which focused on presenting the findings of empirical research in Spain. We started Part II with a description and analysis of the support systems used in Spain during the 1980s and the 1990s for the market introduction and diffusion of three renewable technologies: small hydropower, wind and biomass electricity technologies. This was done in Chapter 6, where we concluded by specifying the hypotheses to be tested for the six case studies distinguished. Further, in Chapters 7, 8 and 9 we tested two hypotheses for each renewable technology.

In this chapter we present the main findings from empirical research in Spain, with accent on factors influencing the assessment of support systems' attractiveness by investors in Spain, and the exogenous variables playing a role in diffusion patterns and the diffusion results for the renewable technologies analysed. In Part III of the book, we conduct empirical research regarding the diffusion of wind technology in the Netherlands and in the United Kingdom in the 1990s. Placing the main findings summarised in the chapter next to those emerging from empirical research in Part III, we will draw the conclusions regarding the explanatory power of the study's theory in Chapter 14.

10.2 The assessment of support systems' attractiveness for investors

The analysis in Chapter 6 revealed that there were differences between our assessment regarding the level of economic risks embedded in the economic governance structures for renewable electricity, and the assessments of interviewed project developers and market experts in Spain. Our assessment was made from a strict legal perspective, looking at the eligibility for protective trade arrangements and price support for different types of project developers, project sizes and types of renewable technologies. We assessed the legal provisions regarding demand risks, contract risks and price risks and noticed that:

- there were different levels of risks for commercial non-hydro renewable resource projects and the other types of renewable energy projects during the first and the second economic governance structures;
- there was a difference in the economic risks for commercial biomass projects and the other types of renewable energy projects, during the third economic governance structure since 1997/1998 (see Figure 6.6).

After analysing the policy risks associated with national support mechanisms, we concluded that the aggregated economic-policy risks of support systems - for all three periods distinguished and for all three technologies - may be defined only by the risks in the economic governance structures. The interviews with project developers and market experts revealed that in Spain a series of factors converged towards a different interpretation of legal provisions. As a result, in Spain it was considered that all types of projects and technologies benefit of the same protection from the economic governance structure, namely that for all types of projects and technologies, those legal provisions are applicable that result in the lowest economic risks. The following factors led to the favourable interpretation of the legal frameworks:

- the governmental interest to reach the target for renewable electricity set for 2000; initially self-generation projects were seen as the main vehicle to the target but investor interest in self-generation power plants proved to be low;

- it was politically easier to adopt laws and royal decrees whereby only self-generation and demonstration projects were eligible, because not all energy utilities and political forces were in favour of supporting renewable energy;
- the interest of certain energy utilities and the renewable energy agency in wind energy investments lead to the tacit interpretation of all non-hydro projects as demonstration systems or as self-generation projects (because all power plants, especially wind systems also consume some quantities of electricity from the grid); this rested on the:
- business culture of flexibility in the application of laws, as long as third parties are not injured or do not disagree with such implementation.

Consequently, these interpretations and factors led to an assessment by project developers and governmental actors, regarding the risks in the support system, that corresponded to the most favourable legal provisions offered for renewable electricity trade and price support. Since in Spain investment decisions were taken based on risk assessments influenced by these factors, we decided to consider them when selecting the hypotheses to be tested. After analysing the ranges of profitability for projects, we concluded Chapter 6 by selecting the following hypotheses to be tested:

- Hypothesis 2 for the market introduction of wind technology during the first support system, 1980-1994;
- Hypothesis 1 for the diffusion of wind technology during the second and third support systems, 1995-2000;
- Hypothesis 2 for the market revival of small hydropower technology during the first support system, 1980-1994;
- Hypothesis 1 for the diffusion of small hydropower technology during the second and third support systems, 1995-2000;
- Hypothesis 4 for the market introduction of biomass electricity technologies during the first support system, 1980-1994;
- Hypothesis specified for the case of a combination of optimal and political investment contexts (mixture of Hypothesis 1 and 3) for the diffusion of biomass electricity technologies during the second and third support systems, 199-2001.

10.3 The extent of compliance of the six case studies in Spain to the theory's assumptions

In Chapter 6 the main focus was on presenting the necessary information regarding - initially - the legal framework in order to support the assessment of economic risks from legal perspective. The description also included information that offers an indication regarding the extent to which some of the assumptions we made in Chapter 2, Section 2.5 for theory elaboration were to be found in the Spanish context. Table 10.1 makes a checklist of assumptions' presence in the six case studies.

Consequently, four of the assumptions we made were found present in all six case studies. The assumption that no other types of obstacles would impede diffusion, such as administrative, social, institutional, technical (grid) obstacles was a very strong one, and - as it was easy to expect - in no case study was this assumption complied with.

Table 10.1 *Assumptions of the theory and their presence in the Spanish case studies*

Assumptions of the theory	6 case studies in Spain
imported renewable electricity is not eligible for the benefits of support system	complied with
electricity industries are liberalised to the extent that market entry of any type of economic actor willing to engage in electricity generation is possible	complied with
there is no governmental limit or requirement on the installed capacity of renewable technology(ies) at industry level	complied with
renewable electricity from partly-self-generation plants may receive the same benefits from the support system as electricity from commercial projects	complied with
the support system remains the same over at least short-medium term	complied with, except biomass in Spain since 1995
there are no direct influences from government intervention on diffusion patterns e.g. on types of developers, types of financing schemes, project size, drivers to invests, technology choice design	limits on project sizes: both in economic governance structures and investment subsidies
no other types of obstacles impede diffusion, such as administrative, social, institutional, technical (grid) obstacles	all technologies: not complied with

Also the assumption that the support system remains the same over at least short-medium term, operationalised as five to ten years was not met in the case study of biomass power diffusion since 1995. The second support system created a political investment context between 1995-1998, while the third support system extended this towards the optimal investment context to some extent (towards high profitability levels), for which we could observe developments only in the years 1999-2001. However, we could still check diffusion patterns, which was important because of the difficulty to find support systems with more than five years of application with political investment contexts.

Finally, the assumption that there are no direct influences from government intervention on diffusion patterns was also not complied with in the case of all three technologies. The second economic governance structure placed a ceiling of 25 MW for the high price design guarantee for all non-hydro renewable resources. The third economic governance structure lifted the ceiling of 50 MW. In addition, the investment subsidy schemes placed different ceilings on plant eligibility at different times. In empirical research, it appeared that for wind power plants these ceilings did have an effect on investment decisions regarding plant size in the beginning. But this constraint could be overcome by designing wind plants next to each other and split in different projects only in the administrative papers. The differentiation of economic governance structure according to the drivers to invest - commercial, (partly-)self-generation and demonstration - which was observed in the legal analysis, did not have an impact on investment decisions and on diffusion patterns because of the interpretation that all types of projects may benefit of the legal protection with minimum economic risks. Beside these, there was the constraint on the types of project developers due to the legal provision that distribution companies (under the first and second economic governance structures) and electricity companies participating in the power pool are not eligible for contract protection and price support for their renewable power investments. But this constraint was also evaded by means of established separate subsidiaries for investments in renewable plants or joint ventures specialised in renewable energy investments together with other companies, regional authorities, financing agents or manufacturers. In conclusion, the theoretical assumptions were present in the Spanish case studies to a satisfactory extent.

10.4 Exogenous factors and alternative specifications

In Table 10.2, we summarise the situations regarding the confirmation of theoretical expectations for diffusion patterns for the six case studies in Spain. We marked with an (X) the 18 cases where expectations were fully ‘confirmed’, with an (Y) the 6 cases when they were ‘confirmed to large extent’. The 3 cases where the indicators could not be tested were marked in grey areas. Further, we marked with a line (-) the 8 cases where the indicators took any other form: partly confirmed, not confirmed, cannot be tested (marked in grey areas), as well as all cases of assessments ‘with comment’ (including ‘confirmed with comment’ and ‘confirmed to large extent with comment’). Overall, a predominance of X can be observed in Table 10.2, which means a large extent of full confirmation.

Table 10.2 *The situations of full/large extent confirmation of the theoretical expectations with regard to diffusion patterns*

Indicators diffusion patterns	Hypothesis 1			Hypothesis 2		Hypothesis 3	Hypothesis 4
	wind	biomass	SHP	wind	SHP	biomass	biomass
drivers to invest	-	Y	X	-	-	Y	Y
developer types	-	Y	X	X	X	Y	Y
financing schemes	X	X	-	X	X	X	
technology design	X	X	X	-	X	X	X
project sizes	-	X		-		X	X

In the theoretical part we assumed that the risk-profitability characteristics of the support systems influence - and have discernible impacts - on diffusion patterns. Looking at empirical findings in Table 10.2, it could be argued that the risk-profitability levels seem to have a strong explanatory power for the forms of the indicators: types of financing schemes and technological designs. As regards the other three indicators - drivers to invest, types of developer, and project sizes - there seems to be a core set of factors recurring in many of the Spanish case studies. They affect these indicators towards the absence/poor presence of the same forms: small developers, self-generation projects and small size projects. In some cases when the inset ‘with comment’ was used on hypotheses testing, this regarded governmental intervention to counteract these interfering factors and enable investments by small developers, the construction of self-generation plants, and the possibility to finance small size projects. The following factors were found to systematically affect the forms of the three indicators:

- low importance attached to the (voluntary) environmental performances and image by production companies and commercial/small consumers; whenever price support improves, most non-energy-core economic actors already involved in renewables switch from self-generation to commercial projects;
- low entrepreneurship among small developers with regard to new technologies;
- (perception) early stage of national technology development and demonstration;
- the business culture of the domestic financing actors raising financing difficulties for small projects and small developers.

Here follows a list of factors that were found to influence the indicators of drivers to invest, project sizes and types of developers, as well as the factors identified as influencing the indicators types of financing schemes, technology design and rate of installed capacity increase:

- *perception* regarding the stage of technical development by active and potential developers and financing agents (affecting the types of financing schemes available and the investment interest and hence, installed capacity too);

- the stage of technological development whereby very small size wind turbines of national technology design dominated the market (affecting project sizes, technological choice, and installed capacity growth);
- governmental special financial support for national wind technology manufacturers and short term market orientation of manufacturers in their decision regarding technical characteristics of turbines (affecting technological choice);
- involvement of manufactures as co-owners in wind projects (affecting technological choice; types of financing schemes);
- business culture: many economic actors not being flexible to accept risks in the support system; preference for clear signals for long term political commitment for renewables and for involvement of influential corporations viewed as opinion makers in business (affecting installed capacity growth);
- the criteria for projects' approval by regional authorities since 1994/1995 (affecting project sizes, technological choice, types of developers, and drivers to invest);
- business interests of the regional and local authorities, which often were interested to develop or co-own the resource rich sites in the regions themselves (affecting types of developers and types of financing schemes);
- the business interest of domestic financing actors: banks since 1998/9 started to invest equity in many projects and companies becoming competitors to many developers, including small developers (affecting types of developers and installed capacity growth);
- business requirement on profitability of economic actors, especially here - energy utilities (influencing the types of project developers; the installed capacity achieved);
- ownership connection between manufacturers and developers (technological choice and types of financing schemes);
- the techno-economic particularities of the supported renewable technology, namely complexity and expensiveness (too large economies of scale); (influencing the presence of small developers, investments in self-generation plants by them and project sizes);
- resource availability per se, but also in relation to the extent of price support that the support system enables (influencing types of financing schemes, the installed capacity achieved);
- environmental local opposition working against the public image of industrial production companies (affecting self-generation investments);
- the local social and administrative opposition to renewable plants leading to impacts on all five indicators of diffusion patterns, and consequently also on the rate of installed capacity growth; this happened in the case of small hydro-power diffusion; positive impacts were noticeable on the choice for technological designs: innovations that would reduce environmental impacts; cost reduction spin-offs;
- competition for loan financing resources and investment interest in other types of resources/technologies (affecting types of financing schemes; possibly the rate of installed capacity growth);
- the assessment of financing agents that the respective renewable resource cannot become 'big business' (affecting types of financing schemes; possibly the rate of installed capacity growth);
- governmental intervention in diffusion patterns (possibly affecting all five indicators; in Spain the government used special policy support mechanisms to stimulate investments in small projects by small developers and/or in self-generation plants, for which many of the above-mentioned factors created obstacles.

In Table 10.3, we summarise the situations regarding the confirmation of theoretical expectations for those indicators of diffusion results for which we decided in Chapter 2 to develop hypotheses. These empirical forms regard also the six case studies in Spain. We marked with an (X) the 10 cases where expectations were fully 'confirmed', with an (Y) the single case when it was 'confirmed to large extent', and with a line (-) the 7 cases where they took any other form: partly confirmed or not confirmed. The negative conclusions concentrate on the explanation of the socio-economic benefits.

Table 10.3 *The situation regarding the extent of confirmation of the theoretical expectations for diffusion results*

Indicators diffusion results	Hypothesis 1		Hypothesis 2		Hypothesis 3	Hypothesis 4
	wind	SHP	wind	SHP	biomass	biomass
installed capacity	X	X	-	X	-	X
socio-economic benefits	X	-	-	-	-	X
industrial basis	X	X	X	-	Y	X

In the theoretical part of the study we assumed that the risk-profitability characteristics of the support systems influence - and have discernible impacts - on these three indicators of diffusion results, by means of the diffusion patterns that investment contexts induce. Looking at empirical findings in Table 10.3, it could be argued that the risk-profitability levels seem to have a strong explanatory power for the forms of the indicators: installed capacity increase and industrial basis and dynamics[1].

However, the independent variables do not appear to hold explanatory power with regard to the extent of socio-economic benefits induced by diffusion. In this case, technology-specific factors appeared to play an important role in the extent possible to realise local indirect socio-economic benefits.

These observations conclude Part II of the book. In Part III we focus on testing two more hypotheses in different national contexts. These case studies should yield more insight into the role of exogenous variables into the forms of diffusion patterns and results. In Chapter 10 we describe the support system used for wind electricity in the Netherlands and specify the hypothesis to be tested. In Chapter 11 we test the selected hypothesis for wind technology diffusion during the 1990s in the Netherlands. The last case study of the book is presented in Chapter 13, which takes both steps of hypothesis specification and hypothesis testing for wind technology diffusion in the United Kingdom during the 1990s.

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[1] As regards the indicator of installed capacity increase, we mentioned in the above list of interfering factors some which we identified as influencing it.

11

The support system for renewable electricity in the Netherlands 1990-2000

11. 1 Introduction

In the Netherlands the interest to support technologies based on renewable energy resources emerged during the 1970s with the oil crises and concerns over security of supply. Towards the end of the 1980s, concerns over the environmental impacts of fossil fuels, especially CO_2 emissions, appeared as co-drivers for a policy to support renewables. There are three main characteristics of the governmental support for renewable energy in the Netherlands, and in particular wind energy: the struggle to establish a national manufacturing industry; numerous and complicated support schemes; and fluctuating policy focus. The target of governmental support changed from emphasis on research and demonstration in the 1980s, to increase in renewable electricity production in early 1990s and towards decrease in fossil fuel based electricity consumption in late 1990s. Therefore, by 2000 the share of renewable resources in the Dutch electricity supply was marginal - only around 3%, excluding urban and industrial wastes.

The governmental target is to increase the share of renewable resources in electricity consumption to 9% by 2010. This is also the orientative target set in the 77/2001 EU Directive on renewables for the Netherlands. However, the achievement of this target is doubtful, unless imports are substantially contributing. The unstable and arm-distance characteristics of the Dutch economic-policy support system during the 1990s, which perpetuated in 2001-2002, have led to an unsatisfactory development of the technology manufacturing industry and shattered the confidence of investors in commercial projects.

This chapter describes the characteristics of the support system for wind technology in the Netherlands during the 1990s. We analyse the risks embedded in the support schemes and the profitability ranges that they rendered during those years, in order to select the hypothesis to be tested. The testing of the hypothesis is the focus of Chapter 12.

The empirical analysis for the Dutch case study of wind technology diffusion starts in Section 11.2 with a short overview of the main governmental programs and policies that addressed the issue of support for renewable energy technologies during the 1980s and 1990s. Section 11.3 provides a short overview of the energy resources used for electricity production in the Netherlands during the 1990s and the potential for both renewable and conventional energy resources. Further, Section 11.4 makes a general description of electricity industry's structure, as regulated by the 1989 Electricity Act[1], and the 1998 Electricity Law opening the system for liberalisation. The discussion of the support system for renewables starts with Section 11.5, where the characteristics of the economic governance structures are described and analysed for both electricity laws. The entire Section 11.6 is dedicated to the description of the policy support mechanisms envisaged - among others or exclusively - for wind technology. Descriptions will be spilt in three parts, according to the actor(s) managing or backing up the support schemes - distribution companies, governmental bodies and green consumers.

Finally, Section 11.7 makes an analysis leading to the specification of the hypothesis to be tested. The decade of the 1990s is spilt into three periods, as defined by the major changes in the policy support systems used: 1990-1995; 1996-1997; and 1998-2000. In addition, the electricity law also changed in 1998. For each period, the way in which support schemes were implemented is analysed in detail in order to derive the aggregated economic policy risks and the likely ranges of projects' profitability. Insights into what

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[1] The 1989 Electricity Act of the Netherlands, Staatsblad 1989, No. 535.

happened in practice lead finally to the conclusion that in the period 1990-1997 the risk-profitability context remained the same in spite of policy changes. Two different risk-profitability contexts emerged and persisted during these years, which applied for different types of developers. But in the last period, 1998-2000, the shifts in the support system did lead to changes in the risk-profitability investment circumstances for both groups of developers. Due to the fact that differences are too substantial as compared to the previous years, a hypothesis will be specified only for the period 1990-1997.

11.2 Overview of governmental policies for renewable resources and wind electricity since the 1970s[2]

The First and Second White Papers on Energy adopted in 1974 and 1980 after the oil crises were mainly concerned with energy conservation and diversification of resources. The 1974 White Paper stated that renewables could not be expected to develop any market share in energy production between 1975 and 1985. Their rise - basically the introduction of wind, solar (thermal) and biomass - could only be expected after 1985, with a probable first introduction of wind technology. Therefore the Dutch government initiated supportive programs predominantly for the development of wind turbine technology[3].

In 1975 the first National Research Program for Wind Energy was adopted. This was updated in the second National Wind Research Program in 1982. The third governmental program for wind energy support, the Integrated Program Wind Energy, unfolded between 1986-1990. It aimed at both market introduction by means of investment subsidies and at the support of the manufacturing industry (Wolsink 1996).

The policy attention for renewables strengthened through the adoption in 1990 of the National Environmental Plan Policy-Plus placing emphasis on the need to address the climate change problem. The policy program introduced the concept of sustainability as a guiding principle for socio-economic development. This stressed the significance of renewable resources and improved the national climate for development of renewable-based technologies (Dinica and Arentsen 2001). The promotion of renewables was placed under a voluntary agreement with the distribution companies (see Section 11.6.1). Environmental voluntary agreements were also concluded with the generation utilities and industrial manufacturing companies but they were focused on energy conservation and efficiency, including promotion of co-generation technologies (Ecofys 1999).

Between 1991-1995, the government adopted the support Program for the Application of Wind Energy in the Netherlands, referred to as Twin-I, whereby the support approach was quite similar to the previous wind program. In 1995, the Third Energy White Paper was adopted drawing the policy lines for up to 2020. The driver behind this white paper was the need to redefine the vision on energy policy in the framework of liberalisation of energy industries and their eventual integration in a single EU market. A target of 10% renewable resources use on total energy production was set for 2020. At the same time, the

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[2] The history of renewable energy policy in the Netherlands is well documented. In this section, we just highlight the milestones referring to some studies for further information.

[3] For an overview of the first national wind programs see Verbong (1999), “Wind power in the Netherlands”, 1970-1995.

White Paper signalled the need to switch to market-compatible mechanisms of support for renewables.

For the short-term policy, an action program was adopted by the Ministry of Economic Affairs in 1997 - “Renewable Energy Advancing Power 1997-2000”. This had three central objectives: the improvement of price performance ratio for renewable technologies, promotion of their market penetration, and addressing administrative bottlenecks. The long-term policy guidelines have been traced in the 1999 Energy Report. They are as follows: emphasis on consumer driven market growth of renewables; the use of fiscal instruments, especially energy tax, to encourage demand and supply of renewable energy; the use of voluntary agreements for renewables use on certain industrial sectors; and the further support of R&D and demonstration activities. The 1996-2000 Program for Wind Energy Promotion TWIN II eliminated investment subsidies for market introduction and preserved them only for R&D and demonstration projects.

The vision of the government in the 1999 Energy Report was that the market share of increase of renewables so far was unsatisfactory not because of lack of investment interest, but due to social-local and administrative obstacles. Consequently, the post 2000 support system for the achievement of the 9% target on renewable electricity consumption is viewed (in 2001) entirely as based on consumer demand, temporarily backed up by fiscal instruments, and strongly focusing on removing the barrier at the supply side to speed up the rate of capacity installation.

The next section makes an overview of the energy resources used in the Dutch electricity sector during the 1990s and the available resource potential.

11.3 Overview of energy resources used in the Dutch electricity sector

The energy resource base of the Netherlands was long dominated by the presence of fossil fuels. During the 1950’s, electricity generation in the Netherlands was almost entirely based on coal but in 1959, the largest gas field in Europe was discovered in Groningen. During the 1960s coal mines in the Netherlands were closed because they were not economically viable anymore. Since then they were not re-opened. Between 1965 and 1975 gas steadily increased its share in the resource base of electricity. But in 1974, the energy policy indicated the shift towards more coal and nuclear resources use and a more restrictive deployment of gas reserves. Since then, coal has slowly but constantly increased its share in electricity generation again, but this time only from import resources only. The shares of the energy resources used by the central generators are shown in Table 11.1.

Table 11.1 *The shares of energy resources in the electricity production of the central generators*

Types of energy resources in central electricity production, %	Coal	Oil	Gas	Uranium
1989	37.4	0.6	54.2	7.8
1994	41,7	0,1	50,1	7,9
1998	44.1	0.1	48.1	7.7

Source: SEP and EnergieNed, 1999; Etsu 1996: 84

Table 11.1 shows that central generators were focused on the use of fossil and nuclear fuels. But while natural gas accounted for around 50% of the energy resources used, it was also the main fuel for de-centralised generators, who were using it in proportion of more than 80%. The other energy resources used by decentralised generators were solid residential and industrial wastes, wind energy and very small amounts of solar PV, wood wastes and biogas (EnergieNed 1998).

In spite of the large gas resources discovered on the Groningen field, it seems that the Netherlands disposes of only limited fossil fuel reserves. Table 11.2 shows the estimated time availability of the reserves of conventional fuels at world level and for the Netherlands in relation to 1991 world consumption levels. As Table 11.2 shows, given the current annual rates of non-renewable resources uptake, the sustainability and security of supply of the Dutch energy sector will be in medium term (30 years) negatively affected, unless more efficient co-generation and renewable technologies are used.

Table 11.2 *The estimated time availability of fossil-fuel resources*[4]

Reserves of primary fuels in relation to 1991 consumption levels, [years]	Oil	Coal	Gas
World	43	344	52
Netherlands	6	Un-economic	24

The availability and quality of wind energy resources is quite low on land, but very large offshore. Estimations on potential varied during the 1980s and 1990s. An elaborated study of the Ministry of Environment assessed in 1987 that it may be possible to accommodate up to 2000 MW if new more flexible policies for physical planning were adopted (Wolsink 1996: 1080). Towards the end of the 1990s, the government set a target of 1500 MW by 2010 for wind power, taking into account the serious restrictions on land availability and difficulties in local social acceptance of wind projects[5]. In 2000, environmental organisations from the twelve Dutch provinces, together with the Foundation Nature and Environment, made a thorough investigation on existing and new siting opportunities and arrived to the conclusion that between 2100 MW and 2250 MW could be installed on land, also with a help of more flexible siting policies[6]. On the North Sea, it is estimated that at least 3000 MW could be placed, with further additional siting possibility for 1000-3000 MW (ECN 2001: 57).

As regards other renewables, for clean biomass resources the potential is very restricted in the Netherlands. Due to due land availability constraints, the cultivation of energy crops and forests cannot provide more than a very small contribution to energy supply. Clean biomass wastes are available and already used in few co-combustion plants but the potential is also small. Among centralised and decentralised generators there is interest to use biomass and its share could grow in long term through imports. As regards small-hydropower plants the currently operating capacity, around 40 MW, represents almost the entire potential available in the country. The potential for solar photovoltaic systems is considered very large for residential and commercial grid-connected systems but there is less agreement on estimations. The next section describes the main characteristics of the organisation and functioning of the Dutch electricity industry during the 1990, as regulated in the two electricity laws that were operational in this period.

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[4] Source: EZ, 1993. Data on the Netherlands calculated by dividing the estimated available reserves with the annual consumption - taken for the year 1991.

[5] Information at website of energy agency Novem: http://www.den.novem.nl.

[6] Publication “Frisse Wind door Nederland ". Information also in ECN in EVN (“Genoeg plaats voor windmolens" 2000: 54).

11.4 The main characteristics of the Dutch electricity industry

During the 1990s, there have been two laws for the organisation and functioning of the electricity industry in application - one introduced in 1989 and the 1998 law, which opened the industry for liberalisation. In this section we present their main provisions with regard to industry structure. This supports the explanations on how the economic governance structure for renewable electricity fits in the electricity system.

11.4.1 The industry structure based on the 1989 Electricity Law

The main goal of the 1989 Electricity Act was to reorganise the industry so as to enable a more cost efficient production of electricity. Renewable forms of energy were encouraged just as long as generation could take place at costs lower than the average industry costs. This was hardly the case at the level of beginning of 1990s.

As regards the industry structure, the 1989 Act required vertical de-integration and allowed a limited extent of decentralised generation of electricity. The following actors were authorised to generate electricity: generators for central public supply with installed capacities higher than 2500 MW and de-centralised generators. In the period between 1989-1998 there were four large central generators: EPON, EZP, UNA and EZH. In addition to these, GKN was a nuclear power plant owned by a consortium of companies and the state. The EPON and EZP were owned by local distribution companies, while UNA and EZH were owned by local municipal and provincial authorities (Huygen 1995).

The 1989 law enabled also the de-centralised generation of electricity, to some extent. Firstly, distribution companies were allowed to own plants for public supply, under certain conditions regarding plant size and technology choice. When they used conventional technologies based on fossil fuels, the limit on plant size eligibility was 5 MW. When they used 'other installations', they could build plants of up to 25 MW capacity based on their own decision, or plants larger than this limit with the special approval of the transmission company SEP[7]. The definition of 'other installations' included technologies with high efficiencies, such as co-generation, wastes incineration; but they also included environmentally friendly systems, such as: wind energy, water power, solar energy, biomass or terrestrial heat" (Art. 42.4). Secondly, *any private and legal person was also allowed to own and operate generation plants using 'other installations'*. The law guaranteed the purchase of power generated by such plants. The purchase obligation was imposed on the regional distribution companies where generation plants were located[8]. There were no restrictions on plant sizes for this group of decentralised generators. No plant size limit was imposed because there was no expectation that in practice natural persons and private companies would have the means and needs to produce electricity in plants larger than 25 MW (Huygen 1995: 44).

At the transmission level, the only company authorised by law to operate the high-voltage grid was the Association of Electricity Producers (SEP). The SEP also had the

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[7] The intention behind the decision to allow distributors own generation plants was to encourage competition, challenging the large central generators produce more efficient. The approval of Sep for distributors plants larger than 25 MW was intended as a means to ensure the technical feasibility and optimal integration in the national grid management of larger plants (Huygen 1995: 44).

[8] An important condition was that the company owning the owner of the plant did not import electricity at the establishment where the plant was located.

responsibility of supporting the introduction of sustainable technologies in the system, as long as this contributed to the goal of lowering consumer' costs. The technologies understood as serving sustainability were those using solar, biomass and wind energy, hydropower, waste incineration and high efficiency co-generation. The company was placed in the joint ownership of the four central generators. Therefore, it was indirectly owned also by distribution companies, and local and provincial authorities. As regards distribution companies, their number decreased during the period studied. They were primarily owned by provincial and/or municipal authorities. Distributors were legally considered as non-profit companies and did not have to pay corporate taxes.

In addition, the organisation and functioning of the Dutch electricity sector was significantly influenced by EnergieNed. This organisation has been set up as a branch organisation of the distribution companies, providing services to its members and promoting their interests. EnergieNed is an independent organisation, with no administrative accountability to the government, and it doesn't engage in any production activities along the value chain of electricity. The 1989 law assigned certain competencies to the association of distribution companies, especially related to price design in the sense that EnergieNed could negotiate on behalf of the distribution companies. The involvement of EnergieNed in the contractual relations of members, the coordination of investments, R&D and environmental plans of distribution companies were not initially intended as tasks of EnergieNed, but in practice they became items on the organisation's statute. As this chapter will show, EnergieNed played an essential role in how renewable electricity diffused.

Finally, consumers were divided in two groups, according to their annual consumption volumes: 'captive customers' and large end-users. The last were those with consumption levels > 20 GWh for at least 4000 hours a year. They were free to choose their distributor, or to import electricity for their own use through the medium of SEP. But large consumers could also engage in de-centralised generation.

11.4.2 Industry organisation based on the 1998 Electricity Law

The 1998 Electricity Law keeps the responsibility for the electricity industry under the Ministry of Economic Affairs. The law opened up competition at generation level based on an authorisation procedure and established a schedule for the introduction of competition for consumers' supply. Privatisation was not required, but the Dutch government decided to proceed with change to private ownership, as other EU countries did too. Regulated third-party access is guaranteed for the high-voltage transmission and for distribution networks. The law requires full organisational, legal and financial separation between the segments exposed to competition and grid activities. Hence, it is possible for generation companies to own transmission and/or distribution grids, but network activities must be organised as separate companies. This way, distribution companies may continue to be present in the generation market too. No minimum or maximum limits on installed capacity have been further required, as in the 1989 law. All generators have the right to be connected to grids and to conclude direct contracts with distributors, retailers or free customers.

The wholesale market was conceived to consist of a bilateral contract market and a spot market where all generators have the right to participate. Although the entrance of new private actors is possible, the transmission and distribution segments have been regulated as natural monopolies. As regards the distribution and supply, the activities have to be unbundled administratively. This is necessary because the supply business is to be gradually fully liberalised. Distribution activities are developed based on license. This is issued by the ministry for a certain geographical area where distributors are obliged to sell electricity to captive customers below a certain price ceiling. The supply of free customers can be done without a license and there is no price ceiling by the ministry.

In the first stage, until 2002, only 33% of the market opened, which means that only customers with consumption rates higher than 20 GWh per year will have the right to choose their generator, distributor or retailer. The rest of the customers had to purchase from distributors that have monopoly in that specific region. The government proposed some accelerated liberalisation schemes aiming at full competition for consumer's supply January 2004. For voluntary consumers of green electricity the market opened however fully already in May 2001. Dutch green consumers of all sizes became the first in the EU to enjoy freedom to choose their supplier.

The next section describes the characteristics of the economic governance structures for the support of renewable electricity production in the 1989 and 1998 electricity laws.

11.5 Economic governance structures for renewable electricity support

In the Netherlands, the support system for renewables during the 1990s had both an economic and a policy component. The first economic governance structure was rooted in the 1989 Electricity Act. The policy component was much more complex and consisted of a series of schemes that replaced one another, and for some time even overlapped each other. Most of them were administered by the government. But there were also schemes initiated by distribution companies, while others drew on the voluntary demand of consumers for green electricity. The final price per kWh that renewable generators could receive was made up of several price components. But these components changed throughout the time, maintaining investment risks high while bringing no or little improvements in terms of feasible ranges of profitability of projects.

11.5.1 Economic risks under the first economic governance structure

The 1989 Electricity Law guaranteed for the first time the purchase of renewable electricity by grid companies. But renewables' support was very weak, as it harboured substantial risks on price and contracts. The legally backed price was extremely low and without financial support from various policy support schemes, renewable projects could not have been developed. The law put distribution companies in charge with the further elaboration of the economic governance structure for renewable electricity, under agreement with independent power producers.

11.5.1.1 Target group, eligible plant sizes, and qualifying resources

The definition of renewable resources was given only indirectly, in Art. 42(4) as "wind energy, water power, solar energy, biomass or terrestrial heat". The 1989 Law regulated that any natural or legal person, could own de-centralised plants for electricity production based on renewable or co-generation technologies, without limits on plant sizes. Distribution companies could also be decentralised generators of renewable electricity, but they needed special approval from the SEP if they wished to build plants larger than 25 MW at one establishment[9].

In practice investments in RET plants took place through the medium of both these types of developers. But in some cases they also formed joint ventures. In this chapter we will refer to the private developers investing on their own as independent private producers (IPP), and to the private companies behind which there were partnerships between natural/legal persons and distribution companies, as joint ventures (JV). Section 11.7 will analyse the two selected characteristics of support systems - the economic-policy risks and the ranges of projects' profitability - for IPPs, on the one hand, and for distribution companies and their joint ventures, on the other hand.

11.5.1.2 Type of demand for renewable electricity

Based on Article 42, decentralised renewable generators complying with the above conditions on technology choice and plant size were entitled to sell their output to the regional distribution company. Therefore, generators of renewable electricity enjoyed since 1989 legal guarantee on demand. Based solely on the interpretation of the law we consider that there were no demand risks - and this applies for all types of developers.

11.5.1.3 Contractual relations and price design

Legally guaranteed demand is not always and in all countries interpreted by potential developers and financing agents as sufficient for investing capital or approving loans. Guarantees on contracts and minimum price are also needed to assess the cash flows and economic viability of projects. But the law did not provide details related to the contracts for renewable electricity sale to distribution companies. Neither did it set a clear price design or price floors based on which trade can take place. It only traced several principles based on which contracts and prices can be drawn, and the actors that may be involved in the process. The rest of the aspects of the economic governance structure for renewable electricity were passed over for self-regulation by the industry, by means of an agreement called Standard Arrangements for Re-Delivery (SAR).

Based on Article 42, the Standard Arrangements had to rely on consultations between the organisation of distribution companies EnegieNed, the SEP, and the private de-centralised generators (legal or natural persons) or their representative associations. If an agreement could not be reached, Article 43 of the law regulated that EnergieNed and the representatives of private de-centralised generators had to designate a commission assigned to mediate negotiations. If a final agreement was still not possible, then the commission was entitled to set the aspects of Standard Arrangements where disagreement persisted itself. The decision of the commission was applicable to all de-centralised generators. As a self-regulation instrument, the Standard Arrangements document became directly enforceable, without the approval of the Minister.

The 1989 Electricity Law allowed different contracts to be elaborated for different technologies or types of generation plants. But there were no provisions on contracts' length. Regarding price design, it traced only the general principle of calculation that should be followed in the elaboration of the Standard Arrangement. This was entirely extrinsic, that is, it did not take into account the production costs incurred by decentralised

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[9] In all these situations it was not necessary that the Ministry of Economic Affairs gives license for plant commissioning and operation.

generators, but the costs that distribution companies avoided by not having to buy from the large central generators. The ‘economic avoided costs’ principle could only result this way in a very low payment, reflecting only the costs incurred for the generation of conventional (fossil fuel or nuclear) electricity plus the costs for grid-transmission and system management. The following legal paragraph, 42(4), attempted to seem generous for renewables by encouraging the search for a calculation methodology that could most stimulate the use of such resources. However, the pricing principle chosen did not allow for too much manoeuvring for a higher price support towards renewable electricity.

The Standard Arrangements concluded throughout the 1990s left the issue of contracts’ length as a matter of bilateral negotiation, and referred only to the detailed price calculation methods for decentralised generation. These methods were annually revised, but changed more importantly only two times: in 1993, and in 1997. There were two elements of constancy in Standard Arrangements price methodologies throughout time:

- they had three main price components: the capacity (KW) tariff, the production (kWh) price floor, and the premium (in %) for avoided losses through transmission grids[10].
- there were separate calculation methods for plants able to supply electricity with good predictability, and for plants that had intermittent and unpredictable supply; renewable resource plants were included in the second option; these were financially penalized by means of a coefficient which reduced the resulting payment per kWh to 70% of the payment available for plants with good output predictability.

The differences occurring consisted of:

- changing the reference for calculating the economic avoided costs, in 1993, which lowered the possible final payment[11];
- introducing, another penalty by means of the 90% coefficient applicable to the price for renewable electricity when owners could not provide long-term certainty on capacity availability; when owners were willing to conclude 5 year contracts for sale, the 90% coefficient was removed; this provision was valid only between 1993-1996.

Consequently, during a period of four years, the Standard Arrangements methodology offered the possibility to link the price components to longer-term bilateral contracts[12]. But, still, no Standard Arrangements document contained a provision regarding a minimum contract length for independent power producers. In 1995, EnergieNed concluded an agreement with the association of independent wind power producers (Pawex) based on which ten-year contracts were offered for wind systems with less than 2 MW installed capacity. The agreement envisaged also a common fixed price for such plants, which will be explained in more detail in Section 11.7.1.1. But it regarded only wind electricity and it

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[10] This had always values between 1,5% and 7,5%, increasing as the plant was located closer to a lower voltage line (EnergieNed 1991 and 1998).

[11] In 1993 the avoided costs of SEP were taken into account instead of those of distributors as actually required by the 1989 law; this way prices lowered because they did not reflect the avoidance of costs for electricity transport through the high voltage grids and the overhead costs of SEP. In 1994 the costs of electricity transport were reintroduced, increasing prices with 0,013 €c/kWh only. But the overhead costs of SEP continued to be excluded from the avoided costs formula.

[12] It was possible to prolong the five year contracts with one year, but it was not clear what was to happen afterwards.

remained outside the scope of the Standard Arrangements document[13]. The prices resulting from Standard Arrangements were considered ‘price floors’ for bilateral negotiations. On top of the applicable standard price, bilateral contracts contained also one or more types of production subsidies, as it will be explained in more detail in Section 11.7. The levels of Standard Arrangements payments in the period 1990-1998 were in the range of 3,2 - 4 €c/kWh, while production costs were between 8 - 11,4 €c/kWh.

11.5.1.4 Qualitative assessment of the investment risks embedded in the economic governance structure

The values taken by the selected characteristics of economic governance structure for renewable electricity based on the 1989 Electricity Law are summarised in Table 11.3. We consider *contract risks* for renewable electricity as ‘*high’ for independent private producers*, because two reasons. In the first place, there was no legal guarantee for a minimum contract length, or a clear provision that the purchase obligation regards the entire lifetime of eligible plants.

In the second place, the Standard Arrangements agreements did not provide for a frame of minimum contract lengths. The 1993-1996 Standard Arrangements linked the price design to the contract length but they retained their character of price-agreements. Contracts continued to be a matter of case-by-case negotiation. If Standard Arrangements had the roots in the 1989 Law, statements on minimum contract lengths may have posed lower risks in the perception of financing agents and potential investors regarding contracts[14]. We assess the contract risks for IPP in the upper part of the ‘high’ risk range, as the context is similar to that of the economic governance structure in the 82/1980 Energy Conservation Law in Spain.

For *distribution companies and joint ventures contract, risks* were however *between ‘nil’ and ‘low’.* When a distributor wanted to develop a plant in the region where it was also supplier, the risk was basically nil because he was both seller and buyer. When the distributor was a smaller-size company that was in its turn supplied by a larger distributor, the risk that the last would only agree on short-term contracts (and/or that these would not be renewed/prolonged) was also basically absent[15]. As it will be explained in Section 11.6.1, distribution companies were bound that together they would reduce CO_2 emissions by 3% by 2000 compared to 1990. This was a voluntary environmental agreement (MAP) concluded with the government and part of this was that they together would generate 1700 MWh/year by 2000 from renewable resources. It was therefore quite unlikely that contracts would - at least before 2000 - not be renewed by the colleague-distributor with supply

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[13] Distribution companies claimed that according to the 1989 law they had to give all decentralized generators, including those using co-generation, equal treatment for the purchase of their output. However the law allowed in Article 42 the conclusion of separate Standard Arrangements for specific types of plants and groups of technologies. But distributors preferred to regulate a standard price for all types of decentralized technologies, differentiating only between intermittent and predictable generation by means of a penalty for the first.

[14] Standard Arrangements could have included statements such as that developers covered by it would enjoy for a certain minimum period of time guaranteed contracts, under the amendment that prices are to be annually revised as required in the Law.

[15] The 1989 law specifically required distribution companies to purchase the decentralized generated electricity from other smaller distributors in the cases when the smaller distributors are supplied with electricity by the larger distribution companies (Art.41).

monopoly in the region. We assess contact risks for distributors in the middle part of the 'low' risk range.

Further, we consider *legal price risks for independent private producers as 'very high'* due to the following three main reasons. Firstly, based on the 1989 Law there was no involvement in negotiations or approval needed from the Ministry of Economic Affairs for the Standard Arrangements payment. The mediating commission that had to be involved in case of disagreements was formed by persons coming from the same two main negotiating parties - EnergiedNed and decentralised generators, voting on simple majority. Therefore, there was no room for hope that a public authority more mindful of the benefit of private generation based on clean resources would come into the scene and enforce a higher price floor for IPPs. Between 1990 and 1995 private wind generators tried to convince EnergieNed to conclude a separate Standard Arrangement for wind energy, internalising in the avoided costs formula the environmental benefits of wind energy. But these efforts have been to no avail and a separate contract-price agreement could only be concluded for very small wind systems. Secondly, there was no price floor guaranteed in the 1989 Law - or a formula guaranteeing minimum acceptable payments - which financing agents and developers could have included in their cash-flow estimations.

Thirdly, in the absence of the key word '*environmental'* in the legal text, in front of the prescribed pricing principle of 'average avoided costs' distributors were enabled to argue that they only have to pay the economic avoided costs. This represents an extrinsic payment approach. Very high risks are generally attached to this, because it means that price components do not reflect in any way the production costs incurred by generators using renewable resources[16]. The risks related to factors outside the workings of a renewables plant are most often perceived as higher than those flowing from the RET plant itself. The risk intrinsic to a RET plant could be more easily identified, and measures could be designed in time to minimise it. When it is known beforehand that intrinsic project risks are not manageable, the project would not go ahead. Besides, independent private producers, as new entrants in the generation segment, did not have the experience of energy utilities in estimating long-term fuel and market risks in national and international energy systems. Based on these three main arguments we incline to assess the price risks for IPP as in the upper part of the 'very high' risk range.

By comparison, the legal price risks in the 82/1982 Spanish Law on Energy Conservation had highly close characteristics. However, in that case tariffs were to be decided by the competent minister. In the Dutch case, we considered price risks higher, because the agreement between IPPs and distributors was a more risky decision mechanism. Dutch distributors did not have too much interest in giving more generous price support to private generators. Distributors had the right to install RET plants themselves and, as it will be shown in the following section, they also disposed of the financial strings for additional policy support schemes that aimed to reduce the environmental emissions of the electricity sector and to increase the RET capacity. The

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[16] One could argue that the extrinsic formula may well lead to the increase of avoided costs due to reasons such as: fossil fuel price hikes, increase in imported volumes of electricity (obliging the centralized supply sector to increase prices to consumers); or investments in generation and/or transmission capacity as a result of increased consumption. However, if and to what extent such events occur is beyond the planing or estimation ability of individual small decentralized generators. The best that they can estimate is the production from their own plants, whose technicalities and economics they can master better.

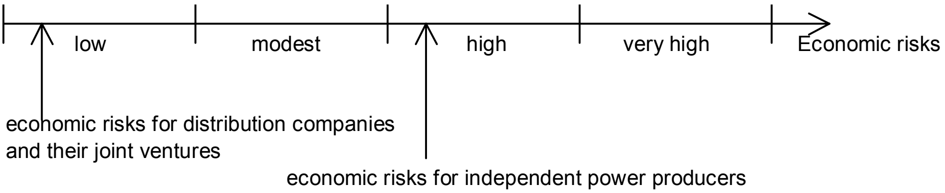
competition between private generators and distributors in their position of interested/potential investors in RET suggests a situation where it is reasonable to assign maximum risks as regard the legal price support for private generators.

On the contrary, *for distribution companies and their joint ventures price risks were also between 'nil' (for the first) and 'low'.* Distributors were coordinating the whole process for Standard Arrangements price design. But in addition to this, they also had control on other instruments of financial support. As it will be explained in Section 11.6.1 distributors had full decision authority on investment and production subsidies associated with the environmental voluntary action plan (MAP). The level of Standard Arrangements payment was always very low because this was the 'card' distributors could play to push away independent private developers that could not enjoy the same extent of non-Standard Arrangements financial support as them. The simultaneous control on Standard Arrangements and Environmental Action Plan payments ensured sufficient profitability for their RET projects, in the framework allowed by their legal position of public companies. In this context, we assess legal price risks faced by distribution companies as basically nil. However, as in the Netherlands the price per kWh consisted of several components, the discussion on price risks associated with the economic-policy support system can only be rounded up after an assessment of the price risks associated with the policy support schemes. Table 11.3 summarises our description of the economic governance structure for renewables in the period 1989-1998.

Table 11.3 *The 1989-1998 economic governance structure in the Netherlands*

1989 Electricity Law		
Eligible generators: any private or legal person and distribution companies (plants > 25 MW only with SEP approval)		
Elements	Characteristics	Forms
Type of demand		Unlimited legally guaranteed demand
Price design	Price components	Not mentioned in the law. In practice annual revision
	Price levels	
	Frequency of updating	
	Methodology	Avoided costs of distribution companies - average
	Decision mechanism	Agreement with distribution companies. No approval of Ministry of Economic Affairs required by the law
Contracts for sale	Contract length	Not mentioned in the law. (In practice between 1 year and life-time contracts)
	Price methodology	Avoided costs or distributors/transmission company. Penalty for intermittent generation. 1993-1996: penalty for short-term offers (< 5 year contracts)

Figure 11.1 *Theoretical assessment of economic risks in 1989-1998 economic governance structure*



In conclusion, we consider that there were no demand risks but since both the law and the follow-up Standard Arrangements were silent with regard to contract length, contract risks were high for independent private developers, and very low for distribution companies and their joint ventures. The risks on the legally guaranteed price were assessed as very high for independent private developers, which we assess to result in aggregated economic risks located somewhere in the lower part of the 'high' risk zone as represented in Figure 11.1. For distribution companies, price risks were considered very low, resulting in aggregated 'very low' risks associated with the economic governance structure.

The next sub-section discusses the characteristics of the economic governance structure based on the new electricity law adopted in September 1998.

11.5.2 The 1998 Electricity Law

The 1998 version of the new electricity law set three approaches for renewables support. After frequent subsequent revisions of the law, one option was modified. We will explain here both the 1998 version and the 2001 version of renewables support. Firstly, the 1998 law gave the possibility to the minister of economic affairs to place the responsibility for market diffusion of RET on generation companies and retailers who supply more than 10 GWh/yr. The financing mechanism for this option was designed as a general transmission levy. Every two years, generators and retailers would have to report to the ministry regarding the way they have complied with this legal task. But this provision did not place any specific tasks beyond this general responsibility[17].

Secondly, the law enabled the competent minister to set a quota obligation on consumers, based on tradable green certificates. If imposed, the quota would have to be set for a period of five years. In case consumers fail to comply with the obligation, the minister is entitled to set a levy on the transmission rates charged to the respective consumers and to re-direct the funds towards the renewable generators with unsold green certificates. By 2002, the minister decided not to make use of any of these two support approaches yet[18]. In May 2001, the market for green electricity was liberalised up to the level of households and the ministry put into operation a voluntary system of tradable green certificates. In the period 1998-2000, only the third support approach envisaged in the 1998 law was used.

The 1998 law provided for the continuation of the mandatory model with guaranteed purchase by distribution companies. But this time it restricted the guarantee on three criteria: time, plant-size, and type of developer. This way only some types of renewable energy projects owned by captive consumers have legal guarantee on demand. Larger-size consumers for whom the market of conventional electricity was already liberalised did not enjoy guaranteed demand and dispatch anymore. According to the 1998 formulation, the time frames and the plant-sizes, for which the guarantee was still applicable, were those mentioned in Table 11.4.

As Table 11.4 shows, private generators using wind and solar energy are confronted with more severe terms, as after 2001 the scale of plants enjoying guaranteed demand falls

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[17] These legal provisions were meant as basis for eventual future long-term agreements with energy companies over energy conservation and the use of renewable resources (ECN in EVN, 1998: 78).

[18] If a tougher line for RET diffusion is eventually chosen, it is more likely that the quota obligation would be chosen from the first two approaches. However, such a decision depends to large extent on policy changes in other countries and/or at the EU level through a Directive that harmonizes all support systems in the EU.

from 8 MW to only 600 kW. Initially the law set 2007 as the second deadline in order to link this data with the full liberalisation at consumption level. However, later the governmental liberalisation policy changed and the full market opening for consumers was scheduled for 1 January 2004. This way the eligible IPPs owning small wind and photovoltaic systems had to face an unexpected shortening in the legal guaranteed demand. This suggests the high risk that the legal framework can pose in the Netherlands.

Table 11.4 *Types of renewable electricity projects eligible for guaranteed purchase by distributors under the 1998 Electricity Law*

Types of RET with guaranteed demand	Project sizes	Time availability
small hydropower and biomass thermally processed	< 2 MW	until 31.12.2001
wind and solar energy	< 8 MW	until 31.12.2001
wind and solar energy	< 600 kW	until 31.12. 2006

11.5.2.1 The economic governance structure for small-size projects

The 1998 electricity law limited the guarantee on demand for small size generation systems owned by captive consumers. Their owners have no demand risks until 2001/2003. But all the other projects, as well as these small systems at a certain moment in time will have to face very high demand risk and rely on the voluntary trade of green certificates and trade of physical streams of electricity on the spot or bilateral contracts market. However, in this empirical study we focus on diffusion of wind technology up to the end of 2000. In the period 1998-2000, the demand risks stemming from the new law for wind projects can be described as:

- no demand risks - for captive consumers owning generation plants under 8 MW; and
- very high risks - for commercial projects with plant sizes above 8 MW.

In 1998, a new policy support mechanism entered into force, named the Green Label trade system. A general description of it will be made in Section 11.6.1. The Green Label trade was associated with a voluntary target for renewable electricity for distribution companies. This changes the picture of demand risk in ways that we will explain in Section 11.7.1.3. For this reason, we cannot draw a conclusion on demand risks in the period 1998-2000 at this point. As regards contract risks, the fact that the guarantee on demand corresponded to specific deadlines, can be viewed as merging the contract risks with demand risks.

The legally guaranteed price is the same to that for the average market price of conventional electricity. During 1998-2000, this was 3,6 €c/kWh, therefore basically the same as the average of Standard Arrangements prices in the period 1990-1997. Being entirely dependent on extrinsic production factors it can be described as a price with very high risks. Besides, its level was so low that it would not have made any type of RET feasible without an additional policy support mechanism. For the period 1998-2000, we analyse the economic and policy risks together in Section 11.7.1.3.

The next section, 11.6, presents the policy support mechanisms that addressed only - or among others - wind energy during the 1990s. We focus only on these because we will test the study's hypotheses only for the case of wind technology diffusion. In this section each policy scheme with consequences for the market diffusion of wind plants will be shortly *described* in terms of type and extent of financial support, as well as the types of developers that could benefit from it. The following section, 11.7, analyses what happened in practice with regard to the implementation of and interaction among the various elements constituting the Dutch economic-policy support system. This will lead to the assessment of aggregated economic-policy risks and ranges of project profitability for the two groups of developers, and to the specification of the hypothesis to be tested.

11.6 The policy support mechanisms for wind energy during 1990s

The Netherlands developed an extensive and mixed policy program to support the development of renewable electricity, which covered both the production and the consumption sides of the market. Wind energy was targeted by most policy schemes, as it was more technologically advanced and promising in terms of resource potential than others such as small hydropower and clean biomass. Table 11.5 lists the major policy support schemes that affected the market introduction and diffusion of wind energy projects beginning with 1990. They can be differentiated in three groups: a) schemes managed by distribution companies; b) schemes administered by the government; and c) schemes backed up by voluntary green consumers.

11.6.1 Policy support mechanisms managed by distribution companies

In 1989, the Ministry of Environment (VROM) issued the National Environmental Policy Plan, initiating a plan containing CO_2 emissions reduction targets for different industries and economic sectors. This plan was transposed in a Memorandum by the Ministry of Economic Affairs for the implementation of CO_2 emissions reduction targets in the energy sector. Based on this Memorandum, a convenant was signed in 1990 between the government and the energy industry. The commitments under the convenant formed the basis of the Environmental Action Plan (MAP) voluntarily adopted in 1991 by the distribution companies for the reduction of CO_2 emissions. The targets, technical measures and financial aspects of implementation were revised in 1994 and in 1997[19]. The voluntary agreement terminated in 2000.

The Environmental Action Plan envisaged a wide array of measures pertaining to energy saving and conservation, but it also aimed at the market introduction of renewable technologies. Distribution companies considered the development of renewables an important tool in achieving the CO_2 reduction goal, and chose for an active involvement in the harnessing of the national renewable resources. In 1991, eight distribution companies operating in regions with the richest wind resources made an agreement, referred to as the Windplan. This aimed that by 1994 the eight companies would install 250 MW. The Windplan broke apart however for reasons that we will discuss later. But the fact that it was agreed is an indicator of the strong interest that distribution companies had in becoming main developers of wind energy projects. The costs related to the achievement of CO_2 reduction target were covered by means of an increase in tariffs for captive consumers (Maximum End-users Tariffs) through an environmental levy[20].

[19] These were entitled: "MAP II" (in 1994) and "MAP 2000" (in 1997).

[20] For the implementation of all commitments under Environmental Action Plan, distribution companies concluded an agreement with the government allowing them to charge a levy on consumers' tariffs - the Environmental Action Plan levy. This varied in time between 0,5% and 2,5% (Huygen, 1995) and were annually revised and approved by the Minister of Economic Affairs. In 2000 the MAP levy amounted to between 8 - 18 €c/kWh (Project Agency Renewable Energy www.pde.nl/over-energy/de/l419.html).

Table 11.5 *Policy support mechanisms for price support applicable for wind energy*

Policy support mechanisms	Form of price support	Target group
Policy support mechanisms managed by distribution companies		
Voluntary Environmental Action Plan of distribution companies (1991-2000)	production subsidies (1991 - 1997); 1 - 5,4 €c/kWh	all developers (but in practice distributors benefiting more, especially of investment and production subsidies)
	Green Labels (1998-2000): average 2,3 €c/kWh	
	investment subsidies: no standard; up to 25 % - 35 %	
Policy support mechanisms managed by the government, 1990-2000		
Support scheme by VROM period 1991-1993	small investment subsidies (for selected locations & for low noise turbines (21 €/kW)	all developers
Integral Program Wind Energy (1986-1990)	investment subsidies dependent on capacity [MW] per turbine	all developers
TWIN I: Decree Subsidy Wind Energy (1991-1994)	investment subsidy: dependent on rotor area and MW / turbine max 35 % per project	all developers
TWIN I: Decree Subsidy Wind Energy (1995)	investment subsidy: dependent on rotor area (290 x Area) max 35 % per project	all developers
TWIN II: Decree Subsidy Wind Energy (1996-2000)	investment subsidies for demonstration: 25 % - 40 %	all developers
EINP scheme (since March 1998)	investment subsidy of 14,4 % –20 %	non-profit companies; distributors; individuals (1 turbine owners only)
CO_2 Reduction Plan (since January 1997)	investment subsidies up to 45 % of project costs	all developers (CO_2 saving criteria)
Production subsidies (fund Ecotax; January 1996)	Production subsidies 1,33 - 1,93 €c/kWh	all developers
Ecotax exemption (since January 1998)	consumers buying renewable electricity exempted	all developers (domestic and abroad)
VAMIL (since 1996/7)	fiscal advantage	private profit companies
EIA (since January 1997)	fiscal advantage	private profit companies
Green Funds (since January 1996)	1,5 % lower interest rates for loans; less expensive equity	all developers
Support mechanisms backed by voluntary green consumers		
Voluntary green funds (1993-1995)	voluntary green-minded investments in Wind Funds of ethical banks; no tax exemption	all developers
Various green electricity products & trading schemes	production subsidies: 1,8 - 4,5 €c/kWh	all developers
	investment subsidies	distribution companies

In addition, subsidies and fiscal schemes were made available by the government. The funds collected through the Environmental Action Plan levy were distributed among all types of projects by means of which distributors considered appropriate to reduce CO_2 emissions. Some parts of these funds were annually reserved for investment and production subsidies for renewable generation plants.

All types of developers could apply for the Environmental Action Plan subsidies, but in practice their allocation was un-balanced, favouring investments by distribution

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For more information on the Environmental Action Plan see Ligteringen (1999: 261-306).

companies and their joint ventures. The IPPs could rarely benefit of investment subsidies, while they were always paid lower production subsidies. For a long time, they could get production subsidies only for wind energy projects[21], varying between 1,36-3,63 €c/kWh (Bemmelem 1999). This was meant as a second price component in addition to the Standard Arrangements payment (see Table in Section 11.7.1.1).

There are no clear data on the production subsidies that distribution companies were retaining for themselves, since they did not have to report on such a detailed way on the spending of Environmental Action Plan funds. In addition, they had full liberty on deciding on the level of investment subsidies they retained for their renewable projects. On average this seems to have been up to 25% (Mitchell 1994). But some projects received subsidies as high as 35% (Langniss et al. 1998). The majority of wind projects developed by utilities up to 1997 and their joint ventures were combining Environmental Action Plan investment and production subsidies. In 1997 a common target of 1700 GWh/year renewable electricity by 2000, or 3% of total electricity consumption, was set for all distributors. Moreover, for each distributor company a specific target was calculated on the basis of its 1995 sales. To achieve the distance to the 2000 target more cost-efficiently, new Environmental Action Plan production subsidies stopped to be issued beginning with 1998[22] and were replaced by a new support scheme: *the Green Label trading system.*

Any generator who qualified for receiving a governmental Ecotax production subsidy (introduced in 1996 - see next sub-section) was entitled to receive a Green Label and to participate in the voluntary trade system[23]. But one could not receive simultaneously Environmental Action Plan subsidies and Green Label prices. Distribution companies could purchase Green Labels from private generators or from other distribution companies who succeeded to accumulate tradable Green Labels representing a renewable electricity volume higher than their target levels.

In 2000, the Environmental Action Plan voluntary program was terminated. But those concluding contracts for Environmental Action Plan production subsidies or Green Label payments would continue receiving these payments after 2000, until their contracts expire. With the agreement of both parties, contracts can also be dissolved, so that the generator can enter in new voluntary trade system of green certificates set up since 2001.

11.6.2 Policy support mechanisms managed by the government

We discuss here only the support schemes implemented since 1990 when the electricity law entered into operation. In the period 1990-1995 the main governmental support approach was in the form of investment subsidies from the Ministry of Economic Affairs. In 1990, subsidies were given under the “Integral Program for Wind Energy” (IWP), which started

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[21] Most Environmental Action Plan subsidies for clean energy production went to co-generation and energy saving in industries and households. From renewables, wind technologies enjoyed largest support. The financial contributions to biomass/biogas and PV systems was very modest (EnergieNed 1993; EnergieNed MAP II 1994).

[22] However, those who already concluded contracts, where a Environmental Action Plan subsidy was one of the contractual price components, were allowed to keep them if they preferred so. In this case, the Green Labels issued were passed to the distribution company that was financing the production subsidy from the Environmental Action Plan and was part to the contract. Green Labels were needed by distributors to prove compliance with their individual targets (Bemmelem 1999).

[23] The size of a Green Label was set at 10.000 kWh. The types of renewables exempted from Ecotax were: wind energy, solar PV, small-scale hydropower (<15 MW)[23], biogas, and woody-biomass.

already in 1986. They were in the range of up to 35-40% of total project costs. All types of project developers were eligible. Subsidies were allocated based on the first-come-first-served principle, with applicants having to literally queue at the ministry's door before the first subscription day (Etsu 1996: 88). The technical criteria for subsidy allocation was given by the formula "constant x P", where P was the installed capacity per turbine in [MW]. As a consequence, in the period 1986-1990 the generators of turbines used were substantially oversized and were not able to generate electricity efficiently. There were no requirements in terms of returns on investments, availability of finance or possession of local permits.

In the period 1991-1995, investment subsidies were part of the market introduction component of the multi-annual program "Application of Wind Energy in the Netherlands" (Twin-I), which replaced the IWP. The largest share of the annual budget was planned for projects of distribution companies to support them in the Environmental Action Plan target for CO_2 reduction. Investment subsidies were given under the scheme "Decree for Subsidies on Wind Energy" and could cover up to 35% of project costs. All types of developers remained eligible and the first-come-first-served principle was maintained. Between 1991-1994, the technical criteria changed in order to take into account the rotor area, in addition to the installed capacity. The formula used during these years was: "*constant x (1,5 A + P)*", where A is the rotor area in m^2 and P is the installed capacity per turbine in MW (Ecofys 1997). As discussed in Chapter 4, the electricity production per unit of swept rotor area kWh/m^2 is a generally accepted indicator of production efficiency for a turbine. In 1995 the formula changed again. This time the technical allocation criteria took into account only the rotor area (A), multiplied by a constant: "*290 x A*". In addition, in the period 1993-1995, priority was given to projects in advanced stage of development. In 1993-1994 applicants were required also to prove that they received planning permit. In 1995, they were asked to provide evidence of all local permits and grid connection agreements (WPM 1995 April: 16).

All projects developed up to (and including) 1995 were built with investment subsidies from one of these schemes. In addition, several projects also benefited of a small investment subsidy that the Ministry of Environment was giving to projects located in areas that minimise environmental impacts and caused lowest noise disturbance. This amounted to 21 €/kW installed (Wolsink 1996; Etsu 1996: 87).

In November 1994, the new government winning elections decided to make important cuts in the energy budgets. Together with a sense of moving towards liberalisation in electricity industries, the decision was taken to change the support approach from investment subsidies towards more market-compatible instruments such as fiscal instruments and schemes to encourage voluntary demand of renewable electricity. Investment subsidies did not disappear completely, but were only maintained for specific target groups and types of projects that could not gather sufficient benefit or incentives to invest from the new fiscal schemes.

The Tenders for Industrial Energy Saving Program (TIEB) was introduced in 1996. One of its aims was to encourage the use of renewable energy in production activities of private industrial production companies. The Program subsidised up to 30% of investment costs for demonstration projects and 20% of project costs for market introduction projects.

In 1998, yet another subsidy scheme was introduced, the "The Energy Investments Regulation for the Non-profit Sector and Special Sectors" (EINP). This program offers also an investment subsidy, which for wind energy can range between 14,4% and 20% of project costs. The scheme was designed in order to compensate for the fact that one of the fiscal advantage instruments used (VAMIL, see below), could not be used by the so-called 'non-profit' generators. Among them were distribution companies which, on the one hand, did not have to pay taxes and, on the other hand, were considered as non-profit companies although in practice they were allowed to raise some maximum returns on their investments. But other interested investors were also eligible for the EINP subsidies, such as water companies, the Schipol airport companies, and physical persons owning solitary wind turbines. The IPPs that invested in single turbines were normally eligible for the fiscal advantage scheme VAMIL. But Dutch tax authorities refused during the first two years of its operation, 1996-1997, to acknowledge their eligibility. The new investment subsidy EINP was then extended to this group of developers to compensate for their un-rightful losses in the two years. The EINP budget for wind was expected to support annual investments of around 30 MW wind capacity (WPM April 1998: 23)[24].

The CO_2 reduction plan, introduced in 1997, is another investment subsidy scheme applicable among others to renewable electricity projects. Subsidies are set as a function of cost effectiveness for annual CO_2 emission reduction. Projects using renewables qualify when cost-effectiveness is up to 22,7 € per ton of CO_2 avoided and contribute to the reduction of at least 250 tons CO_2 per year. Investment subsidies can be up to 45% of the project costs and are allocated based on a tender system organised by the minister[25]. In the period 1996-1999, 12 wind projects benefited of subsidies under this program. Besides, a proposed 100 MW demonstration wind-park, located near-shore on the North Sea Coast was also considered eligible for subsidy. An amount of 132,6 Million Euro was put aside for this project (EZ 1999: 40). Therefore, after 1996, certain investment subsidy schemes were maintained for wind technology, especially for demonstration projects and special target groups. But since 1996, the main financial support schemes were *fiscal instruments*. In October 1996, the Regulatory Energy Tax (or Ecotax) was introduced to stimulate energy saving attitudes by consumers. The scheme placed high and annually increasing taxes for electricity, natural gas and heat oil consumption, chargeable by distribution companies[26]. Their levels are shown in Table 11.6. Initially the tax had to be paid irrespective of the types of energy resources used. A certain amount had to be paid pack however by distribution companies, in the form of production subsidy to generators of renewable electricity. The levels of production subsidies[27] for the period 1996-2001 are shown in Table 11.7.

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[24] During 1998, only few requests were made for subsidies under this program. The Ministry of Economic Affairs (EZ 1999) mentions two main reasons for this: the fact that the scheme was not yet approved by the European Commission and the fact that negative attitude of regional governments in wind-rich provinces with regard to solitary turbines approval, which became more strongly manifest in 1998. The approval of the European Commission for the EINP investment subsidies came only in the end of 1998 (EZ 1999).

[25] The scheme was introduced in late 1996 when it became clear that the CO_2 target of 3% emission reduction by 2000 compared to 1990 will not be reached due to "underestimated economic growth" (Ecofys 1999).

[26] The Ecotax is part of a larger governmental program for the greening of the tax system. As compensation for Ecotax, the income taxes and corporate taxes decreased. Netherlands promotes the idea of an EU-wide CO_2 and energy tax on all consumers, including large industrial companies. However, this proposal was not successful so far (ECN in EVN 1996).

[27] The renewable resources for which an Ecotax production subsidy was issued are: wind, solar energy, small-scale hydropower (< 15 MW), woody-biomass and biogas.

Table 11.6 *The levels of Ecotax on electricity*

Electricity [€c/kWh]	1996	1997	1998	1999	2000	2001
0-800 kWh	0	0	0	0	0	5,47
800-10000 kWh	1,33	1,33	1,33	1,93	3,71	5,47
10000-50000 kWh	1,33	1,33	1,33	1,46	1,60	1,74
50000-10 million kWh	0	0	0	0,10	0,21	0,33
> 10 million kWh	0	0	0	0	0	0

Source: PDE 2000

Table 11.7 *Production subsidies from Ecotax funds*

Year	Production subsidy from Ecotax [€c/kWh]
1996-1998	1,33
1999	1,46
2000	1,60
2001	1,93

Source: PDE 2000

Both private generators and distribution companies owning renewable generation installations were eligible for these subsidies. But, in addition, distribution companies who imported green electricity - generated based on the above mentioned resources - and had contracts to prove this, were also entitled to receive a subsidy from the Ecotax funds (Niermeijer 2001). On January 1998, the government introduced the 'nil tariff' policy exempting domestic renewable generators from paying Exotax[28]. Consequently, the Ecotax instrument has become a very powerful scheme for the stimulation of green demand.

In addition to the Ecotax, an earlier established Accelerated Depreciation Scheme on Environmental Investments[29] (VAMIL) was extended for companies investing in wind energy in 1996. This had the effect of lowering project costs and increasing company's profits. The payment of taxes is postponed, so as during the first years of project operation companies benefit of increased liquidity. This results in improved financing conditions such as lower interest rate or lower debt maturity, and enables earlier booking of return-on-equity (ECN in EVN 1996). The years when taxes are deducted are at the choice of the generator. Per lifetime of investment, taxes remain basically at the same level (Etsu 1996: 91). However, the scheme works only for companies that are obliged to pay income taxes or corporate taxes, and it is especially advantageous for small business and farmers (Etsu 1996: 90). Due to the fact that distribution companies were organised as ('non-profit') public companies and didn't pay taxes, they could not benefit of the scheme.

In parallel to the VAMIL scheme, private developers could also resort to the Green Investment Reduction scheme (EIA) since 1998. This is a tax reduction measure applied to investment costs and meant also to increase the after-tax profits of the company. Until 2000, between 40% and 52% of the green energy investment costs of a private company could be exempted from the income or corporate tax, increasing the final profits. Since 2001, the tax reduction allowed was raised to 55%. As already mentioned, the problem was that the scheme could not benefit non-profit companies, and in practice also not owners of

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[28] Since 2002 the exemption was also applied for imported green electricity. However, the government removed then hydropower of all sizes from the Ecotax exemption list.

[29] The list of types of projects that qualify for VAMIL scheme is drawn up by Ministry of Environment. Since 1996 it includes wind turbines, solar PV, biomass from wood and energy crops.

solitary turbines. Consequently, the EINP investment subsidy was introduced as an alternative, respectively compensation.

Governmental intervention also took place in the financing arena by setting the *Green Funding* scheme. This has been in operation since January 1996[30] and is administrated by banks under the coordination of the Central Bank of the Netherlands. Private persons can direct their personal savings towards green funds. If at least 70% of fund money is directed in investments recognised by the government as 'green', investors are rewarded by exemption from taxes on returns. Investments are used either in the form of soft-loans for green projects or lower-cost equity investments (WPM February 1995: 8). The tax exemption results into lower interest rates (1,5% less) on loans for projects certified as 'green investments'. Wind energy was quite popular among the green funds. In public polls among green investors, it was on the second place of preference after organic agriculture. It is estimated that this scheme enables wind generators a reduction in production costs of around 0,5-0,9 €c/kWh (WPM September 1995: 22).

11.6.3 Support mechanisms backed up by voluntary green consumers[31]

In 1995, the distribution company PNEM[32] was the first to introduce a voluntary green electricity scheme, whereby green consumers could choose to pay higher prices for electricity generated with renewable resources[33]. By mid 2000, a number of 18 suppliers developed such schemes under different marketing names, both for households and for larger-scale consumers. Two approaches can be differentiated for the voluntary purchase of green electricity. In the first approach distributors offer consumers the opportunity to buy green electricity in the form of percentages of annual consumption. In the second approach, they offer the possibility to buy a number of packages of certain amounts of green electricity, such as units of 500 or 1000 kWh.

Initially participation in these schemes was low. But with the allowance of Ecotax exemption for voluntary consumers of renewable electricity, from 1 January 1998, the demand for subscription increased significantly. Green demand increased the more the Ecotax level raised. At the end of 2000, green-pricing schemes counted 200.000 households and 885 professional customers. The extra-prices that consumers could voluntarily pay up to 2000 were between 1,8 and 4,5 €c/kWh[34].

The funds collected through these schemes were mainly used by distribution companies, as investment or production subsidies. Most distributors collected the green premiums with the intention to build new wind plants or for the re-powering of their wind projects that ended economic life (Akerboom 1999). To a smaller extent, private generators

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[30] However Green Funds started to be set up early 1995, after the new scheme had been announced.

[31] Empirical data in this sub-section is mostly based on information available between 1999 and 2001 at http://www.greenprices.com.

[32] Later PNEM merged with EDON and MEGA, and formed the distribution company Essent.

[33] Voluntary green consumers did not have to pay the Environmental Action Plan levy on top their (governmentally approved) tariffs (Source: http://www.pde.nl). The Economic Affairs Minister modified the Decrees for annual approval of Maximum End-User Tariffs so as to allow for the voluntary payments for green electricity above these ceilings (ECN in EVN 1996).

[34] Sources: Ecofys (1999: 13) and information at www.greenprices.com in June 2002. Two distributors selling only to large-end-users preferred to negotiate the premiums through confidential bilateral contracts.

could also benefit of production subsidies for their running wind projects in financial difficulties (see Section 11.7.1).

The allocation of the green premium funds was designed to follow the additionality principle, saying that generators are not eligible for production subsidies from these funds if they receive in the same time financial support from the Environmental Action Plan fund (either subsidies or Green Label payments). That is because the renewable capacity supported by green consumers had to be additional to that already supported by distributors from the Environmental Action Plan levy fund. The capacity subsidised by Green Premiums was however eligible for counting in companies' Environmental Action Plan targets for renewables.

Beside green pricing, another voluntary scheme emerged in 1993. This was initiated by ethical banks appealing to green minded investors to invest in wind projects. In this period Wind-Funds aimed to finance wind plants by means of low-cost equity. The first two Wind-Funds were set up by the ethical bank Triodos[35] in 1993. One aimed to collect savings from private persons and the other one from companies. The bank estimated that investors would benefit of returns on equity of 7% over a 15-year period. The Wind-Fund seemed to be quite popular, with around 3,63 million Euro subscription within one year, mostly from households (WPM April 1994: 22). In 1994 several commercial banks developed similar funds, but they aimed to provide soft loans rather than equity as the funds of Triodos Bank. In 1995 the government introduced the Green Funding scheme that allowed investors in green projects exemption of income taxes. All early voluntary wind funds were then accredited under the governmental scheme that entered into operation on January 1996.

Section 11.7 makes a discussion leading to the specification of the hypothesis to be tested. This is done in two steps. Firstly, an analysis will be made of what happened *in practice*, in terms of bilateral contractual relations, the design of prices paid for wind electricity production and the implementation of policy support schemes between 1990-2000. Due to changes in the policy instruments, three periods will be distinguished during this decade: 1990-1995, 1996-1997, and 1998-2000. This analysis includes qualitative assessments of the risks surrounding the policy support mechanisms - in terms of likely time availability, and stability of level of price support. Secondly, the lines of analysis will be brought together in order to assess the aggregated economic-policy risks and the ranges of projects' profitability for each of the two main groups of developers emerging in practice: independent private producers, on the one hand, and distribution companies and their joint ventures on the other hand. Based on this, the hypothesis to be tested in Chapter 12 will be formulated.

11.6.4 Methodology of data analysis

In Section 11.7, we analysed policy risks looking at the details regarding their design, implementation and the context in which they were used. The risks from the interaction of policy support mechanisms, as well as the interaction of the policy and economic components of the support system were assessed by taking into account the extent of financial support represented by each support scheme. As regards profitability range, we

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[35] The initiative for these funds came from contacts of the bank with green minded companies, such as the Body Shop, and the environmental organization Milieudefensie (WPM January 1994: 16).

operationalised projects' profitability as: low - up to 4%; modest 4-8%; high 8-12%; very high > 12%. For empirically assessing it in the Dutch case study we used an approach that combined the third method mentioned in Chapter 5 - namely a rough comparison of production costs and extent of price/financial support - with information regarding the ranges on equity returns and interests rates from the available empirical literature. This literature consists mainly of previous research studies into the issue of financing of renewable/wind energy projects and articles of the journal Wind Power Monthly (WPM).

In the Wind Power Monthly journal we found a series of valuable information with regard to the extent of financial support offered to the different types of project developers, the opinion of the representatives of independent power producers with regard to the support schemes, and information regarding the ranges of equity returns of investors and the interest rates for wind energy projects. In addition we used information from several studies where similar inquires were conducted into financing schemes and the particularities of financing parameters[36]. Aggregating information from empirical literature and our own analysis of the ranges of production costs as compared to the extent of financial support, we made inferences regarding the ranges of project profitability. Several interviews have been conducted to test the inferences on profitability.

11.7 Specification of the hypothesis to be tested

11.7.1 The implementation of the economic-policy support systems - what happened in practice

11.7.1.1 The period 1990-1995

Since the entry into force of the 1989 Electricity Act, private developers of wind projects tried to convince distributors to negotiate separate Standard Arrangements for wind energy to include the environmental benefits of wind energy into the avoided costs methodology. Distributors constantly rejected this proposal arguing that based in the 1989 law they should pay all decentralised generators the same price and there was no legal basis to pay more than the economic avoided costs. The dispute escalated and the Arbitration Commission was called to mediate the conflict, in 1992, based on Article 43. After one year, the arbitrators ruled that there was indeed "no legal basis for payments for clean energy which are higher than the standard tariffs" for conventional electricity[37] (WPM July 1994: 16).

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[36] Here, we drew mainly on the empirical data in the work of Mitchell (including her doctoral dissertation, 1994) who studied the financing of wind energy projects in the Netherlands in the first part of the 1990s. Besides, we also drew on the (more limited) empirical data in the research study of Langniss et al. (1998), van Zuylen et al. (1993), and country overviews on wind energy of the International Energy Agency (IEA).

[37] The avoided costs formula was proposed as an amendment to the electricity law proposal in 1989 by the liberal party (D66). The intention was to reward renewable resources for their environmental benefits. However, lack of experience on specialized terminology on renewables and electricity economics resulted in the omission of word 'environmental' or 'social' in the article regarding payment principle. Distributors and the lawyers consulted in the mediation process argued that "based on a strict interpretation of the law (...) avoided costs are related to the generation of electricity in general" (WPM July 1994: 16).

In March 1994, the parliament asked the ministry to intervene in negotiations. After one year, on August 1995 an agreement was finally reached between EnergieNed and Pawex - the association of private wind turbine operators negotiating on behalf of IPPs. This entered into operation in January 1996 and envisaged a payment of 7,4 €c/kWh wind projects below 2 MW, under 10 year contracts[38]. Only a few distributors implemented the agreement during 1996 and 1997. Those who didn't, continued their policy of discretionary contracts and prices. Between 1990-1995, the sale of wind electricity between IPPs and distribution companies took place based on bilateral contracts between 1 and 15 years[39].

Contractual prices were made up of two components. The first was the Standard Arrangements payment, which varied between 3,2 - 4 €c/kWh[40]. The second was an Environmental Action Plan production subsidy, which was discretionarily decided upon and liable for annual revision by distribution companies. Moreover, it varied from one distributor to another, while some did not even agree to pay it at all. Different sources quote various levels for this price component, which is not surprising since distributors insisted it was confidential[41]. On average, the Environmental Action Plan production subsidies for IPPs seem to have been in the range of 1-3 €c/kWh. Several distributors were paying higher levels - up to 5,4 €c/kWh - in isolated cases such as very small turbines or cooperatively owned projects[42]. But towards the end of this period, end 1994 - early 1995, many distributors, among which also Edon and Nuon lowered the Environmental Action Plan production subsidy to only 1-1,8 € c/kWh (WPM March 1995: 24).

It can be concluded therefore that in the period 1990-1995 contractual prices of IPPs generating wind electricity varied mainly in the range of 4,2 - 7 €c/kWh[43], with isolated cases where they could reach 8,6 - 9,4 €c/kWh. Besides, IPPs benefited of governmental investment subsidies, of maximum 35% of project costs, and rarely of small investment subsidies from the Environmental Action Plan. Pawex lobbied throughout that investment subsidies would be better replaced by guaranteed contractual prices around 9,2 €c/kWh.

As regards production costs, EnergieNed admitted that in regions with very rich wind resources, production costs are no lower than 7 €c/kWh[44] (WPM July 1994: 7). The

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[38] Pawex insisted for at least 7,7 €c/kWh, without project-size constraints, for 15 year contracts, but these terms were not acceptable for EnergieNed (WPM October 1996: 30).

[39] Interviewed project owners and representatives of cooperatives and associations of owners (Kap en Wiegersma-Colmer, Scheuerman, van Vliet, Kersten 2002) mentioned contracts of length between 5 and 15 years. In some cases these were considered to be authomatically renewed when no message was received from the buying distribution company.

[40] Since 1993, the Standard Arrangements payment also varied depending on contract lengths, i.e. shorter or longer than 5 years, but the margin was small anyway.

[41] EnergiNed (Bemmelem 1998) mentioned a range of 1,36 - 3,63 €c/kWh for all types of renewables. Members of Pawex referred in 1994 to a rate of 2 €c/kWh for wind electricity (WPM June 1994: 16). In 1993, Pawex representatives inventorised the contractual prices offered by different distributors. Considering an average Standard Arrangement payment of 3,63 €c/kWh, the data they provide imply ranges of Environmental Action Plan subsidies between 0,9-5,45 €c/kWh (van Zuylen & van Dijk 1993).

[42] In 1993, the distribution company RED paid 5,45 €c/kWh for turbines below 350 kW owned by cooperatives. The distribution company Deltan paid 5 €c/kWh for a cooperative project for a maximum output equal to the electricity consumption of cooperative members (van Zuylen & van Dijk, 1993; WPM October 1994: 46). Interview co-operative Noordenwind (October 2002).

[43] The International Energy Agency mentions average contractual prices with IPPs at industry level of 5,5 €c/ kWh (IEA 1995: 107). This falls within the range we estimated in Table 11.8

[44] The International Energy Agency also mentions production costs of minimum 7 €c/kWh in 1994 for high resource sites, with wind speeds of 7m/s or higher (IEA 1995: 107).

investigation of the economic affairs ministry on production costs for wind electricity indicated an average level of 11,4 €c/kWh in 1990. It was estimated that this lowered to around 8,2 €c/kWh by 1995. The assessments of the ministry do not include assumptions on financial support such as investment subsidies. Table 11.8 summarises the situation regarding sources and levels of financial support for IPPs and for distributors and their joint ventures between 1990-1995.

Table 11.8 *Sources and levels of financial support for IPPs, 1990-1995*

Sources of financial support for independent power producers	Level of financial support for independent power producers	Level of financial support for distributors and joint ventures
Governmental investment subsidies (IWP & TWIN-I)	up to 35 %	
Environmental Action Plan investment subsidies	small and occasionally	around 25 %
Standard Arrangement payment	3,2 - 4 €c/kWh	
Environmental Action Plan production subsidies	1 – 3 €c/kWh (isolated cases up to 5,4)	1 - 5,4 €c/kWh
Contractual prices	4,2 - 7 €c/kWh (isolated cases up to 9,4 €c/kWh)	4,2 - 9,4 €c/kWh
Production costs average	11,4 €c/kWh in 1990; 8,2 €c/kWh in 1995	

Profitability of projects

It is difficult to estimate the likely profits in terms of €c/kWh because there are no empirical data regarding the reductions on production costs resulting from investment subsidies. Besides there were differences in the extent of investment support IPPs were receiving both from the government and from the Environmental Action Plan funds, when available. But data in Table 11.8 suggest that IPPs were facing financial difficulties for wind projects during 1990-1995. Some projects could make some profits in wind rich regions while others were at the border of cost-recovery limit.

In empirical literature, previous research and articles in specialised journals[45] indicate that up to 1995, IPPs invested mainly by means of internal financing schemes. The returns on equity contribution most often cited were between 2% and 8%[46], while interest rates were between 3% - 9%[47]. One study mentions that, wind projects developed up to 1993 by independent producers had profitability ranges between 2% - 8% (van Zuylen et al. 1993). During interviews with several developers it was indicated that the profitability of projects owned by cooperatives in this time varied mostly around 4% - 5%. The range expanded for some projects up to 8%. For other projects however, this was as low as 2 -3% because over-estimations on wind regime[48]. This suggests that the profitability of projects should

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[45] Van Zuylen et al. (1993); Mitchell (1994); Langniss et al. (1998); IEA (1995: 107); a series of articles in the Wind Power Monthly in the years 1994 -1996.

[46] Mitchell (1994: 151); Langniss et al. (1998).

[47] IEA (1995: 107); Mitchell (1994). Soft loans and equity contribution for wind projects were given by the ethical bank Triodos since 1993.

[48] Interviews August and September 2002 with cooperatives Zeeuwind (Scheuerman); Noordenwind (Kap en Wiegersma-Colmer); CVWd (Kees Veerman), , Zaanse Energie Koöperatie (Dick Beets), VCBW (Wim Kersten), and with Fred van Vliet.

have been mostly in the low/modest range, with perhaps few projects making higher levels of profitability.

Regarding the financial situation of distribution companies and their joint ventures with private investors, van Zuylen et al. (1993) mention that on average distribution companies used in the first years of the 1990s: 25% governmental investment subsidies and 25% investment subsidies from the Environmental Action Plan funds. But there were also cases where investment subsidies of up to 66% of total project costs were obtained from these two sources (Langniss et al. 1998). As regards Environmental Action Plan production subsidies some companies claimed that they did actually not allocated themselves such subsidies, while others argued that they are not higher than those given to IPPs. The private investors joining distributors in joint ventures kept tight confidentiality arguing that they "did not get rich" with what they received (WPM July 1994: 16).

Since direct data were not available we assume that the range for this price component was the same as for IPPs. This would mean that contractual prices for distributors and their joint ventures were also in the range of 4,2 - 9,4 €c/kWh. But having in view the availability of investment subsidies from the Environmental Action Plan, this suggests a better financial situation than for IPPs. As regards contracts' length this was mostly in the range of 10-15 years[49].

However, looking at the financing data - it can be argued that their projects may not have benefited of substantially higher profitability than IPPs. As mentioned earlier, distributors were owned by municipalities and organised as non-profit companies. In practice they were actually allowed to make certain levels of profits, in the range of the interest rates required by banks for loans to utilities, which varied between 5% and 9% (IEA 1995: 102; Mitchell 1994). Studying the financing of wind projects in the Netherlands in her doctoral dissertation, Mitchell (1994) argues that distributors were trying to make projects with profitability between 8% - 9%[50]. One interviewee from a distribution company[51] explained that during the 1990s the combination of unfortunate technological design choice and overestimated wind energy regime brought profitability of projects from the targeted 10% to lower than 5%.

Based on the available empirical information and our price-cost considerations, we assess that the profitability of projects developed by distribution companies and their joint ventures can be seen as concentrated in the 'modest' range, 4% - 8%.

The analysis of what happened in practice in the period 1990-1995 suggests that the economic-policy support system was characterised by economic-policy risks for IPPs that can be assessed as in the middle part of the 'high' risk range, and 'very low' risks for distributors and their joint ventures. The range of projects' profitability was between 'low' and 'modest' for IPPs, while for distributors and joint ventures was slightly better, focusing in the 'modest' range. These investment contexts are represented in Figure 11.2. In the following paragraphs we discuss the risks associated with the policy support mechanisms used in the period 1990-1995 for wind energy.

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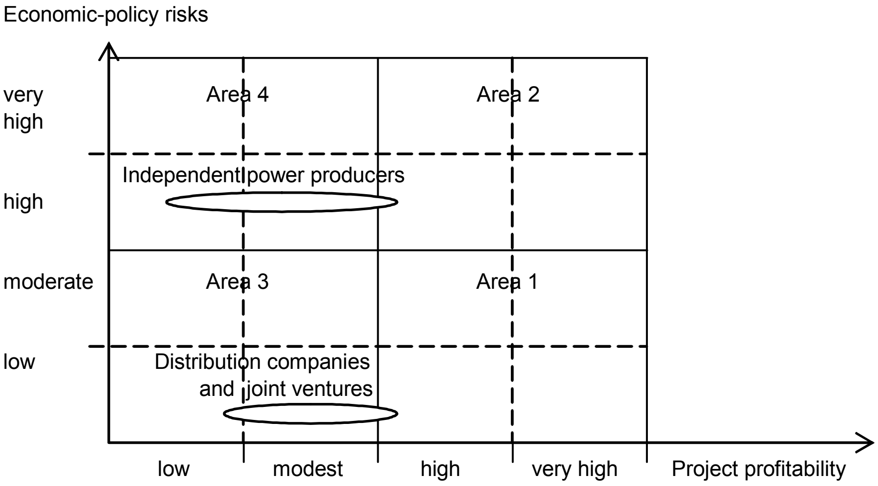
[49] Mitchell (1994: 147; 149), Langniss et al. (1998, case study 4). Interviews mentioned in footnote 50.

[50] Information came only from one distributor (EGD) who said he "expects an average 8% annual real return on investment" (Mitchell 1994: 149).

[51] Our source preferred to keep confidentiality on the company he represents.

Figure 11.2 *The risk/profitability context induced by the Dutch economic-policy support system for wind technology diffusion, 1990-1995*



Economic policy risks in 1990-1995

Table 11.9 presents our assessment of the risks embedded in the support system for the two main groups of developers, analysed in continuation. As discussed in Section 11.4.1 the economic governance structure assumed high risks for IPPs and low risks for distributors and their joint ventures. The scheme of Environmental Action Plan production subsidies placed very high risks on IPPs since their allocation and level was entirely at the discretion of each distribution company. There are some arguments suggesting that there was little reason that the discretion of distributors over Environmental Action Plan funds should not be feared by IPPs and financing agents[52].

Firstly, in the framework of the Environmental Action Plan program, renewables faced serious competition from numerous other types of projects that could realise CO_2 cuts at much lower costs per ton avoided. Co-generation was the biggest threat as it achieved substantial CO_2 reductions at less than half the cost of wind electricity - 2,7 €c/kWh (WPM June 1994: 17). Wind energy was actually the most expensive measure of those proposed in the 1994 Environmental Action Plan revision document (EnergieNed 1994). Secondly, during these years, there was yet no specific target for renewable electricity as part of the CO_2 reduction target. The 1700 GWh/year target came only in the 1997 revision of Environmental Action Plan.

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[52] Wiero Beek from the Arbitration Committee also argued, in 1994, after the pricing conflict that "The electricity companies can decide on the spur of the moment to cut back the environmental subsidy for wind energy. I am afraid that this uncertainty will stop a lot of possible financiers from investing in wind" (WPM July 1994: 16).

Table 11.9 *Economic-policy risks for wind energy investments for the two types of project developers that emerged in practice*

Developer types / Risks 1990-1995	Economic governance structure	Policy support schemes		
		production subsidy Environmental Action Plan	investment subsidy Environmental Action Plan	investment subsidy government
Independent power producers	high	very high	no risks	no risks
distributors; joint ventures	low	no risks	no risks	no risks

Thirdly, the 1991-1994 Wind-Plan of the eight distributors in the wind-richest provinces to installed together 250 MW represented also a serious competitor for Environmental Action Plan financial resources in the first years of this period. Fourthly, if insufficient payment would have led to capacity shut-down of some renewable electricity plants, and this would have resulted in failure to reach the CO_2 target, there would not have been any penalty on distributors since the Environmental Action Plan program was voluntary and did not include a penalty mechanism or regulatory threat in this period.

For distribution companies and joint ventures with their participation, there were no risks related to Environmental Action Plan production subsidy, since distributors were deciding on their level. If funds were not sufficient, distribution companies could have proposed The Economic Minister the increase in Environmental Action Plan levy, justifying the request with cost estimations. As regards investment subsidies, neither the Environmental Action Plan nor governmental investment subsidies did pose risks to developers. Risks associated with investment subsidies depend mostly on the timing of their approval and availability. In case availability would be conditioned by the entry into the construction or operation phase of projects, this would pose higher risks than when subsidies become available soon after approval. In the Netherlands, such conditions were not placed rending these schemes as no risk policy support.

One additional element of price risk facing all developers in early 1990s was given by the claim of local authorities that wind turbines are not machines but real estate and their owners should pay property tax on them. The conflict emerged between SEP and local authorities in Frisland and went up in the judicial system to the Supreme Court. The Court agreed that “a wind turbine is a structure which will remain in the landscape and is therefore real estate” on which tax should be paid (WPM April 1994: 6). Later the decision was reversed and wind turbines were categorised as machines.

In conclusion, we consider that in the period 1990-1995 the policy support schemes applicable to IPPs moved the investment framework to an investment context of ‘high’ risks but enabling a ‘low/modest’ profitability of projects, as suggested in Figure 11.2. In the same time the attribution of full authority to distributors for the allocation of Environmental Action Plan subsidies contributed to the preservation of an investment context for distributors where economic-policy risks were very low. The same holds for the joint ventures benefiting of distributors’ participation. The policy support schemes mentioned in Table 11.8 moved the investment framework to a context with very low risks and generally ‘modest’ profitability.

11.7.1.2 The period 1996-1997

The years 1996-1997 were a transition period between the end of subsidies in 1995 and launch of the green label system (GL) and new electricity law in 1998. They were characterised by the gradual introduction of fiscal instruments and voluntary pricing schemes towards a market-driven support system, as well as a continuation of disagreements between IPPs and distributors over contractual prices and length. But during 1994-1995 there was strong uncertainty among all developers as to what kind of support schemes would replace investment subsidies and which would be their financial effect. In early 1995 it was known that renewables would benefit of a 1,36 €c/kWh production subsidy from the Ecotax funds that would be introduced in January 1996. The Vamil and the Green-Funds schemes were also announced. But it was not clear if these support schemes would compensate for the loss of investment subsidies and wind projects would still be profitable. At a certain moment, discussions envisaged the possibility that the government obliges distributors to pay a premium price on wind power. But many doubted that this proposal would be successful.

As regards the projects of IPPs, the contractual relations and prices were unstable and quite complicated. Four trading-pricing models emerged in this short period. Firstly, there was the August 1995 Agreement between EnergieNed and Pawex, which offered 10 year contracts only for wind plants smaller than 2 MW. The contractual price was fixed at 7,4 €c/kWh and was made up of the following price components:

- Standard Arrangement payment 3,63 €c/kWh;
- Environmental Action Plan production subsidy 2,45 €c/kWh;
- production subsidy from Ecotax funds 1,36 €c/kWh.

Ultimately, the EnergieNed-Pawex agreement was implemented only by few distributors[53] and only during 1996. Pawex argued that with this price wind projects were economically feasible only in two provinces with the richest wind resources: Friesland and Flevoland (WPM August 1995: 10).

Secondly, for 1997 no agreement could be reached between EnergieNed and Pawex on contract length and Environmental Action Plan production subsidies[54] (WPM February 1997: 24). Only the Nuon company agreed to prolong the contract terms for plants smaller than 2 MW. Besides, it was also the only company to agree signing purchase contracts with IPPs owning plants between 2 - 5 MW. But the contract and payment terms were not attractive. Nuon's offer was to pay between 5 - 7,27 €c/kWh, depending on the wind regime, for the first 20.000 hours load and afterwards to lower contractual price to the level of Standard Agreement payment. In wind-rich regions, the 20.000 hours load would equate to contracts of around 6 years long (WPM February 1997).

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[53] Some distributors, such as Edon refused to buy in 1996 more than 2 MW wind power from all IPPs in the region, although this ceiling was for individual plants according to the terms of the agreement (WPM, February 1996: 30).

[54] There were two main new reasons for the reluctance of distributors to enter new engagements. Firstly, discussions already started regarding industry liberalization and the drafting of the new electricity law. Secondly, proposals were discussed for the introduction of a special target for renewables in the framework of the Environmental Action Plan which was intended to be implemented by means of tradable green labels. This would have enabled distributors with insufficient renewable generation capacity to shop around for cheaper labels. The update of the Environmental Action Plan was only decided upon in 1997 and the new law was passed in 1998. But during most of 1997 distributors had to face new uncertainties.

Thirdly, few distributors were still willing to give slightly higher contractual prices for IPPs in their regions[55]. Contracts and prices were bilaterally negotiated with distributors and Environmental Action Plan production subsidies were confidential (ECN in EVN 1996). Regarding contract length, they were also varying at distributors' will between 1 and 15 years[56].

Fourthly, some distribution companies were not willing to pay Environmental Action Plan production subsidies but agreed to give contracts where one price component was a green premium from the voluntary green pricing schemes they were administering. In addition, in both above cases, the IPPs received also the Standard Arrangements payment and the Ecotax production subsidy. The green pricing schemes for consumers, introduced by more and more companies after 1995, proved quite popular. Up to 1997, the green schemes benefited of voluntary premiums between 1,8 - 3,7 €c/kWh (Ecofys 1999: 13). However, more types of renewable resources were included in the green electricity products, assuming different production costs. These costs were taken into account at the distribution of green premiums among IPPs. This way, payments for wind projects were generally in the lower range, of 1,8-2,3 €c/kWh (Ecofys 1999: 13), which was hence lower than the 2,45 €c/kWh Environmental Action Plan production subsidy given under the 1995 Agreement. But IPPs, believed that in time the willingness to pay of green consumers would increase. Besides, looking back at all negative experiences with distributors, IPPs considered green consumers more reliable than distribution companies, in terms of price and contract risks (WPM May 1997: 38). Consequently, four trade-pricing models can be differentiated in this two-year transition period:

- based on the 1995 Action Plan between EnergieNed and Pawex, for plants smaller than 2 MW: 10 year contracts for 7,4 €c/kWh;
- based on the trade-pricing offer made by Nuon for 1997: 10 year contracts with contractual prices between 5-7,4 €c/kWh, depending on plant sizes (up to 5 MW);
- based on bilaterally negotiated contracts between IPPs and distributors regarding the level of Environmental Action Plan production subsidy and contract length;
- based on bilateral contracts with distributors administering green premium schemes for the negotiation of green production subsidies from voluntary consumer's funds.

In addition to the contractual prices the IPPs investing in new[57] wind projects could also benefit of soft loans from the Green-Funds scheme introduced in January 1996. The estimation was that this scheme would bring financial benefits of around 0,45-0,9 €c/kWh, manifested in the form of reduction in production costs.

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[55] Langniss et al. 1998 (Case Study 5).

[56] ECN in EVN (1996 and 1997); Langniss et al. (1998 Case Study 5); Interviews Zeeuwind cooperative (nine wind parks; Scheuerman, 2002), van Vliet (2002), VCBW (Kap and Wiegersma-Colmer 2002), ZEK (Beets 2002).

[57] The new fiscal schemes applied only for the plants built since 1996. Older wind projects had to continue relying on contractual prices with distributors because they received investment subsidies in the past.

Table 11.10 *Sources and levels of financial support, 1996-1997*

Sources of financial support Independent Power Producers	Financial support for Independent Power Producers		Distributors / joint ventures
	with Environmental Action Plan subsidies	with green pricing	
Vamil tax deduction	not allowed by tax authorities		applicable only for joint ventures
EIA tax deduction	Yes: since January 1997 (eqv. 0,7 €c/kWh)		
Green-Funds soft-loans	YES: production costs lowered 0,4-0,9 €c/kWh		
Investment funds from green consumers' premiums	No		Yes (Confidential)
Environmental Action Plan investment subsidies	small and occasionally		Yes (25-35 %[58])
Standard Arrangement payment	3,2 - 4 €c/kWh		
Production subsidy (Ecotax)	1,36 €c/kWh		
Environmental Action Plan production subsidies	some: 2,45 €c/kWh; others: 0 - 2,27 €c/kWh; the rest: confidential	No	Yes (Confidential)
Green consumers premium	No	1,8 - 2,3 €c/kWh	Yes (Confidential)
Contractual prices	some: 7,40 €c/kWh; others: 5 - 7,27 €c/kWh (annually decreasing) the rest: confidential[59]	6,36 - 7,66 €c/kWh	Confidential
Production costs	8,2 €c/kWh in 1995 to 7,72 €c/kWh in 1997[60]		

The EIA fiscal rebate scheme entered into operation only in 1997, offering a reduction in production costs of around 0,7 €c/kWh. But distributors argued that their agreement to give 2,45 €c/kWh Environmental Action Plan subsidy was motivated by the un-availability of this fiscal scheme and that, once it becomes available, the IPPs should not claim it. If they did, this would affect contractual prices by a decrease of 0,7 €c/kWh. Further, the Vamil scheme was envisaged for application beginning with January 1996. But it only entered in operation in January 1998 due to implementation problems with tax authorities.

The financial types of support schemes applicable for IPPs during 1996-1997 are summarised in Table 11.10. The cells highlighted in dark-grey represent the core of the differences between the four trade-pricing models co-existing in this very short period for IPPs. The light-grey rows represent the schemes that were under the administration of distribution companies.

Profitability of projects

Comparing production costs with contractual prices and price support available for IPPs it appears that their financial situation did not improve compared to the previous period. Considering the range of production costs of 7,7 - 8,2 €c/kWh and subtracting from it the assessed cost reduction brought about by the EIA[61] and Green Fund schemes of 1,1 - 1,6 €c/kWh, it appears that for investment cost recovery contractual prices should have been at

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[58] Mitchell (1994); Langniss et. al. (1998; case study 4)

[59] Joosen mentions a price of 6 €c/kWh for a turbine of 2 farmers (1998 CS6) and 6,5 €c/kWh for a project of a cooperative (in Langniss et. al. 1998 case study 5 and 6).

[60] EZ (1997: 28) “Renewable Energy - Advancing Power 1997-2000”.

[61] But during 1996 the EIA scheme did not apply which means that developers could only benefit of the effects of the Green Fund scheme bringing reductions of 0,4 - 0,9 €c/kWh (WPM, September 1995:22).

least between 6 - 7 €c/kWh. This suggests low/modest levels of project profitability for IPPs, as in the previous period. However, the return-on-equity for developers of new projects increased, since Green Funds were offering loans at lower interest rates. The returns on equity were often in range of 4 -10 % during the two years[62].

As regards the projects of distribution companies and their joint ventures, they continued to benefit of MAP investment and/or production subsidies at their discretion. The same held for the joint ventures between distributors and private investors[63]. Another element of difference compared to the IPPs was the privilege of managing the green pricing schemes for captive consumers. As mentioned in Section 11.6.1, the green premium funds were used both as:

- investment subsidies, as donations in the green investment funds of distributors for future projects (e.g. by Edon, Nuon, ENW, Pnem); and as
- production subsidies for existing plants (e.g. by Pnem [ECN in EVN 1996]).

One company, Energie Noord West managed by October 1997 to install the first wind plant of 4,5 MW that was partly financed from the investment fund fuelled by green consumers (WPM October 1997: 34). But the detailed financial aspects of the green pricing schemes were very un-transparent in terms of spending. When distributors were the sole owners of wind projects, the Vamil and EIA schemes were not applicable, but when they formed joint ventures with private developers, they could take advantage of the two deductions. The Standard Arrangements payments and Ecotax production subsidies had the same levels as for IPPs. In addition, distribution companies used soft loans from Green Funds in all projects were they had ownership share.

Consequently, it was not possible to draw a conclusion on likely ranges of projects' profitability for distributors and their joint ventures looking at contractual prices and price support because information on this is largely confidential. However, having in view that they were still publicly owned companies with ceiling on equity-returns, it could be safely argued that projects' profitability was still in the 'modest' range.

Policy risks[64]

If policy support mechanism did not bring improvements in the profitability of wind energy projects, they also did not bring about changes in policy risks. For IPPs, the overall economic-policy risks remained high, while for distribution companies and their joint ventures the overall risks remained very low. Table 11.11 mentions our assessment of the

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[62] WPM, January 1996: 17. Interviews with cooperatives Zeeuwind (Scheuerman); Noordenwind (Kap en Wiegersma-Colmer); CVWD (Bruining), Fred van Vliet, Zaanse Energie Koöperatie (Dick Beets), VCBW (Wim Kersten), August and September 2002.

[63] The number of these ventures increased, as it proved easier for private agents to find sites and ease the way towards local acceptance and permits (Mitchell 1994: 147).

[64] The discussion of policy risks takes into account the context present and information available in mid 2002. After the writing of this chapter things changed in the Dutch policy for renewable energy support affecting also wind projects. They were mainly caused by the change in the political colour of the government after the May 2002 elections, followed perhaps by further reshuffling after the January 2003 elections. Policy changes refer mainly, so far, to the Ecotax whereby renewable electricity consumers would not benefit of Ecotax exemption. A second change regards the cancelling of the tax advantage for households and corporations for investments in Green Funds, leading to the disappearance of soft loans for wind projects and perhaps also of the project finance scheme.

risks associated with the individual policy support schemes applicable in the years 1996-1997 for the two categories of developers.

Table 11.11 *Economic-policy risks for RET investments for the two types of project developers that emerged in practice, 1996-1997*

Developers / Risks 1996-1997	economic governance structure	Policy support schemes					
		MAP investment subsidies	Green Funds loans	production subsidies[65]			Vamil EIA
				Ecotax funds	MAP	Green premium	
IPP	high	no risks (rarely used)	moderate		very high	high	high
Distributors Joint ventures	low	no risks	theoretically moderate; in practice no risks		no risks	rarely used	not applied

Governmental investment subsidies assuming no risks on cash flow during projects' life were replaced by schemes posing superior policy risks. We assess Ecotax production subsidies and Green Funds soft loans as placing moderate risks on IPPs, and this will be motivated below. The Vamil scheme proved to bring high risks due to implementation difficulties. This shattered the confidence in the implementation of fiscal instruments more broadly. This contagiousness, cumulated with some uncertain aspects in the design and implementation of the EIA fiscal scheme leads us to assess this also as posing high policy risks. The risks faced by IPPs related to MAP production subsidies remained very high. In the same time, all developers who chose to rely on green premiums from voluntary consumers faced high risks on this price component.

For distributors, the two fiscal schemes, Vamil and EIA were not applicable when investing as single project owners. Besides, they rarely used green premiums as production subsidies. Precisely in order to hedge from price risks, new projects were built after sufficient financial reserves accumulated in the green investment funds. Green premiums were therefore mostly used as investment subsidies. Green Funds and Ecotax production subsidies posed theoretically moderate risks, like for IPPs. However we argue that - due to their full freedom to decide on the level of Environmental Action Plan production and investment subsidies and on Standard Arrangements payments, if the new governmentally administered schemes would have reduced or cancelled price support, the RET projects of distributors would not have reached the situation of financial collapse.

Therefore even if looking at the context of emergence and/or implementation of the two schemes one could assess them as posing moderate risks on developers, as it will be motivated below, we argue that for distributors in particular they basically did not represent a threat. For this reason we consider that the overall economic-policy risks remain the same ‘very low’ for distributors in the period 1996-1997. Hence, the risk/profitability context for the two main types of developers in the transition years 1996-1997 could be represented in the same way as in Figure 11.2 for the period 1990-1995.

The governmental fiscal deduction scheme Vamil posed high risks for small IPPs, especially for single turbine owners because of implementation problems. The Dutch tax

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[65] The columns for Environmental Action Plan (MAP) subsidies and the green premiums were highlighted with in order to point out that they were alternative options, hence setting separate trading channels.

authorities claimed that investments in wind turbines do not qualify for Vamil deductions. The debates escalated up to confrontations between the ministry of finance and the ministry of economic affairs. Tax authorities opposed especially the eligibility of small private developers - mostly farmers - for the tax rebate arguing that when projects were very small or made up of solitary turbines, this constituted a form of capital management and not a business activity susceptible for tax deductions (WPM April 1994: 6).

The dispute was only settled in the end of 1997, when the Ministry of Economic Affairs announced that all private investors were indeed eligible for Vamil benefits. It was then decided that when the EINP subsidy scheme for non-profit companies enters into force, January 1998, the IPPs who were stripped of their fiscal benefits would be considered eligible for the new subsidies. The Ministry of Economic Affairs' estimation was that by the end of 1997, "around 25 MW of installed capacity has been affected by the dispute, either in un-realised projects, or projects which have had to find alternative means of finance" (WPM November 1997: 17). The problems with implementation of Vamil scheme led Pawex and other potential developers to fear that the application of the EIA fiscal benefit scheme would run into similar problems (ECN in EVN 1996). Fiscal instruments started to be perceived as risky because of:

1) poor coordination among governmental authorities and departments, and
2) the competence - legal or self-assumed - of tax authorities[66] to interpret how they implement governmental regulations.

For this reason, we associate the EIA fiscal rebate scheme also with high policy risks.

Green funds resulting in soft-loans were also not a very reliable policy instrument for wind diffusion support because of constant uncertainty on whether income taxes could be reintroduced on green investments[67]. Firstly, due to over-subscription in the first years of scheme introduction, there were discussions in governmental spheres that, if returns on green investments prove to be too high for certain types of projects, those projects should be excluded from the Green-Funds list (WPM July 1997: 8). It was not clear however whether the exclusion would regard future investments or would also apply for already commissioned projects using green funds. Secondly, in 2000 it was announced that a reshuffling of the income tax system could still place some small taxes - 2,3% - on the income from green funds (WPM June 2000: 22). Consequently, we assess the policy risks associated to the Green Funds scheme as moderate, having in view that there were discussions for the elimination or reduction the financial benefit of the scheme but it was not clear how would this affect wind projects already committed based on these incentive.

Green premium schemes financed by voluntary consumers were considered by some IPPs preferable to the Environmental Action Plan production subsidies. They argued that distribution companies undervalue wind electricity and that consumers' preference for green electricity posed lower price risks than Environmental Action Plan subsidies (WPM May 1997). Although green premiums for wind electricity were only in the range of 1,8-2,3 €c/kWh, compared to the Environmental Action Plan subsidy of 2,45 €c/kWh included in the 1995 Agreement with EnergieNed, the expectation was that the willingness to pay

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[66] The story with the claim of local tax authorities, backed up by the Supreme Court, that wind turbines are real estate and not machines was another reason to associate fiscal instruments with price risks.

[67] The consequence for existing wind project would have been that the increase in interest rate would have negatively affect the cash flow of projects and the profits of project developers too.

would increase in time. However, we argue that the green premium choice should be seen as a situation of 'least worse' option for IPPs. There were no civil/commercial law contracts with green consumers that could guarantee a certain minimum convenient contract length or based on which IPPs could ensure some minimum prices. As explained in Section 11.6.3, distributors were offering often more choices of green electricity packages. Consumers could revert their choice towards lower cost packages or smaller amounts of green electricity in their total consumption. And, of course they were free to withdraw from the list at any time. Green premium schemes could be then assessed as posing high risks for developers who used the funds in the form of production subsidies.

Risks associated with the Ecotax production subsidy can be assessed as moderate in those years due to uncertainties in policy direction at EU level, requiring changes at national level. Two examples can be given here. Firstly, there were increasingly louder discussions that an international green certificate trading scheme will be implemented soon after 2000. The fiscal schemes that did not distort prices and trade were expected to be maintained. However, the subsidy part of the REB scheme was seen as one of the first that would need to be phased-out, to avoid trade distortions. Secondly, there were also some EU proposals whereby renewable electricity production is allowed to be subsidised only until it reaches 5% in national electricity consumption, and in any case not after 2010. As policy analysts observed, (ECN in EVN 1999 October) "This guideline has not been yet adopted and has no official status. However member states take it into account, for example in the formulation of national targets".

In conclusion, the economic-policy risks faced by IPPs remained high in the transition period 1996-1997, while those specific to distribution companies and their joint ventures remained very low. No changes occurred also in the ranges of possible project profitability, remaining in the 'low'/'modest' range for IPPs and in the 'modest' range for distributors and their joint ventures. The risk-profitability profile for this two-year period can be represented in the same as in Figure 11.2.

11.7.1.3 The period 1998-2000

In the period 1998-2000 four policy changes occurred:

- the entry into operation of the EINP investment subsidy for non-profit organisations, distributors and single turbine owners;
- the practical entry into operation of the Vamil fiscal rebate scheme for individuals, farmers and small private companies;
- the exemption of renewable electricity from payment of Ecotax; and
- the replacement of Environmental Action Plan investment and production subsidies with the Green Labels (GL) trade system.

In addition, the new electricity law entered in operation in September 1998. As summarised in Table 11.12, there were two trading models between which project developers could choose in this period:

- one where Green Label payments constituted a price component; and one where
- production subsidies from voluntary Green Premiums (GP) were one price component.

Table 11.12 *Sources and levels of financial support, 1998-2000*

Sources of financial support	Independent Power Producers		Distributors / joint ventures
	Green Labels	Green Premiums	
Vamil tax deduction	Yes: since 1998 (0,2 - 0,7 €c/kWh)[68]		Yes
EIA tax deduction	Yes: since 1997 (eqv. 0,7 €c/kWh)		
EINP investment subsidies	only for single turbine owners[69]: 14 - 20 % of project costs		Yes 14 % - 20 % of project costs
Green-Funds soft-loans[70]	Yes: production costs lowered 0,4-0,9 €c/kWh		
Ecotax exemption	Yes: no direct financial benefits; main effect: increase in green demand		
Investment funds from green consumers' premiums	No		Yes (confidential)
Green Label payments	average 2,3 €c/kWh maximum 3 €c/kWh	No	average 2,3 €c/kWh; penalty 3,4 €c/kWh
Green consumers premium	No	2,7 - 4,5 €c/kWh	
SAR payment	3,6 €c/kWh		
Production subsidy (Ecotax)	1,36 - 1,6 €c/kWh		
Contractual prices[71]	7,3 - 8,2 €c/kWh	7,6 - 9,7 €c/kWh	7,3 - 8,6 €c/kWh (GL) 7,6 - 9,7 €c/kWh (GP)
Production costs	7,7 €c/kWh in 1997[72] to 6 - 8 €c/kWh in 2000[73]		

The additionality principle aimed to ensure that there was no financial interaction between these models. However, electricity traded through both these schemes was eligible for counting in the Environmental Action Plan 3% target for renewables. In addition to the price components from the two trade models, all developers could benefit of governmental support schemes mentioned in Table 11.12.

The fiscal instruments available - Green Funds, EIA and Vamil - offered reductions in production costs estimated by the Ministry of Economic Affairs as around 1,8 €c/kWh (EZ 1998). When the Vamil scheme was not applicable, the EINP investment subsidy was offering equivalent cost reductions. Further, the level of Ecotax-based production subsidy increased from 1,36 to 1,6 €c/kWh. This increase was a consequence of Ecotax increase for conventional electricity, as shown in Table 11.7.

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[68] This range was estimated by subtracting from the amount estimated by EZ (1997) for the effect of all three new fiscal schemes, the estimation on production costs reduction from Green funds and for EIA rebate.

[69] The scheme was applicable for the single turbine owners refused Vamil benefits 1996/7, and for their new projects after 1998.

[70] In 1997, 181 wind turbines used soft loans from Green Funds (EURE 2000: 23).

[71] According to the IEA overview, during 2000 most of the purchase contracts with distributors were signed for 5 to 10 year periods, for contract prices 6,8-8,0 €c/kWh (IEA, R&D Wind 2001). The governmental enrgy agency Novem mentions in information at its website (http://www.novem.nl) that: "In 2000 contracts were concluded for prices between 7,3 - 8 €c/kWh" in the framework of the Green Label market. Mulekom (Kema 1999: 27) also refers to contractual prices between 7,4 - 7,7 €c/kWh in 1998, when only 3 distributors concluded contracts with IPPs: Nuon, ENW and Edon. The PDE agency mentions that in 2001 contractual prices were mainly in the range of 7,3 - 7,7 €c/kWh (www.pde.nl)

[72] Source Ministry of Economic Affairs (1997: 28) “Renewable Energy - Advancing Power 1997-2000”.

[73] Kwant and Ruijgrok, 2001, "Development of renewable energy in a liberalized market in the Netherlands by fiscal instruments". The agency Project Renewable Energy (PDE) mentions that in 2001 production costs for wind electricity mainly in the range of 6 - 7,7 €c/kWh (http://www.pde.nl).

The levels of green premiums paid voluntarily by consumers also increased in this period as result of Ecotax level increase. Depending on distributors and the composition of the green electricity product this was in the range of 2,7 - 4,5 €c/kWh. Some distribution companies were using also green premium funds as investment subsidies but detailed information is not available. The average price of Green Labels - as calculated at the close of the system in May 2001 - was 2,3 €c/kWh (Marbus 2001). The highest price paid for IPP was 3 €c/kWh, while the penalty price that non-compliant distributors paid for distribution companies over-passing their target was 3,4 €c/kWh (Marbus 2001).

Profitability of projects

The ranges of contractual prices are shown in the above table for both trading options. Table 11.13 puts these into contrast with the production costs after the effect of fiscal incentives is subtracted. These numbers suggest that for all types of developers the range of project profitability moved in the 'modest-high' area. However, for the Green Premium model of trading, the range appears to be sensitively larger, which may have enabled 'very high' profitability levels[74]. One interviewee mentioned under confidentiality that with the Ecotax exemption scheme and Green Funds financing, wind projects are surely above 10% profitability. When in addition the EIA and Vamil schemes are used, the profitability of projects may reach 20% or higher.

Table 11.13 *The profitability of wind projects in the period 1998-2000*

Financial parameters	Green Label system		Green Premium system (all developers)
	Independent Producers	Distribution companies and joint ventures	
Production costs	6 - 8 €c/kWh		
Fiscal incentives	1,8 €c/kWh		
Remaining costs to be recovered	4,2 - 6,2 €c/kWh		
Contractual prices	7,3 - 8,2 €c/kWh	7,3 - 8,6 €c/kWh[75]	7,7 – 9,7 €c/kWh
Profits (after tax)	average 2,1 €c/kWh maxim 4,0 €c/kWh	average 2,1 €c/kWh maxim 4,4 €c/kWh	minim 1,5 €c/kWh maxim 5,5 €c/kWh

Policy support mechanisms and policy risks

As regards the economic-policy risks in the period 1998-2000, the situation changed only incrementally. As discussed in Section 11.4.2, the 1998 Electricity Law resulted in very

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[74] The new comer Energie-Concurrent supply company mentioned profits of 4,2 €c/kWh in 2001. In addition, the large distributor Essent - who operates a scheme with the same price for green electricity as for conventional electricity - admits that the real price difference needed is actually below what is charged as green premium. But they do not communicate this because: 1) they would have then to ask consumers to pay smaller Green Premium and 2) they fear that EU will withdraw approval of the Ecotax exemption scheme if prices become lower than for grey electricity (information at the website of the Project Renewable Energy PDE on 15 June 2000). This can be seen as an example that a free market and voluntary demand do not necessarily lead to cost-efficiency in supporting renewable capacity.

[75] The 7,3 €c/kWh represents the contractual price for the average price of a Green Label, therefore it is not the minimum of the range. Data on the minimum Green Label price were not available. The 8,2 €c/kWh contractual price for IPPs was calculated based on maximum price received by IPPs for Green labels. The 8,6 €c/kWh price represents what wind plant owners received from distributors who had to pay penalties.

high demand risks for RET plants above certain size limits, since there was basically no form of protection given anymore. For very small RET plants the new law guaranteed demand only for a very short time period: 2001/2003. There was no direct mentioning of contracts for renewable electricity purchase. The price to which renewable generators were entitled based on the law was the same as the average conventional electricity price on the market. This way the law forced developers to rely on policy support mechanisms. Consequently, the risks in the new support system need to be assessed by looking at all price components and forms of financial support generators faced when using one of the two trading models characterising this period: the Green Label (GL) or the Green Premium (GP) trade models.

As it will be shown below, under the GL trade system IPPs continued to face overall high policy risks, while distribution companies and their joint ventures were only confronted with moderate aggregated policy risks. Under Green Premium model both groups of developers faced similar levels of risks that we assess as moderate-high (see Figure 11.3 further below). In continuation, we discuss first the risk context for IPPs and distributors with their joint ventures when wind electricity was sold in the Green Label system. After that, we analyse the risk conditions for generators choosing the Green Premium model. The summary is made in Table 11.14.

In the previous section, we already analysed the risks associated with the three fiscal instruments - Vamil, EIA and Green Funds - and the Ecotax production subsidy. One of the differences compared to the previous period is that Green Funds risks changed into 'moderate' for distributors too (see Table 11.14). This is due to the fact that Green Label payments, based on balancing supply with demand, replaced the self-allocation of Environmental Action Plan subsidies which could function in the past as a back up if governmental policy reduced or cancelled support. Another difference is the increase in the risks related to the Ecotax production subsidy to moderate-to-high levels for all types of project developers due to reasons that we will explain below. The EINP investment subsidies did not pose risks for projects' cash flows since they are ex-ante types of support. Hence, discussion needs to be focused here on the two elements of Ecotax exemption scheme and the Green Label system.

Table 11.14 *Economic-policy risks for wind investments for the two types of project developers that emerged in practice, 1998-2000*

Developers / Risks 1998-2000	1998 law	Policy support schemes and the risks, 1998-2000				
		Vamil EIA	Ecotax exemption / subsidy	Green Funds loans	production subsidies[76]	
					Green Label	Green Premium
IPPs	very high	high	moderate to high	moderate	high	moderate to high
Distributor; Joint venture		low			moderate	

The Ecotax exemption for renewable electricity may in principle be seen as a low risk scheme in a liberalised framework because it is a market-conform policy instrument. However, we argue that moderate-to-high risks can be attached to it due to policy uncertainty at both national and EU level. On the one hand, a green line was given by the

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[76] The columns for the Environmental Action Plan subsidies and the green premiums were highlighted with in order to point out that they were alternative options, hence setting separate trading channels.

EU to use the Ecotax exemption scheme only until January 2003 initially. An extension had to be re-analysed later. In late 1990s, the EU policy on renewables was still unclear. Approvals for national plans for fiscal and subsidy schemes had to be given on a case-by-case basis. There were intense debates as to whether or how to harmonise RES support at EU level. The extension of Ecotax exemption depended strongly on the outcome of those debates. Finally, in 2001 an EU Directive on RET support was adopted allowing countries to use their preferred support system at least until 2012[77]. But individual national schemes still needed special EU approval when they involved direct state financial support. The largest part of uncertainty shade was only lifted when the EU Court of Justice decided that the fiscal/financial support schemes for RET do not represent state aid but internalisation of environmental benefits of renewables[78]. However, some uncertainty on the admission of the Ecotax exemption remains because the EU *does not allow* that the use of such fiscal schemes (or subsidies) makes renewable energy less expensive than the other alternative forms of energy (ECN 2000: 26). If the Ecotax exemption increases too much, in pursue of its main aim of energy saving attitudes by consumers, it will make renewable electricity cheaper than conventional electricity and the EU will withdraw its endorsement of the scheme.

On the other hand, this scheme can be viewed as posing some moderate risks because the Dutch government was still not convinced that the scheme is indeed able to drive up national production of green electricity. With the increase in Ecotax level, the number of green consumers increased, reaching 95.000 in July 1999, and 159.000 in May 2000. But to serve this demand, an increasing amount of green electricity traded through voluntary schemes had to come from imports[79]. Under pressure from both inside and outside he country not to disturb international competition in the newly liberalised industries, the Dutch government was considering to open up the border and allow also foreign RET generators the benefits of Ecotax exemption. This eventually happened in January 2002. The major negative consequence relevant for policy risks was that the government considered lifting the Ecotax exemption totally for all RET producers, and revert to investment subsidies in order to protect new domestic capacity. If this happens, all already built RET plants would face substantial reductions in cash flows, as the willingness to pay of consumers would not be able to fill in the emerging cost gaps. Consequently, the uncertainty on national policy direction and on how this should be harmonised with the other EU countries leads us to assess risks of this scheme as moderate-to-high.

As regards the production subsidy from Ecotax funds, the arguments used to assess risks in the transition period 1996-1997, together with the above arguments lead us to consider the risk posed by this scheme also as moderate-high.

The Green Label (GL) system was introduced in order to speed up the achievement of the 3% Environmental Action Plan target for renewable electricity and share the financial

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[77] The EU Directive on Renewables states that in 2005 the effectiveness of national schemes will be reviewed. If a decision is taken to adopt a harmonized system at EU level, a period of seven years will be allowed for transition to the new system. This provision was meant to create a frame of confidence in support system stability for developers and financing agents.

[78] Information regarding this issue can be found at the website of the European Wind Energy Association http://www.ewea.org.

[79] Due to further sharp increase in Ecotax level the number of green consumers lifted to 1.000.000 in mid 2002. At that time 50% of green electricity sold under Green Premiums came from imports (http://www.greenprices.nl).

burden for it. Taking into account that there was already renewable capacity generating around 900 GWh/year electricity, the 3% target represented a net increase of around 800 GWh/yr. This can be approximated to come from 500 MW new capacity. Most of this was expected to be provided by wind plants[80].

There are a series of positive aspects associated with the new support scheme. The association of private wind developers Pawex welcomed the Green Label system because of two main reasons. Firstly, the 3,2% target offered some certainty on demand and it was clear that available supply was lower with an 800 GWh/year gap to be filled by new plants (ECN in EVN October 1997). Secondly market-pricing offered more price differentiation than the 10-year Agreement with EnergieNed or the bilateral contracts. There are quite large differences in production costs for wind electricity as this is strongly influenced by local wind regimes. Pawex argued that the Green Label system could make wind projects feasible in more regions than before 1998. Moreover, matching demand with supply, takes care that lower-wind sites can also have attractive levels of project profitability (WPM May 1997: 36).

Individual IPPs declared themselves also happier with the Green Label system because they could be liberated from the difficult negotiations with the regional distribution companies that were constantly refusing long-term contracts and ‘decent prices’ (WPM December 1997: 19). Green investors were also optimists as Green Funds recorded growth in the number of investors subscribing to it, in the expectation of higher capacity increase (WPM December 1997: 20).

However, due to certain design and circumstantial factors, we consider that the risks associated with the Green Label trade system can be assessed as high for IPPs and moderate for distribution companies. In the case of both Green Labels and Green Pricing we only discuss sources of demand risks and price risks because:

- in a quantity-driven support scheme, such as Green labels, the main uncertainties are the size of demand and the level of price, while
- contracts are the tools to hedge against these uncertainties.

Table 11.15 summarises our assessment of demand risks and price risks for IPPs and for distribution companies and their joint ventures under Green Label trade. The sources of risks - represented by numbers in the first row of the table for demand risks, and by small letter for price risks - are discussed below.

Table 11.15 *Demand risks and price risks under the Green Label trade system*

Sources / Developer		1	2	3	4	5	overall
Demand risks	IPPs	moderate	high	very high	high	high	**high**
	DC /JV	low risks	high	high	low	high	**moderate**
Sources / Developer		a	b	c	d	e	overall
Price risks	IPPs	high	high	high	high	high	**high**
	DC /JV	modest	high	high	low	low	**moderate**

We consider that the following design elements constituted sources of demand risks in the Green Label system:

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[80] Kema website at http://www.kema.nl/sustainable in April 2002.

1) A decentralised approach was used whereby distributors could issue themselves Green Label (WPM July 1999: 20); registration and verification was done by EnergieNed which was not a "truly independent organisation" (Schaeffer et al. [Realm] 1999: 9).
2) During the first year the market was very un-transparent. There was an acute lack of information on the volumes traded, since all market players preferred to engage in bilateral contract negotiation and the spot market did not function (WPM April 1998: 24; October 1998: 41). The market size was known: 800 GWh/year, but it was not clear which distributors had plans to invest, who had strategies to overpass targets and become sellers of Green Label, and how much was already under development from applications under approval procedures from previous years.
3) There was un-clarity regarding the eligibility of imported green electricity for accounting on the Environmental Action Plan target[81].
4) The only penalty for non-compliant distributors was a financial penalty on each Green Label they came short of[82]. This was set at 50% above the resulting average label price at the end of trade period[83]. A high demand risk for IPPs emerged from the fact that the penalty price was recycled only to the distribution companies who had still unsold labels. Therefore, distribution companies could have afforded to over-invest while IPPs had to face high uncertainties on market size. Besides, even if the over-investment of the active distribution companies was so large that after the payment of penalties price there were still Green Labels left, they could have been re-directed to the Green Premium trade channel where demand was increasing.
5) The main demand risk was the absence of intermediary targets. Distributors only had to prove their target in 2000. Besides, it was known that the levels of production subsidies from Ecotax funds would increase during the three years. Distributors who bought or settled Green Label prices in the 'proof-year' 2000 could this way buy cheaper. These two design elements effectively reduced trade during 1998 and 1999. During these years, demand risks were high for all types of developers selling Green Labels (ECN in EVN 1998: 91).

Further, we consider that the following design elements constituted sources of price risks in the Green Label system:

a) Green Labels were valid for trade only in the production year, leading to sharp price decrease at the end of each year (ECN in EVN 1998: 91-92).

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[81] The alarm was raised in 1999 when the distribution company Energie Noord West bought green electricity from the UK. Those projects had been already subsidized by the British government under the first two rounds of guaranteed contracts that expired in 1998, and could bid low prices for Green Labels (WPM July 1999: 20; March 1999: 20). Some distributors were also importing from Denmark, and Germany (ECN in EVN, 1998: 94).

[82] In February 1997 the new Law of Distribution Companies entered into operation. The law gave a legal basis to charging the Environmental Action Plan levy on captive distributors. A ceiling of 2,5% was placed on this levy at the proposal of EnegieNed (ECN in EVN 1996). However the law did not include the 3% target of renewable electricity distribution. Besides, the Green Label system entered into force in the same year as the new electricity law when it appeared clear that distribution company will not be subjected to quota obligations for RET. The law reserved the government the option to resort to such as support system but envisaged that an eventual obligation would only be placed on consumers. There was therefore no regulatory threat for failing to meet the 3% target by 2000.

[83] As this was only to be known ex-post this was an incentive for distribution companies missing labels to buy them timely on the market even when bidding prices seemed high.

b) There was competition from cheap biomass cofiring. Most of the new capacity installed in 1998/1999 came from such plants (Schaeffer 1999).

c) It was not clear if imported green electricity, which was generally much cheaper, was eligible for accounting in Environmental Action Plan target.

d) There was a very large number of renewable generators - 590 producers of Green labels in 1998[84] - while there was only a small number of buyers. Besides, some distributors decided to merge as part of their strategies to face liberalisation, further reducing the number of buyers (WPM February 1999: 25). For IPPs, this posed high price risks while for distribution companies only low risks emerged, because they could settle prices among themselves as they were merging.

e) There were no price floors for the Green Labels. This posed high risks for IPPs and moderate risks only for distributors, because distribution companies had insight into the financing of the Environmental Action Plan Program, including the funds allocated for meeting the renewable energy target, and could assess better what the minimum price for Labels could be.

Beside the specific demand and price risks there were the uncertainties about what will happen after 2000. Pawex was worrying that given the pending policy vacuum after 2000 "fewer people will be willing to invest in new projects" (WPM October 1998: 41). In conclusion, we assess the risks associated with the Green Label scheme itself as high for IPPs and moderate for distribution companies and their joint venture. Finally, in order to estimate the aggregated economic-policy risks for developers engaging in the trade model developed around the Green Label scheme we need to consider two elements:

- the risk level posed by each scheme for which developers were eligible as mentioned in Table 11.14. and discussed above and
- the financial contribution of each scheme.

Table 11.16 *The risks in policy support mechanisms and their financial weight, 1998-2000, Green Label trade system*

Type of developers under GL system	Risk level	Number of support schemes	Financial contribution
Independent Private Producers	high	4 (EGS, Vamil, EIA, GL)	7,1 €c/kWh
	high-moderate	2 (Ecotax: exemption and production subsidy	1,3-1,6 €c/kWh
	moderate	1 (Green Funds)	0,4-0,9 €c/kWh
Distributors and Joint Ventures	high	1 (1998 law)	3,6 €c/kWh
	high-moderate	2 (Ecotax: exemption and production subsidy	1,3-1,6 €c/kWh
	moderate	2 (Green Funds and GL)	average 3 €c/kWh
	low	2 (EIA and Vamil)	1,2 €c/kWh

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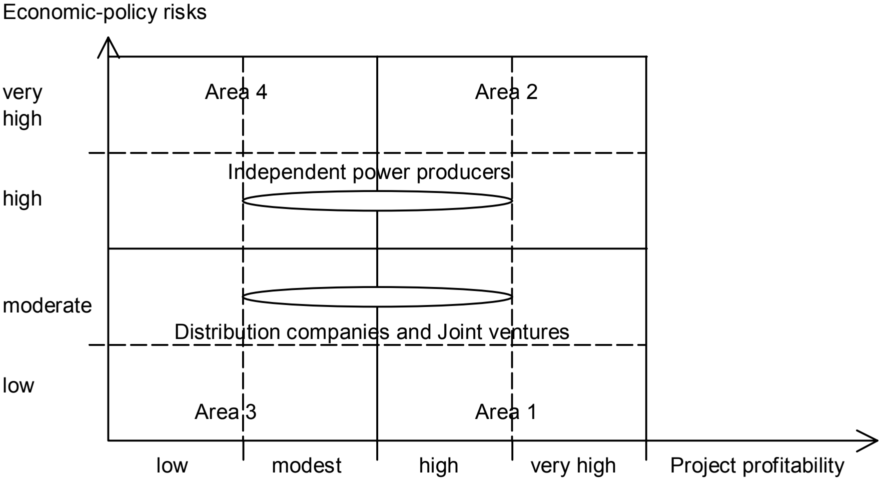
[84] Information available at the website of the company Kema in charge with monitoring the results of the Green Label system http://www/kema.nl/sustainable.

Table 11.17 *Risk levels and profitability ranges under the Green Label trading system and all accompanying support schemes, 1998-2000*

Types of developers Green Label system	Aggregated economic-policy risks	Ranges of projects' profitability
Independent Private Producers	high	modest-to-high
Distributors, Joint Ventures	moderate	modest-to-high

Figure 11.3 *The risk-profitability investment context under the Green Label trading system and all accompanying support schemes, 1998-2000*



This operation is summarised in Table 11.16. Based on these we conclude that the aggregated economic-policy risks facing IPPs engaged in the Green Label trading option as 'high', while those faced by distribution companies choosing to actively fulfil their Environmental Action Plan targets as well as their joint ventures were 'modest'. Combining this with our assessments on the ranges of project profitability for the two groups of developers, the risk-profitability profile for the Green Label trading option can be illustrated as in Figure 11.3. These conclusions are also summarised in Table 11.17.

The second trading option that existed in 1998-2000 in parallel with Green Labels was the Green Premium scheme. The additionality principle ensured that there was no financial interaction, that is, cross-subsidisation between the systems. The analysis of the circumstances where the Green Premium scheme operated leads us to assess the risks associated with this price component as 'moderate-to-high'. The increase was announced in policy documents and was known to potential developers in the period studied here 1998-2000. Voluntary consumer demand was driven by Ecotax exemption and its annual increase. This scheme was assessed as holding moderate-to-high risks due to policy uncertainty at national and EU level. Enabled by this scheme, consumer demand increased so drastically that imports were needed to respond rapidly to the booming demand. As mentioned in Table 11.7, the Ecotax level increased more substantially beginning with

2000[85]. In 2000, 50% of the green electricity supplied to the around 200.000 voluntary consumers came from imports. In mid 2002 there were 1.000.000 green consumers and the share of imported green electricity was the same.

If the Ecotax exemption scheme is eliminated, Green Premiums would have to increase again. In this case it is possible that the number of consumers willing to subscribe to green schemes will decrease. If contracts for imports are only for short period, existing domestic generators choosing this trade option could be protected if the decrease in consumer participation can be compensated by abandoning import contracts. But in a liberalised market energy companies have the freedom to decide with whom they contract. Preference is likely to be given to the price-competitiveness criterion. Only if the remaining green demand is strongly in favour of 'made in Holland' could domestic renewable generators survive competition in this trading channel[86]. Consequently, if the Ecotax exemption scheme is cancelled the demand of green consumers will lower substantially. The willingness to pay extra is very limited. Based on these considerations, and having in view the demand existing by 2002 (which could have been also forecasted) we assess the risks associated with the Green Premium scheme as 'moderate-to-high'.

An argument in favour of considering green premium risks as 'moderate' is the fact that not all green premium payments were going as production subsidies for existing plants. Due to demand over-passing 'not-Environmental Action Plan-financed' supply some distributors were selling electricity already subsidised by Green Labels. But in order to respect the additionality principle they were diverting the money towards their green investment funds for new plants (WPM May 1999: 40). If the Ecotax exemption is cancelled, these funds could still be used to pay for the contracts already concluded with existing domestic generation plants. In order to estimate the aggregated economic-policy risks for developers engaging in the Green Premium trade model we considered, as in the previous case, the risk level posed by each scheme involved in projects' economics and the financial contribution of the respective scheme. The results are summarised in Table 11.18.

Based on these considerations, we conclude that the aggregated economic-policy risks facing IPPs engaged in the Green Premium trading option as 'moderate-to-high', while those faced by distribution companies choosing to actively fulfil their Environmental Action Plan targets as well as their joint ventures were 'moderate'. The small difference comes from the risks associated with the Vamil and EIA schemes. Combining this with our assessments on the ranges of project profitability for the two groups of developers, the risk-profitability profile for Green Premium trading option could be represented as in Figure 11.4. These conclusions are also presented in Table 11.19.

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[85] Empirical data show that the boom after May 2001 is not related to the liberalization of the green electricity market (which happened eventually in June 2001) but to Ecotax increase. Data from energy companies show that green consumers did not change their traditional supplier. They just switched to green electricity. The market share of new entrants is very small, around 1% (Information at http://www.pde.nl in the News Section 2002).

[86] This marketing label has already started to be used by one distribution company with ambitious investment plans in wind energy inside the Netherlands (Essent).

Table 11.18 *The risks in policy support mechanisms and their financial weight, 1998-2000, Green Premium trade system*

Type of developers under GP system	Risk level	Number of support schemes	Financial contribution
Independent Private Producers	high	3 (EGS, Vamil, EIA)	4,8 €c/kWh
	high-moderate	2 (Ecotax: exemption and production subsidy	1,3-1,6 €c/kWh
	moderate	1 (Green Premium)	2,7-4,5 €c/kWh
		1 (Green Funds)	0,4-0,9 €c/kWh
Distributors and Joint Ventures	high	1 (EGS)	3,6 €c/kWh
	high-moderate	2 (Ecotax: exemption and production subsidy	1,3-1,6 €c/kWh
	moderate	1 (Green Funds)	0,4-0,9 €c/kWh
		1 (Green Premium)	2,7-4,5 €c/kWh
	low	2 (EIA and Vamil)	1,2 €c/kWh

Figure 11.4 *The risk-profitability investment context under the Green Premium trading system and all accompanying support schemes, 1998-2000*

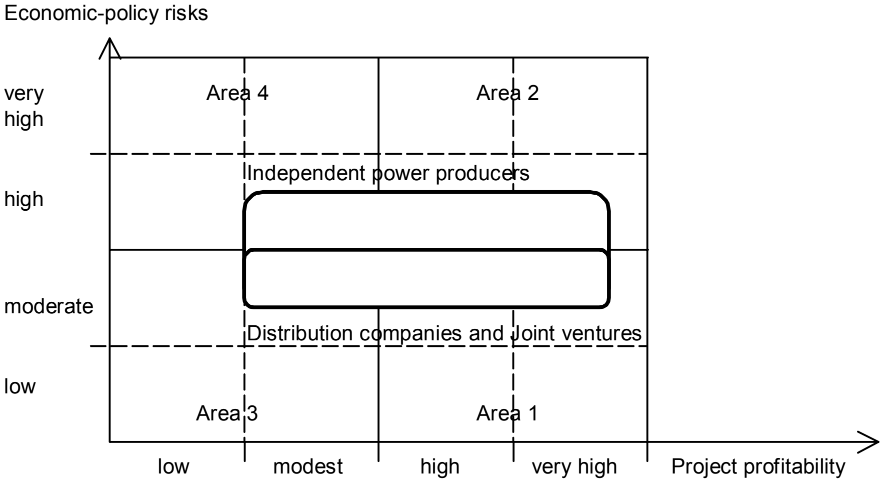

Table 11.19 *Risk levels and profitability ranges under the Green Premium trading system and all accompanying support schemes, 1998-2000*

Types of developers Green Premium system	Aggregated economic-policy risks	Ranges of projects' profitability
Independent Private Producers	moderate - to - high	modest - to - very high
Distributors and Joint Ventures	moderate	modest - to - very high

11.7.2 Formulation of the hypothesis regarding wind technology in the Netherlands

Considering the entire decade of the 1990s as the period for empirical study, our analysis of the risk-profitability context created by the Dutch economic-policy support system led to the following conclusions:

1. In the period 1990-1997, the economic governance structure remained the same but the types of policy support mechanisms changed; however, overall the risk-profitability context remained unchanged for the two groups of developers differentiated. For independent power producers this was placed into the minimal investment context, while for distribution companies and their joint ventures, the support system was placed into political investment context (see Figure 11.2).
2. In the period 1998-2000, the new electricity law put in place another economic governance structure, and new policy support mechanisms entered into operation. These led to the emergence of an investment context that can be described as spanning from moderate-to-high/very high risks and modest-to-high profitability of projects. The investment context for this three-year period overlaps therefore partly all four contexts of risk-profitability theoretically differentiated.

Under these circumstances, we will test a hypothesis for the period 1990-1997 that specifies diffusion patterns for the case when the support system creates a mixture of minimal and political investment contexts - a situation that was not theoretically dealt with. These diffusion patterns draw on those patterns underlying Hypothesis 3 and Hypothesis 4. For developments in the period 1998-2000 no hypothesis will be tested. Instead, diffusion patterns will be analysed and discussed in terms of the main diffusion consequences of the changes in support system and expectations for future investment activity.

Hypothesis 3 contains two branches as regards diffusion results, differentiated by the three preconditions. In Chapter 3 we stated that the installed capacity increase could be modest in short-medium term and market diffusion processes could be sustainable in long term if *three conditions* are simultaneously met:

1. there is a national tradition of entrepreneurship among small developers
2. there is a high level of individual welfare that would enable the expected project developers to invest in such technologies
3. the business culture of traditional financing community is characterised by openness towards small developers and less stringent requirements regarding the minimum profitability of the projects they finance.

The analysis of the extent to which these preconditions are met in the Netherlands led to the conclusion that the branch of the hypothesis that predicts a modest capacity increase and sustainable diffusion should be included in specifying the hypothesis for political-minimal investment contexts. The following paragraphs explain the situation regarding the three exogenous factors influencing diffusion in the Netherlands. After that, we enounce the hypothesis to be tested in Chapter 12 for wind technology diffusion. In Section 11.8 we summarise this chapter.

11.7.2.1 The fulfilment of preconditions under Hypothesis 3 in the Netherlands

Table 11.20 presents the situation regarding the fulfilment of the three preconditions underlying Hypothesis 3. A series of studies commissioned by the Ministry of Economic Affairs[87] lead to the idea that in the Netherlands the spirit of entrepreneurship among small developers is high, and that Dutch entrepreneurs are opened towards investments in

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[87] EZ "Entrepreneurship Monitor Spring 2001"; EZ, 2002: "Entrepreneurship in the Netherlands: Innovative entrepreneurship. New policy challenges!" The Hague.

technology and innovations. Ministerial data show that during the 1990s the entrepreneurial activity increased in the Netherlands. While in 1990 only 30.000 new businesses were registered, this number rose to almost 55.000 in 2001. The number of entrepreneurs as share in the labor force is around 10%, which places Netherlands at the top of the entrepreneurship list internationally. Indeed, a study comparing the net annual growth in the number of small and medium size companies (less than 250 employees) among seven countries found that the highest net growth rate was in the Netherlands with 4,3%[88].

In terms of attitude to innovations, Dutch entrepreneurs do not hold back to invest in innovations. As data in Table 11.21 show, less than one third are ‘followers at a distance’. Small companies are either early adopters or close followers in a proportion of 50 - 65%.

Table 11.20 *The empirical situation for the 3 preconditions of Hypothesis 3*

Preconditions	Empirical situation
Entrepreneurship among small developers	high
Welfare individuals	on average high
Business culture financing agents	favourable to small developers

Table 11.21 *Attitude to innovations of small fast and slow growing enterprises (with up to 100 employees), in percentages*[89].

innovation strategy	fast growing	slow growing
innovators	23	17
early adopters	23	13
close followers	42	37
followers at a distance	12	33

Besides, small/medium size companies do not hold back from investments in technology. For example in 1998, 68% of such companies entering the market, invested in the equipment sector (Wolters et al. 2000: 16). The companies formed during the 1990s proved to be more innovative than incumbent companies. By 2001 around 50% of the total number of registered small/medium size companies launched a new product on the market (EZ 2001), reflecting again the propensity to work with innovations. The largest share of the innovative aspects of their activities regarded new technologies (EZ 2002).

Looking at the investments in wind technology during the same decade the Dutch entrepreneurship spirit appears in its prominent dimension. In spite of the unfriendly risk-profitability investment context for independent power producers, many individuals, cooperatives and small firms dared to invest. They were confronting both the economic-policy risks and the technological risks assumed by an innovative technology that was in addition distant to their core business activities anyway. In terms of number of wind projects, small IPPs were clearly on the first place among the types of developers during the entire 1990s. But because their wind systems had quite small sizes, their share in terms

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[88] The other countries included were the United States, the United Kingdom, Japan, Denmark, Germany and Belgium. Source: Ministerie van Economische Zaken (2001), Ondernemerschapsmonitor zomer 2001 (Entrepreneurship Monitor Summer 2001), Den Haag.

[89] Source: EIM, 2001 based on S.H. Baljé and P.M. Waasdorp (1998), “Snelgroeiende ondernemingen in Nederland” (Fast growing enterprises in the Netherlands), Ministerie van Economische Zaken, Den Haag, figure 6-3, p. 29.

of total MW installed oscillated between 20% - 40%. Some of them also developed projects in joint ventures with distributors or other types of large developers. The cooperative formula is very popular in the Netherlands, especially in agriculture, and had been an important investment vehicle in wind energy too[90]. It can be therefore argued that the precondition for entrepreneurship among small developers is met in the Netherlands, especially during the decade of interest for us, the 1990s.

As regards individual welfare, the situation for Gross Domestic Product per Capita for EU countries since 1995 suggests a high level of individual welfare. The Netherlands takes the 8th place in the European Union with 20.500 €/capita in 1995 and 25.200 €/capita in 2000 (Eurostat 2001). The fact that at EU level the Netherlands comes only on the 8th place is because for three other countries this numbers are just slightly above the Dutch average. Individuals and households are active private investors and investment funds using personal savings have been flourishing during the 1990s. The sufficient availability of private capital enables investments both inside and abroad. Hence, this precondition can be seen as fulfilled in the Netherlands.

Empirical literature[91] suggests that the business culture of the financing community is opened towards small developers and individuals. Compared to other countries, it is relatively easy for them to secure private finance loans. Before the introduction of the Green Funds scheme, small private developers could finance their projects using private loans. Personal assets, generally the house, or farming assets were often considered as collateral. One large bank, the Rabobank has been especially opened towards farmers, since it was initially set up as an agricultural cooperative bank. Dutch farmers are still on the board of the bank which makes it “supportive towards farmers’ financial needs, including loans to wind energy projects” (Mitchell 1994: 150). In addition there are also several ethical banks present in the Netherlands, while a series of commercial banks have special sustainable / green or socio-ethical funds and programs that can offer loans for wind projects developed by individual or small developers[92]. This precondition can be hence also regarded as fulfilled in the Netherlands.

In conclusion, all three preconditions considered are met in the Netherlands in the period 1990-1997. This points towards including the ‘optimist’ branch of Hypothesis 3 in the fine-tuning of theoretical expectations. The investment framework created by the support system for wind energy in the Netherlands would induce diffusion patterns that have features of the patterns expected under Hypotheses 3 and 4. We formulate the theoretical expectations for the situation of a simultaneous use of political and minimal investments context as follows:

An economic-policy support system that creates a minimal risk-profitability investment context accompanied by a political investment context may induce diffusion patterns characterised by:

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[90] “The cooperative ownership concept is well-known in the Netherlands, especially in the agriculture. Cooperative members put cash on the table to create a pool of start-capital large enough to make it worthwhile shopping at the bank for more money” (WPM October 1994: 46). Whenever they have the opportunity to invest again, cooperatives prefer to recycle profits made in new wind projects.

[91] Van Zuylen et a.l (1993), Mitchell (1994); Langniss et al. (1998); Etsu 1996, articles Wind Power Monthly 1994-2001.

[92] See information at the website for investments in projects supportive for sustainable development http://www.duurzaam-beleggen.nl.

- predominately very small and small project sizes;
- developed mainly by small developers, and to a smaller extent electricity companies and other large developers;
- potentially driven to invest by a variety of reasons - commercial, strategic and (partly)-self-generation;
- using predominantly internal financing schemes; and
- conventional technological designs.

These diffusion patterns are likely to lead in short-medium term of diffusion to a modest capacity increase. Diffusion patterns may be able to stimulate the emergence of a socio-economic-industrial context that could lead to sustainable diffusion processes in the long-term. The socio-economic-industrial context would resemble that expected under political investment contexts.

11.7.2.2 The fulfilment of the theory's assumptions in the Dutch case study

In Chapter 2 we formulated a series of assumptions based on which the theoretical analysis was built. In Table 11.22, we summarise the extent of compliance with these assumptions for the case study of wind technology in the Netherlands in the period 1990-1997. On the basis of support system' descriptions made in this chapter, it can be argued that the first four mentioned assumptions in Table 11.22 were complied with.

The fifth assumption was not complied with, because imported electricity could be sold to green consumers too. However, its impact in terms of competition with domestic generators and increase in the investment risks they face was felt more after 1998.

Further, the assumption regarding direct influences on diffusion patterns was not entirely complied with. Firstly, there was pressure - during the first part of the 1990s - from some distribution companies on independent power producers to develop as small as possible projects. When project sizes were not conveniently small in the assessment of distributors, this could have the effect of very low price support per kWh. Later, this came at odds with the pressure from the administrative approval bodies and distribution companies to develop larger size wind projects in order to deal more efficiently with the technical-cost-environmental impacts of wind projects.

Secondly, we assumed that diffusion patterns emerge from market developments and no special encouragement is given to specific forms of the five selected indicators. In the Netherlands however the indicator of financing schemes changed its form in mid 199s when the government introduced a special policy instrument - Green Funds - to encourage non-recourse loan financing. After the introduction of this scheme, external financing schemes became the dominant financing tool. Finally, the assumption that there were no other types of obstacles to impede diffusion - such as administrative, social, institutional, technical (grid) obstacles - was not complied with. In conclusion, the theoretical assumptions were present in the Dutch case study to a satisfactory extent.

The next section summarises the main findings of the analyses made in this chapter. The following chapter tests this tailor-made hypothesis for 1990-1997 and discusses the diffusion patterns for the period 1998-2000.

Table 11.22 *Assumtions of the theory and their presence in the Dutch case study, 1990-1997*

Assumptions of the theory	wind in the Netherlands
electricity industries are liberalised to the extent that market entry of any type of economic actor willing to engage in electricity generation is possible	complied with
there is no governmental limit or requirement on the installed capacity of renewable technology(ies) at industry level	complied with
renewable electricity from partly-self-generation plants may receive the same benefits from the support system as electricity from commercial projects	complied with
the support system remains the same over at least short-medium term	complied with
imported renewable electricity is not eligible for the benefits of the support system	not complied with
there are no direct influences from government intervention on diffusion patterns e.g. on types of developers, types of financing schemes, project size, drivers to invests, choice of technology design	constraints on project sizes and supplementary stimulation for financing schemes (green funds)
no other types of obstacles impede diffusion, such as administrative, social, institutional, technical (grid) obstacles	not complied with

11.8 Summary and conclusions

In this chapter, we analysed the support system for market introduction and diffusion of wind technology in the Netherlands during the 1990s. We started with a short presentation of the governmental support for renewable resources and wind electricity since the 1970s. During the 1970s and 1980s the governmental focus was on the stimulation of research and the creation of a national wind technology industry. In the 1990s, the concern for the market introduction of wind technology was added to the policy program. In terms of the energy resource base of the Netherlands, a decreasing domestic availability of fossil fuels could be observed. The resource security policy concentrated so far on the import of coal. For the long term, biomass, solar-photovoltaic and offshore wind energy offer prospects for a higher contribution in the energy resource base. The potential of on-shore wind energy is very limited both in terms of resource quality and in terms of possibility of siting wind parks. It is estimated that only around 1500 MW wind power could be installed on land.

The 1989 Electricity Law created a legal framework for investments in wind power installations. Both energy utilities and independent power producers could build and operate decentralised wind power plants. This law was replaced by the 1998 electricity act that introduced competition in the electricity sector. In Section 11.4, we made brief descriptions of the structure and operation of the electricity industry based on these two laws. This aimed to put the discussion on the economic governance structure for renewable electricity in its more general framework.

The 1989 law enabled any economic actor to invest in decentralised power plants using renewable resources. Decentralised distribution companies had a limit of 25 MW per plant, but for independent power producers there were no constraints on installation size.

Therefore, there was a partial constraint on the indicator ‘project sizes’, while in theory we assumed that no policy/legal or other factors influence diffusion patterns.

The 1989 law guaranteed the purchase of renewable electricity. But it left most aspects of price design and the issue of contract length at the level of agreements between distribution companies and renewable generators. Analysing the economic governance structure, we concluded that this created an investment context with high economic risks for independent power producers. But in the same time it enabled an investment context with very low economic risks for distribution companies (in their simultaneous position of investors in renewables) and their joint ventures with other economic actors.

Besides, the 1989 law created (unintendedly) the possibility for a very low payment for renewable electricity. The law required renewable electricity be paid the avoided costs of distribution companies. This gave distribution companies a legal basis to interpret the ‘avoided costs’ as the ‘economically avoided’ and not the social or environmental avoided costs of renewable. Consequently, the economic feasibility of wind power investments became entirely dependent on the application of policy support mechanisms able to lift price support sufficiently.

In Section 11.6, we differentiated among three groups of support mechanisms: a) schemes managed by distribution companies; b) schemes administered by the government; and c) schemes backed up by voluntary green consumers. After describing their design, the context of their use and the extent of financial support offered, we concluded that three periods need to be differentiated in order to analyse the risk-profitability context of the support system constructed around the 1989 economic governance structure.

In Section 11.7, we looked at what happened in practice with the implementation of the applicable policy support mechanisms and the economic governance structure in the periods: 1990-1995; 1996-1997; and 1998-2000. Looking closely at the interaction among the numerous support schemes in terms of aggregated risks and overall ranges of profitability for projects, we concluded the following:

- In the period 1990-1997, the support system resulted in a minimal investment context for independent power producers. This was characterised by high economic-policy risks and low-to-modest levels of profitability for wind projects.
- In the period 1990-1997, the support system resulted in a political investment context for distribution companies and their joint ventures with independent generators. This was characterised by very low economic-policy risks and generally modest levels of profitability for wind projects.

In the period 1998-2000, the support system created two trading systems: Green Label and Green Premium. Both of them spread over all four risk-profitability investment contexts as follows:

- For independent power producers, the Green Label trading system enabled modest-to-high profitability for wind projects, but it maintained a context of high economic-policy risks. The independent power producers choosing for the Green Premium trading system had an investment contexts with moderate-to-high economic-policy risks which enabled modest-to-very high profitability levels.
- For distribution companies and their joint ventures with independent generators the Green Label trade system led to moderate economic-policy risks and modest-to-high profitability for wind projects. The distribution companies and their joint ventures sold renewable electricity under the Green Premium trade model, in a framework of

moderate and a economic-policy risks range of profitability for projects that expanded from modest-to-very-high level.

Given the complexity of the risk-profitability investment contexts for the period 1998-2000 and the short time available to observe diffusion patterns and results, we decided to test a hypothesis only for the period 1990-1997. For this period, we developed a hypothesis that specifies diffusion patterns and results for the situation of a support system that simultaneously creates a political and a minimal risk-profitability investment context. The hypothesis states that, under such support systems, diffusion patterns may be characterised by:

- predominately very small and small project sizes;
- developed mainly by small developers, and to a smaller extent electricity companies and other large developers;
- potentially driven to invest by a variety of reasons - commercial, strategic and (partly)-self-generation;
- using predominantly internal financing schemes; and
- conventional technological designs.

These diffusion patterns are likely to lead in short-medium term of diffusion to a modest capacity increase, which may be able to stimulate the emergence of a socio-economic-industrial context that could lead to sustainable diffusion processes in the long-term. The socio-economic-industrial context would resemble that expected under political investment contexts. The next chapter tests this hypothesis for wind technology diffusion in the Netherlands for the period 1990-1997. The diffusion patterns during the years 1998-2000 are analysed only empirically in order to gain insight into the dynamics induced by the described change in the risk-profitability environment.

12

Diffusion of wind technology in the Netherlands

12.1 Introduction

This chapter discusses the diffusion patterns and diffusion results for wind technology in the Netherlands during the 1990s. The purpose of the analysis is to test the hypothesis specified for this case study in Chapter 11. In addition, we also make a discussion on the diffusion patterns in the period 1998-2000. In these years, the support system changed its risk-profitability characteristics in a way that a hypothesis could not be formulated. Besides, the period was too short for hypothesis testing as it was followed by substantial changes in the support system after 2000. In Chapter 2 we argued that a hypothesis may be tested if the support system studied remains the same for at least a short-medium period of time, that is between 5-10 years.

This chapter is organised as follows. Section 12.2 is dedicated to the testing of theoretical expectations for the diffusion patterns of wind technology in the period 1990-1997. Section 12.3 discusses the diffusion patterns for the years 1998-2000 and highlights the changes as compared to the previous diffusion period.

In Section 12.4, we focus on testing the theoretical expectations regarding diffusion results - the installed capacity and the prospects for sustainability of market diffusion processes. The expectations will be compared to the empirical forms as they appeared in 2000. The changes in the empirical forms of the selected indicators between 1998 and 2000 were too small to make two separate and lengthy analyses for them. The important changes that did occur will be specified and explained. Section 12.5 discusses the extent to which the hypothesis was confirmed and draws the conclusions of the Dutch case study on wind technology diffusion.

12.2 Testing theoretical expectations on diffusion patterns, 1990-1997

This section compares the theoretical expectations regarding diffusion patterns for support systems mixing political investment contexts and minimal investment contexts with the empirical diffusion patterns registered by wind technology in the period 1990-1997 in the Netherlands.

12.2.1 Types of project developers

The hypothesis formulated in Chapter 11 expected that projects will be developed mainly by small developers, and to a smaller extent by electricity companies and other large developers. During the period 1990-1997, three types of wind project developers can be differentiated in the Netherlands: energy distribution companies, joint ventures of distributors with private companies and independent private producers (IPPs). Table 12.1 shows their market shares in 1994, 1998 and 2000[1], in terms of MW installed.

Distribution companies dominated in terms of wind capacity owned in the period studied here. However, independent private producers developed by far more projects. Their capacity share remained low because their projects' sizes were predominantly very small. Table 12.2 shows the sizes of projects entering in operation in the period 1990-1997, based on the database of wind projects maintained by company Kema. It appears that around 90% of the

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[1] Data for 1994 came from Wind Power Monthly (July 1994: 16). For 1998, data came from company Kema (Mulekom personal communication file August 1999) and for 2000 from energy agency Novem (website http://www.den.novem.nl 21 June 2002).

projects developed had very small sizes, that is less than 1 MW. They were either solitary turbines or wind systems formed by several low capacity turbines. The database of company Kema also provides the names of projects. These are not always suggestive regarding who are the owners. But combining information from this database, to the extent to which ownership is clear, with information regarding the names of wind projects developed by utilities from other sources[2], it can be safely concluded that the vast majority of projects put into operation in 1990-1997 was developed by independent power producers[3].

Table 12.1 *Market shares in terms of capacity for different types of developers of wind projects in the Netherlands*

Share in terms of MW installed	Distribution	Joint venture distributors private investors	Independent private producers
1994	60 %	19 %	21 %
1998	50 %	26 %	24 % (of which 4 % associations)
2000	38 %	23 %	37 %

Table 12.2 *Project sizes for wind systems in the Netherland,s 1990-1997*[4]

Project sizes	1990	1991	1992	1993	1994	1995	1996	1997
single turbines or small systems </=1 MW	13	15	21	47	60	113	53	4
projects 1 - 5 MW	2	2	2	2	2	5	3	7
projects 5 - 15 MW	-	1	1	2	1	4	1	2
projects > 15 MW	-	-	-	-	-	1	-	-
Total number projects 1990-1997 = 364	15	18	24	51	63	123	57	13

In the group of independent private producers, farmers and cooperatives formed the backbone of owners. Cooperatives were in most of the cases agricultural, but sometimes they also included other local actors, such as local authorities and building societies (IEA 1995: 104). Green-minded associations and small companies also developed a small number of projects[5]. But often behind the small companies there were also farmers who sometimes were required to adopt this legal status in order to secure financing[6].

In 1993 the ethical bank Triodos also entered the market. Later, in 1995/1996, other investment groups and banks emerged as project developers (co-owners), with the introduction of Green Funding scheme (See Chapter 11). They developed projects both in joint ventures with distributors and as independent private producers.

Industrial production companies were expected to appear as project owners. However, they did not invest in renewables because they were part of long-term voluntary agreements

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[2] The articles in Windpower Monthly from 1994 to 2001 and the annual reports of distribution companies mention many wind projects where distributors were sole owners or co-owners. The project names from these sources were confronted with those available in the Kema database.

[3] During the first years of the 1990s, distribution companies also developed very small systems. But in the same time, independent power producers also invested in several small and modest size plants during 1996-1997.

[4] Based on database wind projects of company Kema available at http://www.kema.nl/sustainable on the 20th of January 2001.

[5] Kema (Mulekom 1999) and information at Novem website 20 June 2002.

[6] Sources: International Energy Agency (IEA 1995: 104); Langniss et al (1998; case study 5).

with the government for energy conservation. The use of renewable forms of energy was included in the list of options. But this proved to be one of the most expensive alternatives for energy saving (Ecofys 1999: 6). ‘Green image’ did not seem to be so important for them as for distribution companies and it could have been eventually defended based on the application of other measures for energy conservation. This is also the main reason why (partly-)self-generation projects by industrial production companies did not emerge.

From energy companies, only distributors developed wind power projects, as part of the Environmental Action Plan (MAP). The four large electricity generation companies had long-term agreements with the government to improve energy efficiency. The only renewable resource used was biomass in co-combustion plants.

The presence of joint ventures between distributors and independent private producers can be explained by the following factors:

1) it was easier for independent private producers to arrange local permits than for distributors;
2) distribution companies were interested to harness profits from as many as possible wind plants, and not only to intermediate the flow of subsidies from Environmental Action Plan levy fund to independent private producers[7].

It can be concluded that the expectations regarding types of developers are *to large extent confirmed*. The predominant developers were indeed small independent power producers, who were behind around 80-90% of the number of projects commissioned. Beside them, there were distribution companies investing in fewer but larger projects, which gave them the leadership in terms of capacity market share. Wind systems owned jointly by independent producers and distributors were also developed. What is missing from the predicted picture is the presence of industrial production companies.

But one comment needs to be added. Both the emergence of distributors as developers and the absence of projects owned by industrial-production companies are related to the voluntary agreements concluded between these actors and the government. Although distribution companies built some wind projects already before 1990, it was the 1991-2000 Environmental Action Plan that brought distributors more substantially into the wind business. However, the multi-annual agreements of the government with production industries were not stimulating for their involvement in wind energy use. The agreements left it to the choice of companies if they wanted to use renewables as means to reduce environmental impacts, or if they preferred other technologies. The industrial production companies that chose to become (partly-)self-generators preferred to develop co-generation plants, as they were both cheaper and able to provide heat energy too.

12.2.2 Project sizes

The hypothesis formulated in Chapter 11 predicted that project sizes will predominately be very small and small. Based on data shown in Table 12.2 it can be calculated that in this period:

- almost 90% of projects had very small sizes (< 1MW);
- 6,8% of projects were small size (between 1 - 5 MW);
- 3,3% of projects were medium size (between 5 - 15 MW); and

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[7] As a distributor put it, they were interested in projects "where costs and profits would be shared between the utility and private developers" (WPM May 1997: 38).

- only one project was larger than 15 MW, representing 0,3% of total capacity installed in this period.

These data *confirm* our expectations. Theoretically, the 1989 Electricity Act posed constraints on this indicator, as there was a plant size limit of 25 MW for distribution companies. However, by making joint ventures with private companies, distributors could go around this constraint. During the 1990s there was only one wind project larger than this ceiling developed: the 34 MW plant owned by distributor EDON and the American manufacturer Kenneth.

The vast majority of very small size systems were in the form of solitary turbines with very small installed capacity. Almost 200 solitary turbines - i.e. 55% of total projects - used Lagerway 80 kW or 75 kW turbines. The installed capacity of solitary turbines increased only very slowly after 1995, when around 80 solitary turbines (22% of projects) had capacities of 250 kW or 300 kW. The overwhelming presence of very small size systems is partly due to constraints placed by distribution companies buying wind electricity on independent private producers.

There are many indications that, distributors were placing ceilings on the sizes of independent private producers' plants for which they were willing to pay production subsidies from Environmental Action Plan budget and to increase contract length. But there were no uniformities: different distributors placed different ceiling and they were not even the same for all independent private producers in the region[8].

In 1995/1996 some distributors started to complain that there is "poor economic and technical sense" in building single turbines or small systems. This initiated a reverse trend in the preference of distributors to conclude contracts with independent power producers. At least three main reasons can be pointed out for this reversal. Firstly, distributors had to pay for grid connection costs, and per company these piled-up indeed with the increase in solitary turbines. Secondly, distributors wanted to be part of the profits generated by as many as possible wind plants in the country. And thirdly, they were interested in joint ventures with independent power producers as this would have made it easier for them to get local permits and as they would not face the 25 MW plant size limit in this case, as regulated in the 1989 Electricity Act. These overlapped with the decision of regional authorities to promote rather large wind farms, in line with the recommendations of the governmental 1997 "Renewable Energy Report".

12.2.3 Drivers to invest

The hypothesis formulated in Chapter 11 predicted that project developers would be potentially driven to invest by a variety of reasons - commercial, strategic and (party)-self-generation. In practice, small developers such as farmers, cooperatives and associations were driven to invest by a combination of green ideology[9] and the attractiveness of a secondary

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[8] For example the distributor Deltan agreed to purchase from the Zeeuwind Cooperative only as much electricity as its members consume annually. This was estimated as 750 kWh per year per person and 5x750 kWh/year per company member to the cooperative. Wind electricity generated above the total consumption ceiling was only paid the Standard Arrangement payment of 3,2-4 €c/kWh. In 1993, the distributor RED paid 5,45 €c/kWh only for turbines below 350 kW owned by cooperatives (van Zuylen & van Dijk 1993). The distribution company PEN said only projects smaller than 600 kW can ensure a production subsidy from the Environmental Action Plan, and "anything more has to be negotiated" (WPM March 1995: 24). For the year 1996, the distributor EDON "decided it would not contract more than 2 MW of privately owned wind power" in its region (WPM February 1996: 30).

[9] The energy agency Novem mentioned about cooperatives that "This form of private initiative comes especially from idealistic reasons" (http://www.den.novem.nl). See also Langniss et al. 1998 (case study 5)

income stream. As regards the first driver, the connection with land is felt very strongly among farmers and cooperatives in the Netherlands. For them the idea of sustainability and leaving future generations a clean environment is very close to their mind and has more weight than for city dwellers. But in the same time, wind energy is attractive for them as a secondary economic activity, since wind turbines do not hinder agricultural activities of small scale.

The absence of (partly-)self-generation investments by industrial companies was already explained in Section 12.2.1. As regards distributors, the main driver behind their investments in wind plants was innitially the improvement of environmental performances in agreement with the government. They also had the intention, in the first part of the 1990s, to become leaders in the exploitation of the national wind resources. Later, in 1995/1996, the liberalisation of energy industries brought about new strategic reasons such as green company image and improved public relations. Distributor PNEM was the first to become aware of this, already in 1994, and took action to build up an image of green utility (Mitchel 1994: 149). There are several other companies who emphasized their interest for renewables in the ideological sphere. For example, NUON had already chosen a more ambitions company target than its corresponding share in the Environmental Action Plan target. But in the same time distributors did not agree to operate unprofitable wind plants. They ensured that they would make profits within the limits allowed by their legal status (see Chapter 11). Consequently, the overwhelming majority of projects were developed based on a combination of strategic and commercial resons to invest. Having in view the absence of self-generation projects, we conclude that the expectations regarding this indicator have been *partly confirmed* by empirical findings.

12.2.4 Types of financing schemes

The hypothesis formulated in Chapter 11 predicted that projects are likely to be predominantly financed based on internal financing schemes.

In practice, up to 1994, internal financing schemes were indeed used as the main investment tool[10]. Independent private producers were using either private finance or participation finance[11]. Private finance was mainly used when developers were individual farmers. Farming assets and land formed the loan guarantee most frequently. Loans were given by Rabobank for 10 years debt-maturity at interest rates of 7 - 8% on average (i.e. 1 - 2% above average market rates). In her study covering the topic of financing of wind projects in the Netherlands in ealry 1990s, Mitchell explains (1994: 150) that Rabobank was set up as an agricultural cooperative bank and the overwhelming majority of farmers carried out their financial transaction with it. Besides, farmers were still present on the board of the bank and had influence into "the lending policy of the branch". For these reasons Rabobank was especially sensitive to the financial needs of farmers and continued supporting them with loans even in the difficult circumstances of high investment risks and low profitability. In addition, other cooperative banks were helping farmers with loans too[12]. By 1994 around 100 single-turbine projects developed by farmers used the private finance approach.

[10] There were two exceptions: a wind park that used project finance and a project that used institutional finance. Both of them had the involvement of the same distributor (EGD from Groningen).

[11] Van Zuylen et al. (1993); Mitchell (1994: 151); Langniss et al. 1998 (Joosen S., case studies 5 and 6); Articles Wind Power Monthly 1994 - 1996. Interviews August and September 2002 with cooperatives Zeeuwind (Scheuerman); Noordenwind (Kap en Wiegersma-Colmer); CVWD (Kees Veerman), Fred van Vliet, Zaanse Energie Koöperatie (Dick Beets), VCBW (Wim Kersten).

[12] Langniss et al. 1998 (Joosen S., case study 5).

Participation finance was used when the developer was a cooperative. Money was coming from savings of cooperatives' members, or sometimes from building societies too, when they were also members of the cooperative. In some cases loans also contributed to the capital structure of projects (van Zuylen et al. 1993). But, still, mainly non-project assets were accepted as collaterals. Cooperatives have been traditionally large in the Netherlands, with 150-500 members. Individual members invested between 230-500 Euro for a return on equity of 2 - 8% over 10 years (Mitchell 1994: 151). The small amount individually invested can partly explain the willingness of cooperatives to accept the high policy risks for wind projects. This created synergies with the interest to have secondary income streams and with the ideological motivation to invest in a green business. By 1994, around 30 small or single-turbine projects were financed by cooperatives, based on the participation-financing scheme.

In addition, independent power producers could use investment subsidies. These are considered in the Netherlands as reductions from the equity that developers have to contribute in the capital structure of projects, and not as reductions from the contribution of bank loans, as in Spain[13]. This approach of banks added to help independent power producers have more easy access to bank loans. Thanks to availability of investment subsidies, the equity contribution of cooperatives in total capital structure of projects could be sometimes as low as 5%. In this period, the returns on equity for independent power producers were between 2 - 8%, while interest rates were between 3 - 9% (See Section 11.7.1.1). Soft loans for wind projects were given by the ethical bank Triodos[14] beginning with 1993, but collaterals were still formed by non-project assets (Mitchell 1994: 150).

Distribution companies used generally investment subsidies up to 50%[15], and sometimes up to 66%, while the rest came, up to 1994, in the form of[16]:

- debt-corporate corporate finance or
- in-house corporate finance (more rarely) or
- a combination of in-house cash and corporate loan.

Their projects had generally lower interest rates, of 5 - 6%[17]. Distributors used frequently loans from public funds with long debt-maturity, of around 20-30 years (IEA 1995: 107). Besides, given their public company status, they could also benefit of substantial contribution of corporate loans in projects' capital structure, of 95% or even higher (Etsu 1996: 94). When projects were built under joint ventures between distributors and independent power producers, the financing formulas were highly similar to the ones when distributors invested on their one, with the difference that the independent power producers generally participated with 5% of equity in the capital structure of the project (Mitchell 1994: 148).

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[13] Mitchell (1994: 150); Langniss et al. 1999 (Joosen S., case study 6).

[14] The main contributors to the Windfunds of Triodos were households, with around 75% of deposits. The rest came from green-minded companies, especially the cosmetics shop chain Body Shop. The returns on investments were small, between 3% - 7%, and relied strongly on environmental motivations: "The incentive of people to buy shares in the fund is the knowledge that they can compensate for the environmental damage cause by their electricity consumption" (Triodos bank, Peter Blom, in Wind Power Monthly [April 1994: 22]).

[15] Around 25 % Environmental Action Plan investment subsidies, and around 25% governmental investment subsidies (van Zuylen et al. 1993; Mitchell, 1994).

[16] Etsu 1996: 94; van Zuylen et al. 1993.

[17] However, when they had to justify and calculate their returns on equity, as limited by their status of public companies, they were using the upper level on the general market, of 9%. These were generally in the range of 8 - 9% (Mitchell 1994), resulting in overall profitability of projects of 5-10%.

As mentioned there was also one particular case of finance that can be described as 'institutional finance' in our typology. As Mitchell explains (1994: 149), one distributor was not ready to invest its own capital in wind energy, and developed a 4,25 MW wind project by issuing bonds to its consumers. The agreement was that after 15 years the bonds would be bought back. The return-on-equity given to consumers buying bonds was only 5% (real annual), while the profitability of the project was 8%. The distributor had the remaining profits while investing no equity at all. The rest of the bond money was used in the form of equity in a new wind project developed in joint venture with the Dutch turbine manufacturer Micon. This was one of the few project based on external finance before 1995.

In 1995, several wind plants benefited of project finance for which interest rates were 9% (IEA 1995: 107). They were developed with the participation of distributors and/or the Triodos Bank which was already offering soft loans from volunatry investment funds[18].

Begining with 1996 the Green Funding scheme entered into operation. The perception of financing community on wind projects improved fast as individuals and company green investors were filling in the newly opened green investment funds[19]. The exemption on income taxes for green funds was linked to the nature of the project. This way the collateral for loans coming from green funds had to be changed from private into wind project assets and cash flows[20]. Banks started to agree more easily to give project finance to a wider range of developers. Moreover, due to the abundance of funds and the restricted number of new project proposals, two phenomena occurred:

1) the reduction of equity contribution of developers in the capital structure of projects; for independent power producers this could be 5% or even 0%; for distributors this was also as low as 1 - 5%[21];
2) the transformation of some already financed projects which used internal financing schemes, into project finance with soft loans.

The number of banks developing Wind-Funds or more generally Green-Funds increased rapidly. In early 1996, the following banks had green funds: Triodos, ASN, ING Bank, Rabobank, Credit Lyonaiss and Mees Pierson (Etsu 1996: 89). The Green Funding scheme has lead therefore to a fast and massive shift from internal financing schemes to 'project finance'. It is estimated that in the period 1996-1999, around 100 MW new wind plants of the total 160 MW built used project finance with soft loans from Green Funds (Ecofys 1999: 22). Besides, some banks - especially Triodos and ING bank (Etsu 1996: 89) were also investing equity in

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[18] For example Joosen (Langniss et al. 1998, Case Study 4) describes a 5 MW wind plant developed by 2 utilities and one green bank based on project finance. All co-owners wanted to remain anonimous. This plant was planned since 1990 but entered into operation only in 1995.

[19] Anticipating the entry into operation of Green Funds scheme, Rabobank and the Robeco Investment Fund set up in October 1995 a wind fund with great popularity. A large financial contribution was achieved in a very short period of time. The commercial bank ABN-Amro also entered market in 1996 with a WindFund. The ASN Bank also opened such funds and was especially opened towards farmers and cooperatives. This is historically a union bank and stimulates sustainable projects (Joosen S., Case Study 6 in Langniss et. al. 1998). The returns on green investment arranged by banks administering WindFunds remained mainly in the range of 3-4,5%, with few funds going up to 7% (WPM December 1997: 17).

[20] Sometimes the bank was also asking the land on which the turbine was placed as collateral, but was still accepting both the turbine and the purchase contract for wind electricity as collaterals (Joosen in Langniss et al. 1998, case study 6).

[21] van Fliet 2002; Scheuerman (2002); Joosen S., Case studies 4, 5 and 6. (in Langniss et al. 1998). Information under confidentiality with a distribution company.

wind projects. Due to exemption on income tax, interest rates remained in the range of 3 - 4,5% during the second half of the 1990s[22]. The average debt maturity was of 10 years.

Consequently, the dominant financing approach for all types of project developers before 1995 was the use of internal financing schemes (but no third party financing). Since 1995/1996 project finance has become the dominant way of financing wind projects. The introduction of the Green Funds scheme explains the use of project finance scheme, which was not expected under the hypothesis. The theoretical expectations can be considered as *confirmed for the period 1990-1995* and n*ot confirmed with comment* for 1996-1997.

12.2.5 Technology choice

The hypothesis formulated in Chapter 11 predicted the use of conventional technological designs. Practical developments *confirmed* this expectation, although there was some restriction in technological choice in the Netherlands.

In the theoretical part of the project it was assumed there are no constraints on developers and their financiers regarding what technology type they should use. In practice, in the Netherlands the technological choice was however constrained by some factors. Firstly, many local and provincial authorities developed approval rules that limit the height of turbines that could be installed. For example, in Friesland and Groningen solitary turbines cannot be higher than 40 - 45 meters, while in Flevoland a maximum hub height of 55 meter is allowed[23]. Data in column 6 of Table 12.11 (Section 12.4.2) show that the hub height of turbines installed in 1990-1997 did not overpass 45 m[24].

Table 12.3 *The years when wind turbine designs were for the first time adopted in the Netherlands, 1989-1997*[25]

Manufacturer / kW-turbine	1989 or earlier	1990	1991	1992	1993	1994	1995	1996	1997
Lagerway	30; 75	80	-	-	-	-	-	250[26]	-
Micon	250	-	-	-	-	225; 600	400		-
NedWind	160; 250	-	500	-	-	1000	-	-	-
Windmaster	-	-	300; 500; 750	-	-	-	-	-	-
Vestas	-	-	225	400	-	-	500; 600	-	-
Bonus	-	-	-	-	-	250 500	300; 600	-	-
Nordtank	-	-	-	-	-	300	500	600	-
Kenetech	-	-	-	-	-	-	362	-	-
Tacke	-	-	-	-	-	-	600	-	-
Enercon	-	-	-	400	-	-	-	-	-

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[22] Information at the websites of company Kema (http://www.kema.nl/sustaimable) and energy agency Novem http://www.den/novem.nl, the Project Bureau Renewable Energy PDE http://www.pde.nl, Case studies 4, 5, 6 by Joosen S. in Langniss et al. 1998.

[23] By 2001, height constraint rules remained unchanged, although there were plans to remove them. (Source: Home Nieuws Newspaper, 27 August 2001 "The height of wind turbines does not increase").

[24] From 1998 to 2002, the maximum hub height of installed turbines remained 55 m.

[25] Based on statistics of company Kema at http://www.kema.nl/sustainable.

[26] This turbine was introduced in 1992 but sold (demanded) only abroad until 1996.

Secondly, up to 1994/5, another constraint was posed by the relationship between the availability of investment subsidies and turbine brand. The 1986-1995 investment subsidy program was also meant as a means of governmental support for the domestic manufacturing industry[27] (Wolsink 1996: 1080). In the last years however, 1994/1995, grants were also received by developers using foreign turbines. As Table 12.3 shows, the four main Dutch manufacturers - Lagerway, NedWind, Windmaster and Micon - produced in this period nine designs of small-size turbines, that is below 500 kW installed capacity.

These Dutch designs accounted for 63% of the wind turbines installed between 1990 and 1995. Since 1996, the general governmental investment subsidies were not available anymore. In the years 1996-1997, only 45% of new turbines installed were from Dutch manufacturers - also with capacities below 500 kW per turbine. In the period 1990-1995, higher capacity Dutch turbines were also available - 500 kW, 750 kW and 1 MW - but they were mostly affordable to distributors.

The limited availability of finance forms the third constraint on technology choice in the case of independent power producers, up to 1995 when the Green Fund scheme entered into operation. Some banks were willing to give independent power producers loans taking non-project assets as collaterals. However, there had to be a match between the expensiveness of the wind project and the financial value of the non-project collaterals. Consequently, most independent power producers could not afford the more expensive larger size turbines and larger-size projects. In Chapter 4 we operationalised the indicator of technological design choice from three performance-perspectives: 1) contribution towards grid-friendliness and compatibility for stand-alone application; 2) improvements brought in the efficiency of wind energy harnessing; 3) the ability to function in low wind speeds, below average annual levels of 5 m/s.

As regards the first two performances mentioned - grid friendliness and efficiency - empirical data summarised in Table 12.4 show that around 44,4% of capacity was represented by turbines harbouring modest improvements in grid friendliness and efficiency. Only 1,6% of total capacity was represented by technology designs with simultaneous substantial improvements in grid-friendliness and modest improvements in efficiency. The rest 54% were conventional designs of wind technology.

As concerns the ability of turbines to use wind energy at lower wind-speed sites, the turbines installed 1990-1997, do not reflect too much progress. The wind speed at which the installed turbines start working remains at around 5 m/s, while the wind speed at which the nominal power is reached stays in the range of 11-16 m/s. These numbers define the conventional turbines. Lagerway is the only manufacturer located in the Netherlands that we identified, which is concerned with developing turbines for moderate wind regimes. One version of the 750 kW introduced in 1999 was especially developed for moderate wind on land. The cut-in speed is lower, 3 m/s. But it reaches nominal power at around 14 m/s, which is still quite high. Progress so far is small, but the concern has emerged on the company's agenda. The R&D activities of Lagerway are strongly stimulated by requests from abroad[28]. Consequently, overall, for the period studied it can be argued that no progress was achieved from this performance perspective. Based on these empirical data, the expectation that conventional designs would predominate market choice can be considered *confirmed*.

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[27] Especially the 250 MW Wind Plan of distribution companies gave preferential treatment to Dutch manufacturers. This initiated protests from foreign companies. But the plan lasted only between 1991-1993 (Wolsink 1996: 1085).

[28] Information at company website: http://www.lagerway.nl.

Table 12.4 *Market shares of technological designs for wind technology from grid-friendliness and efficiency perspectives, 1997, in the Netherlands*

Manufacturer[29]	Wind turbines based on the horizontal axis technological principle			
	Voltage control type	Rotor speed type	Generator type	Design/ Market share[30]
NedWind *	Stall control	Constant speed	Asynchronous	conventional (54% market share in 1997)
Micon *	Stall control	Constant speed	Asynchronous	
Bonus	Stall Control	Constant speed	Asynchronous	
Nordtank *	Stall control	Constant speed	Asynchronous	
Tacke	Initially stall control Later pitch control	Variable speed	Asynchronous	modest improvements in grid friendliness and efficiency (44,4% market share in 1997)
Vestas	Pitch control	Variable speed (limited range)	Asynchronous,	
Windmaster *	Pitch control	Variable speed	Asynchronous	
Kenetech *	Pitch control	Variable speed	Asynchronous	
Lagerwey	Pitch control	Variable speed	Asynchronous, models < 300 kW	
Enercon	Pitch control	Variable speed	Synchronous	substantial improvements in grid-friendliness and modest improvements in efficiency (1,6% in 1997)

12.2.6 Conclusion regarding the extent of confirmation of theoretical expectations for diffusion patterns

Section 12.2 looked at the diffusion patterns of wind technology in the Netherlands in the period 1990-1997. The five indicators for diffusion patterns took in practice forms that are close to those predicted for the given risk/profitability investment framework. They are summarised in Table 12.5.

The expectations regarding project sizes and choice of technological designs were *confirmed.* Investments were predominantly in the form of very small wind projects based on conventional technology designs. The conclusions regarding technological improvements in 1990-1997 in the Netherlands were as follows:

- 1,6% of the total capacity had technical characteristics able to bring substantial performance improvements from the grid-friendliness perspective;
- 46% of capacity used designs with *modest* efficiency improvements, while only
- 54% of the installed capacity was based conventional wind turbines; besides,
- 1 manufacturer was concerned with technological designs for moderate wind speed.

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[29] Manufacturers with (*) do not exist anymore under this name. They were taken over or merged with others as follows: Polenko was taken over by NedWind; Bouma was taken over by NedWind (1990); Tacke was taken over by Enron Wind (1997); Kenetech (former US-Windpower) was taken over by Enron Wind; Micon and Nordtank merged into NEG-Micon (1997); Windmaster was taken over by Lagerwey (1998); NedWind was taken over by NEG-Micon (1998); Enron Wind was taken over by General Electric Power Systems (2002), now named GE Wind Energy. Source: http://home.wxs.nl/~windsh/statsnl.html 27 December 2000.

[30] Source of market shares data based on Kema statistics at http://www.kema.nl.

Table 12.5 *Theoretically expected and empirically registered diffusion patterns for wind technology in the Netherlands 1990-1997*

Practical developments	Theoretical expectations
Types of project developers	
- small developers dominated numerically; - distribution companies and public-private ventures present and dominate in terms of installed capacity (fewer projects)	small developers as dominant investors; presence of industrial production companies and energy companies to smaller extent (confirmed to large extent)
Drivers to invest in wind projects	
- most projects based on a combination of commercial and strategic reasons;	combinations of commercial, various strategic reasons and self-generation (partly confirmed)
Type of financing schemes	
- internal financing schemes before 1995 (private finance, participation finance, debt-corporate and in-house finance) - project finance dominate since 1996	internal financing schemes (overall: partly confirmed: confirmed for1990-1995 and not confirmed with comment for 1996-1997)
Project sizes	
- very small (<1MW) = ~90 % of projects - small (1-5 MW) = 6,8 % of projects - medium (5-15 MW) = 3,3 % of projects - large (15-25 MW) = 0, 3 % (1 project) - very large (>25 MW) = no projects	presence of very small, small and medium size projects (confirmed)
Technological designs	
- predominantly conventional technological designs	conventional technological designs dominate (confirmed)

The parts of the hypothesis that concern the types of developers were *confirmed to large extent*, but the expectations regarding their reasons to invest were only *partly confirmed.* The missing elements from the predicted picture for these two indicators were investments by industrial production companies in self-generation plants. Industrial companies were not stimulated to invest in wind energy as (partly-)self-generation and/or strategic projects because they had environmental long-terms agreements with the government. These agreements made possible the use of cheaper technologies to improve environmental performances. The other types of economic actors considered in the category of small developers did not appear interested in self-generation, but rather in commercial projects.

The expectations referring to financing schemes were assessed as overall *partly confirmed*. In the period 1990-1995, the expectation to observe predominantly internal financing schemes was confirmed. But since 1996, a shift towards external financing schemes was observed, which moreover became the predominant financing approach in a very short period of time. Their presence is explained by the availability of soft-loans from Green Funds. This was a special policy support mechanism used by the government to improve the financing context for environmentally friendly projects. But theoretical expectations were developed by assuming that there are neither constraints nor specially designed instruments that can affect the forms of diffusion patterns. In 1995 there were signs that banks increased their willingness to approve project finance loans for wind technology. But, as it happened in Spain, distributors were the developers envisaged for accessibility to such loans[31].

In conclusion, the observed diffusion patterns match those theoretically expected to an extent that is sufficiently large to support the continuation of empirical investigation regarding

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[31] Forming joint ventures with banks was one of the strategies used by distributors to improve likelihood of project finance loans in 1995 (Joosen S., Case Study 4 in Langniss et al. 1998).

the dependent variables of the analytical framework. This analysis is done in the next Section, 12.4. Before that, the next section presents the forms of the five indicators for diffusion patterns in the period 1998-2000. For these three years there were two trading systems working in parallel. The additionality principle ensured that there was no financial interaction between them. These new trading systems did not have the same risk profitability characteristics, but they resembled to some extent. Figures 11.3 and 11.4 in Chapter 11 show these contexts. They both differ from the context that existed in the period 1990-1997. A hypothesis for this period was not formulated because the risk-profitability profile was spread over parts of all four areas theoretically differentiated. This impeded the design of a tailor-made hypothesis. We only examine how diffusion patterns looked like in 1998-2000 and draw a conclusion regarding which theoretical expectations they resemble most, from the four areas considered in Chapter 3.

12.3 Diffusion patterns in the period 1998-2000

12.3.1 Types of developers and drivers to invest, 1998-2000

In this period there were three basic changes with regard to types of developers. Firstly, with all the obstacles encountered, the number of projects developed by independent power producers was higher than that of distributors. Besides, also the capacity installed by them in 1998-2000 was larger than that put up by distributors[32]. Table 12.6 shows the number of projects developed by distributors as sole owners, the capacity these projects represent and the share in the annual capacity increase. As the last row of Table 12.1 showed, independent power producers and distributors owned by 2000 almost the same market shares, with 37% respectively 38% of the total installed capacity.

Secondly, increasingly more projects of distributors were developed under joint venture approach, either with private companies or with individuals.

Table 12.6 *Projects developed by distributors, 1998-2000, compared to market development*[33]

Years	Number of wind projects		Installed capacity [MW]	
	Distributors	Total	Distributors	Total
1998	3	28	22,5	42
1999	2	36	1,5	46
2000	5	24	20,7	37
2001	2	24	2,6	18

Thirdly, the types of developers inside the group of independent power producers also changed. If up to 1997, the backbone was formed by farmers, agricultural cooperatives and green-minded associations, since 1998 the main developers in the independent power producers group became institutional investors and new private companies[34]. Institutional

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[32] Information from company Kema personal communication file with statistics, Mulekom 2000). As the Wind Power Journal also writes "Even without a guaranteed return, however, private investors continue to set the pace leaving the large utilities trailing in their wake." (WPM February 1997: 24)

[33] Based on information at http://home01.wxs.nl/~windsh/statsnl.html.

[34] Source: energy agency Novem www.den.novem.nl/wind/subsite/data/712.htm. at 17 June 2002.

investors entered the market in 1996 with the introduction of the Green Funding scheme[35] and manage to expand their market share to 24% by 2001.

But behind the 'new' private companies there are often the traditional independent power producers: cooperatives and farmers. As explained in Section 12.2.4 in order to approve project finance some banks require that the developer had the legal status of private company. This ensures the financier that the only and stringent goal of the developer is commercial - to generate as much profit as possible[36]. Overall, the base of project developers was enriched but in terms of number of projects, small independent power producers remained dominant. The picture of drivers to invest remained the same as in the years 1990-1997.

12.3.2 Financing schemes, 1998-2000

During these years, wind projects continued to be primarily financed based on external approaches - project finance and institutional finance as in the previous period[37]. The financing parameters were similar to those in the previous period. However the situation in 2000 started to give signs of return to internal financing schemes. The reason is the uncertainty on preservation of fiscal incentives, especially the tax-status of green funds, and the general direction of the support system post 2000.

The renewables agency opinated in 2000 that "At the moment the banks are particularly cautious and they will become increasingly reluctant to finance projects if this degree of uncertainty continues"[38]. Besides, the increasing complexity of the support system was also a threat for external financing schemes. As two experts explained: "To overcome these complexities investors use consultants and financial advisors to assess the implications for their investment case." (Kwant and Ruijgrok 2001). In addition, the financing agents administering green funds were being offered increasing choice of projects with good prospects for returns on investments. For example, the Triodos bank stopped operating a special WindFund in 2000, to serve new types of green projects with lower regulatory complexity and uncertainty on returns. In mid 2000, the demand for tax-free green capital exceeded the supply by 1,68 billion Euro (WPM June 2000: 22).

12.3.3 Technological choice, 1998-2000

Compared to the previous period, more developers chose for technologies with grid-friendly technical features. Table 12.7 shows the market share at the end of 2000 of different manufacturers. Using their technology characteristics from Table 12.4, it appears that the market-share of designs with modest improvements in grid friendliness and efficiency increased from 44,4% at the end of 1997 to 61,7% at the end of 2000. In the same time the share of designs using synchronous generators increased from 1,6% to 4,3% in 2000.

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[35] Institutional investors are the financing agents who opened Green Funds. As in the first years more money was available than projects requiring loans - especially due to local approval obstacles for small projects of the other independent power producers) some financial agents took the initiative to use parts of the green funds as equity and become project developers themselves.

[36] Joosen S., Case Study 5 in Langniss et al. 1998.

[37] In 2000 the following banks offered green soft-loans and or equity investment funds: ABN AMRO, ING, Rabobank, Triodos, Triodos Groenfonds N.V., ASN Bank. The following green investment certificates were available: Nationaal Groen Beleggingsfonds, Postbank Groenrente Certificaat and Robeco Groenrente (Source http://www.duurzame-belegging.nl).

[38] The director of Project Agency Renewable Energy (in WPM October 2000: 38).

12.3.4 Project sizes, 1998-2000

Table 12.8 shows the sizes of projects based on wind technology developed. In the years 1998-2000, the situation can be described as the same to that in the period 1990-1997, with very small projects being overwhelmingly dominant. In 2001, the situation started to change slightly, with more small size projects being put into operation (1-5 MW). Small projects represented one-third of the total number of projects developed in 2001.

Table 12.7 *Market shares of technological designs for wind technology from grid-friendliness and efficiency perspectives, 2000, in the Netherlands*[39]

Manufacturer	MW in end 2000	% end 2000	Market shares in 2000 per type technological design
NedWind * *	99	16 %	conventional designs (42 %)
Bonus	31	9 %	
Nordtank *	36	10 %	
Micon *	33	8 %	
Vestas	89	25 %	modest improvements in grid friendliness and efficiency (54 %)
Windmaster *	41	7 %	
NEG-Micon	36	10 %	
Kenetech *	35	5 %	
Lagerwey	32	8 %	7,7 % modest improvements.; 0,3 % substantial improvements
Enercon	7	2 %	substantial improvements in grid-friendliness and modest improvements in efficiency (4 %)
Tacke	4	1 %	
Enron Wind	1,5	0,5 %	
Others	1	0,5 %	n.a
Total	445 MW	100 %	-

Table 12.8 *Sizes of projects based on wind technology in the Netherlands, 1998-2001*[40]

Project size	1998	1999	2000	2001
single turbine or < / 1 MW	24	32	21	14
1-5 MW	3	-	2	8
5-15 MW	-	4	-	2
> 15 MW	1	-	1	-

12.3.5 Conclusion regarding changes in diffusion patterns, 1998-2000

In conclusion, the support system described by the two new trading models in the period 1998-2000 induced a change in the types of project developers as compared to the previous period. More projects were developed by independent power producers than by distributors. Financing agents and institutional investors became more active in projects' building and the number of joint ventures between independent power producers and distributors also increased. As regards sizes, projects formed by solitary turbines remained dominant numerically. But more projects were developed with sizes above 1 MW. This happened, on the one hand, due to increase in power of turbines used (MW per turbine), and one the other hand due to still good availability of finance in 1998/1999. Many new turbines incorporated high performance technical features from the power quality perspective. The market share of grid-friendly

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[39] Source: http://home.wxs.nl/~windsh/statsnl.html 27 December 2000.

[40] Based on information at http://home01.wxs.nl/~windsh/statsnl.html.

turbines also increased sensitively. Most new projects could still benefit of external financing schemes.

The 1998-2000 support system induced therefore some positive changes in the diffusion patterns. In terms of the indicators of: types of project developers and types of financing schemes, the registered forms resemble closely the patterns theoretically expected under optimal investment contexts. As regards the indicators of project sizes, technological design choice, and drivers to invest the resemblance is closer to the forms expected under political investment contexts. The next section looks at the issue of whether diffusion patterns during the 1990s contributed to the creation of a social-economic-industrial context able to support sustainable market diffusion processes in the post-2000 period.

12.4 Installed capacity increase and prospects for sustainable diffusion processes at the end of the 1990s

12.4.1 Increase in installed capacity of wind technology

In Chapter 11, it was hypothesised that the predicted diffusion patterns will rather lead to a modest capacity increase, in a short-medium term period (5 to 10 years). One of the assumptions underlying the theoretical discussion made in Chapter 3 was that once the support system is put in place to reduce/eliminate economic and financing barriers, the other possible obstacles are also addressed and eliminated. Hence, it was assumed that no other obstacles are preventing developers and financing agents to implement their investment plans.

This section will test the expectations for diffusion results of the hypothesis formulated in Chapter 11. The hypothesis was formulated for the support system applicable in the eight-year period, 1990-1997. But having in view that the situation at the end of 1997 was not significantly different from that in 2000, we discuss diffusion results for 2000. This avoids lengthy descriptions of the same indicators for two reference years situated at only three year distance.

The capacity and electricity production data are represented in Figure 12.1. By 1997 there were only 340 MW wind systems installed. At the end of 2000 wind capacity increased to 445 MW[41]. The annual capacity increase in 1998-2000, when the profitability of projects improved, was not substantially higher than in previous years[42]. The installed capacity increase realized during the 10 year period can be described stricto-sensu as *small*, being below the operationalised limit of 500 MW.

However, looking at the projects that were still awaiting approval in 2001, the situation is very different. Market experts mention that the proposed investment plans could generate around 4000 GWh of wind capacity, additionally[43]. Administrative bottlenecks and social obstacles were preventing, or in other cases delaying, the market entry of approximately 1600

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[41] Wind electricity production amounted to around 880 GWh/yr, supplying 0,87 % of total electricity consumption (Source: http://home.wxs.nl/~windsh/statsnl.html).

[42] This can also be related to the fact that the 3 % Environmental Action Plan target for 2000 was interpreted as a risk to invest in plants that would overpass the target. As regards the estimated impact on capacity increase of the Green Label system as compared to the Green Premium trading model data are far from clear. Market experts can only guess. It seems that most market analysts guess that the Green Premium trade system, had actually a stronger impact on new capacity increase than the Green Label system (WPM October 1998).

[43] Source: Kwant [energy agency Novem] and Ruijgrok [company Kema] 2001.

MW - 2000 MW of wind plants[44]. This represents a huge investment interest that could lead to a large capacity increase, provided no obstacles were active. The interest covers both the inland and the off/near shore wind potential.

The proposed capacity is large mainly because of the revival in the interest of the largest distribution companies[45], and other private companies with good access to financial resources. In 2001, there were plans for 640 MW off-shore in the North See and IJsselmeer by 2005[46]. Table 12.9 offers an overview of the large-scale initiatives in the Netherlands in mid 2001.

Figure 12.1 *The wind capacity and electricity production increase in the Netherlands during the 1990s* (Source http://www.den.novem.nl).

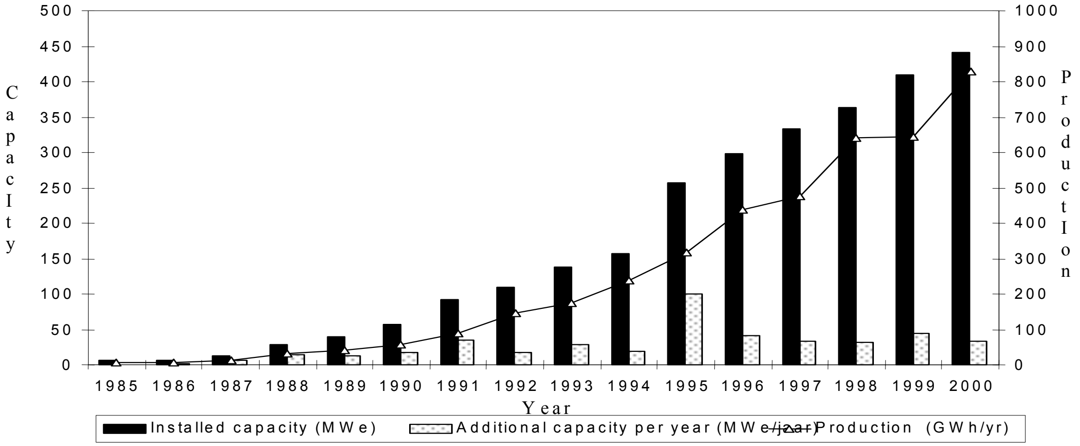

Table 12.9 *Large-scale wind farms proposed in the Netherlands in mid 2001*[47]

Location wind farm	Wind farm installed capacity
Afsluitdijk	300 MW
Eemshaven	250 MW
Noordoostpolder	130 MW
Rijnmondgebied	120 MW
Wieringermeerdijk	60 – 140 MW
Goeree-Overflakkee	50 MW
Total	circa 1000 MW

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[44] This number was approximated by considering the ratio wind production / installed capacity in 2000, that is, 880 GWh from 445 MW wind plants. If more efficient technological designs are used, able to generate 2500 kWh/kW/year (Genera 2001), the 4000 GWh/year of applications may represent only 1600 MW.

[45] In the last years of the 1990s, liberalisation has brought about a wave of mergers and take-overs at distribution level. This resulted in few very large distribution companies. Of these, the most active investors in renewables are Nuon, Eneco and Essent. In 2001 the market shares of distributors for green electricity was comparable to that for conventional electricity: 27% Nuon, 26% Essent, 24% Eneco, followed by 7% Spanish Endesa (taking over Remu) and 7% Delta (ECN and EVN 2001: 32).

[46] This came from a proposed 100 MW near-shore demonstration park at Egmond, two large wind farms proposed by the private company E-Connection (where 2 distributors and one bank have interests), and a 300 MW wind farm proposed to be located at Afsluitdijk (ECN and EMT 2001: 56).

[47] Source: energy agency Novem website: http://www.den.novem.nl.

But despite the interest to invest, it is not clear if all proposed wind projects may go ahead. Firstly, one needs to take into account that the on-land exploitable potential was estimated at only 1500 MW. Secondly, not all projects would be also economically feasible, having in view the available extent of financial support and its risks. At the end of 2000, wind power was installed mainly in the seven provinces with the highest wind resources[48], where more projects became economically feasible in the period 1998-2000. It seems likely that many proposals were made with the intention to advance through the lengthy approval procedure at the ‘speed’ of expected improvements in the support system in general and in its financial-economic aspects in particular. Expectations of possibilities for international trade with renewable electricity, especially with countries that already adopted quota obligations, could also be behind the decision to develop new and large projects.

Consequently, theoretical expectations for capacity increase were *not confirmed*. While we expected a modest capacity increase, it appears that there was a high interest to invest. Provided no approval obstacles (administrative and social) were active, the installed capacity would have been large. From the perspective of diffusion patterns, a possible answer for the contrast between interest to invest and expected capacity increase comes from the unexpected interest in commercial projects and in the availability of external financing schemes. These diffusion patterns were not expected under low profitability circumstances and especially under high economic-policy risks. The business culture of both project developers and financing agents proved to be unexpectedly flexible in the Netherlands.

One should not ask “Why did wind capacity increase so little having in view the continuous governmental support in the last decade?”. But the question should rather be “How is it possible that under such an un-inviting risk-profitability context of investment some 500 MW of wind capacity could still emerge, and there is still interest to invest in as much as 2000 MW more?”. The answers could be:

1) in the Netherlands the willingness to accept economic-policy risks is very high among many types of economic actors, from individuals to financing actors; and
2) in the Netherlands there is a willingness to enter business for quite low levels of profitability among a large range of economic actors; the opportunity to make profits even only slightly above the saving rates offered by banks is seldom left to pass by[49]; besides there is interest in environmentally friendly investments.

In conclusion, taking into account that hadn’t administrative and social obstacles existed, the installed capacity could have been large[50] by the end of 2000, we consider the theoretical expectation on installed capacity increase as *not confirmed*.

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[48] These are also the provinces whose regional governments concluded in 1991 the convenant for wind-planning with the central government: Flevoland, Frisland, Groningen, Noord-Holland, Zuid Holland, Zeeland, and Noord-Brabant. For updated capacity data see http://home.wxs.nl/~windsh/statsnl.html.

[49] A more concrete example of individuals' interest to invest is the number of inquiries made to the Project Agency for Renewable Energy about possibilities to develop wind projects. In early 1996, the agency opened up a hot-line offering information on wind energy. In only one year more than 1000 phone calls were received mainly from farmers who were interested to invest (WPM January 1996: 8). As we described in Chapter 11, the year 1995 was especially difficult, with legal conflicts for higher prices and longer contracts, which moreover ended-up in unattractive contractual terms with distributors. But in spite of all uncertainties and economic obstacles, individuals' and small developers’ interest remained high.

[50] During the 1990s the level of technological development for off-shore applications was not sufficient to enable such developments. But even excluding the 640 MW proposed capacity that regards off-shore wind farms, the investment interest would still be large with around 1000-1400 MW proposed on-land.

12.4.2 The prospects for sustainable diffusion processes in 2000

This sub-section discusses the diffusion results took for wind technology at the end of 2000 in the Netherlands. In Section 12.2.4 we observed that since 1995 external financing schemes became widely available due to the use of Green Funds schemes with income tax advantages. From the standpoint of financing availability, the prospects for diffusion continuity may be viewed as sustainable. Even when the Green Funds scheme is cancelled, internal financing schemes are likely to be sufficient for in-land diffusion, since the potential for maximum installed capacity is only estimated at around 1500 - 2250 MW.

Further, the prospects for sustainable diffusion processes need to be also analysed from the angles of: cost performances, technical performances, and the socio-economic-industrial context created by diffusion at the time of analysis. In the first part of this sub-section, we discuss the progress in cost performance improvements and the sources of cost reductions, based on the four categories of cost factors distinguished in Section 2.8.

After that, we refer to the relationship technical performances - wind resource potential, affecting diffusion. In the following part of the sub-section, we test the theoretical expectations with regard to the socio-economic-industrial context created by diffusion under the mixture of political investment contexts and minimal investment contexts that existed in the period 1990-1997 in the Netherlands. In Chapter 11 it was hypothesised that such a support system may be able to stimulate the emergence of a socio-economic-industrial context that could be able to endogenously create a context for sustainable market diffusion processes in the long-term. The socio-economic-industrial context would resemble that expected under political investment contexts[51].

Cost performances and the remaining resource potential

The production costs per kWh for wind electricity lowered from 11-12 €c/kWh in 1990 only to around 8 €c/kWh in 1997/1998 and down to 5-6 €c/kWh by 2000 in good resource sites. This represents a decrease of 30-45%. These cost data represent the lower end of cost ranges, since production costs come in large cost ranges depending on many factors. Progress by 2002 can be viewed as good, but results were still at distance from competitiveness with gas-based electricity production, which costs as low as 3,5-4 €c/kWh. In Section 2.8, we differentiated among four groups of factors influencing production costs. Table 12.10 summarises our assessment of the evolution each group in production costs in the Netherlands, during the 1990s.

The category of *technology-specific factors* has a heavy weight in production costs. This includes technology costs per kW based on factory price, as well as all technical characteristics that could influence electricity generation such as availability and efficiency. Empirical data show that significant reductions were achieved in technology-specific costs. Table 12.11 shows in the last column the evolution of technology-specific costs in the period 1990-2000. These data indicate a reduction on average of 25% of factory costs per kW of wind technology installed in the Netherlands: from around 1100 €/kW in early 1990s to around 800 €/kW in 2000. However, because of the novelty of higher size turbines, technology-specific costs spread in 2000 in the range up to 730 - 900 €/kW, and possibly even higher.

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[51] In this chapter we do not enter into the details regarding the administrative and social obstacles for wind technologies in the Netherlands. They have been documented in e.g Wolsink 1996, Verbong 2001.

Table 12.10 *Cost performances of wind technologies in the Netherlands during the 1990s*

Cost factors, 1990-2000	Wind in the Netherlands – political / minimal investment contexts
1. Technology-specific costs and factors	33 % decrease; (in 1990: ~ 1100 €/kW; in 2000: 730 €/kW up to 900 €/kW)
2. technology- complementary costs	decrease
3. context induced costs	decrease
4. quality resource: wind regimes[52] feasible with 2000 price support	at wind speeds > 7 m/s, mostly 5 - 8,5 €c/kWh
lowest production costs (per kWh) in 2000, wind	at wind speeds > 9 m/s, costs 5 €c/kWh
gas-based electricity costs	3,5 – 4 €c/kWh

Table 12.11 *Technical and cost characteristics of wind technology used in the Netherlands*[53]

Year	Average capacity per turbines [kW]	Rotor diameter [m]	Average hub height [m]	Specific technology costs	
				[€/m^2]	€/kW
1990	209	n.a.	30	556	1054
1991	286	n.a.	32	291	1055
1992	263	27	31	511	1136
1993	209	24	32	506	1129
1994	212	25	33	370	1055
1995	325	31	37	413	1028
1996	365	33	40	360	1036
1997	489	38	44	350	866
1998	642	44	48	360	950
1999	716	46	53	n.a.	909
2000	814	48	51	n.a.	818

Besides technology-specific cost reductions, there are reasons to believe that cost decrease was also realised on other cost components. This can be assumed from the fact that in 1994 the specific-technology costs represented on average 70% of total investment costs (IEA 1995: 106), while by 2000 this share raised in 82% (see Table 12.12). Having in view that wind turbine costs actually decreased, the raise in share of technology-specific costs can only be explained by substantial reductions in the other categories normally included in investment costs: technology complementary costs and some aspects of context induced costs. In the last category the factors usually included in investment costs are: financing costs, expenses for administrative-social approval and expenses in all preparatory and construction phases necessary to put a plant into operation. Although no information was found in the empirical literatures and governmental/industry statistics regarding the evolution of these costs factors, it may be assumed that their weight in production costs decreased.

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[52] These wind speeds represent average annual speeds at 10 m above the ground.

[53] Source: Mulekom (Kema) personal communication, combined with information at website http://euwinet.iset.uni-kassel.de/euwinet/owa/statistics.dispatch. Last column source: IEA, "R&D Wind Annual Report" 1999: 118.

Table 12.12 *Breakdown of wind plant investment costs in the Netherlands*[54].

Components of investments costs (%)	Wind in the Netherlands
Plant foundation works (construction)	6
Electrical connections	9
Infrastructure design	1
Grid connection	1
Technology-specific costs	82
Context induced costs in pre-operation phase	1

Some inferences on cost level could only be made with regard to the third group of factors, based on the available empirical information. In Table 12.12, the breakdown of investment costs shows that context-induced costs were in the end of the 1990s only around 1% of investment costs[55]. In the context-induced cost category we differentiated in Chapter 2 among: financing/trade cost factors; costs incurred during project life-cycle stages; and administrative (social) consent/tax expenses.

As regards the financing/trade-induced cost factors, there are reasons to believe that they did not pose pressure on production costs. In the period 1990-1995 internal financing schemes dominated, assuming no or low financing costs, while since 1996 soft loans were available based on the non-recourse approach. When project finance was used, the debt-maturity was generally 10 years or longer. This means that there was no pressure from financing agents to lift the price per kWh needed for loan repayment. As regards costs incurred during project life-cycle stages, although there was very limited competition for industrial services and among manufacturers (see below), these cost components also do not seem to have posed pressure on production costs.

For example, many independent generators were designing their own wind installations with help from their branch organisations. An important role in the support of farmers for the task of project development was played by the national organisation of farmers. LTO Nederland trained advisers in order to assist farmers and cooperatives in assessing the feasibility of wind projects and how to design wind projects[56]. The distribution companies and their venture were using their in-house expertise for wind projects planning, construction and operation-maintenance. As long as no external economic agents were involved, this minimised the contribution of this cost-component in production costs.

As the group of administrative (social) consent/tax expenses is concerned, we did not find information on whether the local taxes and delays due to administrative and social approval played a negative role in production costs or not. The only inference can be made with regard to the component of land rent. This was not an issue in the cases when the owners were farmers and cooperatives installing wind systems on their own land. When joint ventures were made between such developers and distribution companies, land rents are not likely to have played the negative role on production costs due to speculation as it happened in Spain. Table 12.1 shows how the cumulated market share of independent power producers and joint ventures increased in the second part of the 1990s. This can be seen as reflected in the

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[54] Source website http://euwinet.iset.uni-kassel.de at 8.10.2001.

[55] They included components such as land rent, project approvals, management, and feasibility studies, bank fees and legal costs. In Spain these costs were at least 5%, in addition to the local investments developers were suggested to make. In the United Kingdom context induced costs represented 5-8% (see Chapter 13). Source: http://euwinet.iset.uni-kassel.de at 8.10.2001.

[56] Information at the website of the energy agency Novem http://www.den.novem.nl.

reduction of the role of land rent cost-component in the overall production costs - seen in terms of societal costs for diffusion at industry level.

Finally, as regards the resource quality and availability, these are quite low inland in the Netherlands. Estimations on potential varied since early 1980s, but it seems that there is increasing agreement that with a flexible location policy the potential that could be harnessed on land is around 1500 MW. On the North Sea, it is estimated that at least 3000 MW could be placed, with further additional siting chances for 1000-3000 MW[57].

There is only a restricted availability of high quality wind energy resources in the Netherlands. Wind speeds above 5,5 m/s at 10m height can only be found in few provinces and represent a small area[58]. Even if siting and social acceptability obstacles are overcome in these regions, more substantial financial support or production cost decreases would be necessary in order to make wind energy economically feasible in the provinces with lower wind resources.

In 2000, the lower production costs were of 5 €c/kWh but could be obtained only at sites with more than 9 m/s at 10 m above the ground. The availability of such sites is very limited in the Netherlands. Further, for sites with wind speeds above 7 m/s, production costs could be in the range of 5 - 8,5 €c/kWh, but this depends strongly on the annual availability of nominal wind speeds. With all technological improvements, there are many sites where wind energy could only be exploited if price support could be in the range of 11-12 €c/kWh or higher[59].

We now turn to the issue of technical performance requirements for long-term diffusion expansion potential.

Technical performances and resource potential

In terms of relationship between country-specificity of innovation priority and resource availability, we distinguished between two situations in Chapter 4. The first was when the exploitable wind potential is higher than the possibility for its grid integration. The second situation occurs when the wind potential is lower than the opportunity to integrate wind energy in the grid system. In the Netherlands, the inland available potential is very small, estimated at around 1500 MW[60]. This is estimated taking into account land constraints, as well as the remaining availability of high and medium wind speed sites. Only the offshore potential is high, estimated as between 3000-6000 MW (ECN 2001: 57).

Therefore, from the perspective of increasing the degree of wind energy penetration in the electricity system, the priorities for innovation would be:

a) increasing the efficiency of turbines for inland applications;
b) developing turbines able to extract wind power at low wind speeds;
c) ensuring grid-friendliness for the off-shore turbines, which are expected to be grouped in very large parks; if grid friendly designs are used, the problem of dis-balancing the transmission network is avoided, and the ceiling for grid integration can be lifted.

Figure 12.2 shows the relationship between the inland wind resource potential, grid integration ceiling and type of technological design needed with priority in the Netherlands. In Sections 12.2.5 and 12.3.3, we concluded that technological designs able to perform at substantially

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[57] These estimations were performed by The Dutch Center for Energy research ECN (2001: 57).

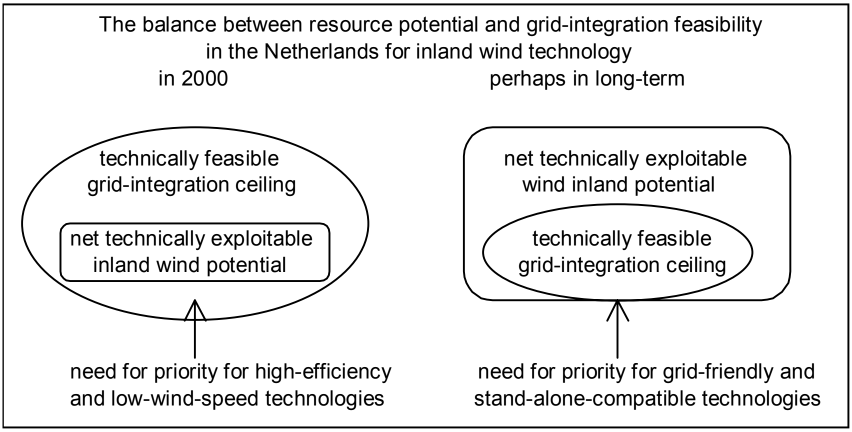
[58] See the map with the distribution of inland wind speeds in the Netherlands at: http://www.energievisie.nl/Duurzame/WindEnergy/index.html.

[59] Taller wind turbines with larger rotor areas are more expensive and if wind resources at higher heights are still not sufficiently rich, investment costs would have to be recovered from a limited amount of annually generated kWh. This assumes higher prices per kWh to be received.

[60] Information at the website of the energy agency Novem: http://www.den.novem.nl.

higher efficiency and at low wind speeds did not emerge (in the market place) during the 1990s. Therefore, from the technical performance standpoint, the inland diffusion may continue until the maximum capacity of 1500 MW is reached. After that, if such technology designs do not become available, the sustainability of diffusion becomes a matter of re-powering the operating capacity (as discussed in Section 2.7).

Figure 12.2 *Resource potential and technical designs of inland wind technology needed with priority in the Netherlands*



In order to sustain diffusion through re-powering, further reductions in technology specific costs will be necessary. These will depend then on developments abroad: the foreign demand for Dutch technology (only Lagerway remaining) and the domestically available foreign technology. When technology specific costs do not fall sufficiently, the continuation of wind capacity re-powering depends on the political will to extend the financial support. The socio-economic-industrial context induced by diffusion at that time may influence political will, or not.

The features of the socio-economic-industrial context of diffusion in 2000

In Chapter 11 it was hypothesised that the socio-economic-industrial context would resemble that expected under political investment contexts. Table 12.13 presents the theoretical expectations in comparison with empirical observations.

We expected to see modest socio-economic benefits from diffusion and empirically we assessed them to have been small/modest, hence *confirmed to large extent*. The expectation to observe a modest size industrial basis and dynamics was *not confirmed* by empirical observations. After one decade of market diffusion, the Dutch wind industry had a small size and the level of competition for products and services was low. In these paragraphs, we explain first the socio-economic benefits of diffusion and then the aspects of industrial basis and dynamics.

Socio-economic benefits

The socio-economic benefits after one decade of diffusion can be assessed as between *small and modest*. They occurred mainly in the form of local direct ownership, and social ownership involvement at national level by households and various types of companies. The last took place by means of participation finance and project finance loans from Green Funds investments.

Table 12.13 *Diffusion results of wind technology in the Netherlands, in 2000*

Diffusion context likely to emerge		Theoretical expectations political investment contexts	Wind in the Netherlands
Socio-economic benefits		modest	small / modest
Local	Direct: ownership	likely	confirmed
	Indirect: more attractive (than usual) benefits from ~ land rents; ~ local taxes; or ~ local economic or social welfare investments	not likely	confirmed
	Indirect ~ local employment	technology specific	minimal / no
National	Ownership individuals (shares)	likely	confirmed
	Employment in industry	likely modest	very small
Industrial basis and dynamics		modest	small
Number companies offering products / services for renewable electricity plants		modest	not confirmed (small)
Types of companies involved in industry		mostly industrial companies with activities in conventional energy technologies	confirmed
Degree of specialisation in renewables		modest	not confirmed (small)

At local level, the direct ownership channel ensured local economic benefits. In some cases agricultural cooperatives and farmers were sole owners, while in others they - and other local people have ownership shares in locally developed wind plants. This was actually one of the reasons behind distributors' change in investment policy towards joint ventures - to offer locals some benefits and get local approvals faster. But special indirect benefits at local level beyond the legally required taxes have not been the case in the Netherlands, as in Spain and the United Kingdom (see Chapter 13)

At national level the Green Funding schemes (see Chapter 11) offered all green investors, from households to companies of all sizes, tax-free returns in investments since 1996. Thousands of people and tens of companies have had economic benefits from funding green projects, of which wind projects formed a substantial share.

The wind-industry employment has been low throughout the 1990s, with a decreasing trend in early 2000. As presented below, not too many companies have been exclusively (or largely) dedicated to wind technology. In 1999 there were only 550 people directly employed in the wind turbine and blade manufacturing companies in the Netherlands (IEA 1999: 117). Indirect employment was estimated in 1998 as around 680 people, mainly in subcontracting firms, consultancies, service companies, research centers and universities (IEA 1998: 114). The low employment in wind industry is mainly due to the small domestic market size and the difficulty to expand beyond niche markets in foreign countries. The decreasing trend since 1998 is mainly due to the taking over of Dutch companies by foreign firms.

In early 1990s there were 4 Dutch turbine manufacturers: NedWind, Windmaster, Micon and Lagerway; and there were 3 blade manufacturers: Aerpac, Polymarin and Rotorline. Dutch turbines were dominating the domestic market with around 85% share of installed capacity. By 2000 the only ‘pure-Dutch’ turbine producer was ‘Lagerway the Windmaster’ (a take over of the latter by the former). NedWind was taken over by Neg-Micon in 1998, who in its turn had been formed by the Dutch Micon and the Danish Nordtank. Most of the new capacity installed since 1998 came from Danish-owned turbine companies[61]. The superior cost-performance parameters of Danish and other foreign turbines has been the main reason for the drop in demand for Dutch turbines, which led to the take-over of Dutch manufacturers by Danish firms.

As regards blade manufacturers, Aerpac moved in late 1990s most of its production facilities in other countries and retained only its research activities and the Almelo factory in the Netherlands[62]. In 1999 Aerpac had 600 employees world-wide (IEA 1999: 117). But in 2001 it went bankrupt and the assets were taken over by the German office of the U.S company Enron Wind (IEA 2001: 167). The second important Dutch blade manufacturer was Polymarin. In 2000 the company employed (together with other activities) 230 people, based in two locations in the Netherlands (Medemblik and Oosterhout). Since 1998 it has a 50% participation in a Canada-based blade production company. In 2000, more than half of blades production went to external markets.

Finally, in 1999 the Danish blade producer LM Glasfiber took over the Dutch manufacturer Rotorline. This resulted in the Dutch subsidiary LM Glasfiber Holland with two production facilities in the Netherlands. But soon afterwards, in 2001 one facility was already closed. It was considered that it is not able to produce the large blades that Nordic countries need for the new wave of large-capacity turbines (IEA 2001: 167). Consequently, the small size of the domestic market, and the take-over by foreign companies of Dutch wind technology manufacturers have been the main reasons for low levels of wind-related employment.

Table 12.14 *Companies serving diffusion of wind energy in the Netherlands, in 2000*

Products / Services related to wind energy	Number of companies per product / service
Wind turbines larger than 50 kW	7 (from 10 in 1998)
Wind turbines larger smaller than 50 kW	5 (from 10 in 1998)
Blades	2 (from 3 in 1998)
Turn-key project providers	5
Total companies wind industrial sector 2000	**17**
Financing agents – green funds	7
Insurance	2 (from 9 in 1998)
Advisers	51 (technical matters: 20; financial aspects: 20; projects' feasibility: 29; environmental assessment: 16)

Industrial basis and dynamics

As regards the first and third indicators for *industrial basis and dynamics* (see Table 12.13), economic actors have emerged to provide services related to commissioning of wind projects. But their numbers suggest a low level of competition, while they kept wind energy mostly as non-business core activity. Table 12.14 shows the situation per type of service and products offered. In 2000 there were only seventeen companies offering hardware technology, that is wind turbines, blades and turnkey services. The wave of market-exit and take-overs reduced the number of turbine manufacturers active on the Dutch market from twenty in 1997/1998 to twelve in 2000[63]. By the same year, there were only two manufacturers of blades.

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[61] For example, in 1999 more than 90% of the newly installed capacity was manufactured by the Danish companies Vestas and Neg Micon (IEA 1999: 113).

[62] Information at the website of the energy agency Novem http://www.den.novem.nl.

[63] There were originally four Dutch manufacturers of larger-size turbines, and only one remained in operation on its own by 2000 - Lagerway.

The number of turnkey providers was restricted to only five. This service is crucial for new comers, and especially independent power producers who have no expertise in the technical aspects of electricity plants building. The presence of only five companies is insufficient for competition. Of the total seventeen companies registered as offering industrial services/products, thirteen offered only one type of product/service, as shown in Table 12.15. This suggests an attitude of hold-back from specialisation in wind technology business.

Table 12.15 *The degree of specialisation of wind industrial companies along the value chain of wind energy systems*

Number of services / products offered by wind industrial companies	Number of industrial companies offering services / products
1	13
2	4

In contrast, there was an abundance of advisers offering counseling on projects feasibility (29 companies), technical matters (20 companies), financial aspects (20 companies), environmental impact assessments (16 companies). The high number is not surprising, since such services do not require sunk investments in hardware. In their overwhelming majority, advising companies emerged from large long-established economic actors - such as distribution companies, strong banks and society trusts, Siemens, large environmental consultancies, e.g. Arcadis and Ecofys, and institutes with long-established research activities such as ECN and Kema. Around three-quarters of the 51 companies were offering only one or two types of services, while the few rest were more specialized in wind projects integrating more types of advice. Financial resources were offered by seven agents using green funds. Most striking is the steep reduction in number of companies offering insurance, from 9 to only 2 by 2000.

The above empirical data in industrial size and dynamics suggest the following:

- in 2000 there was little competition for products and services for wind plants building;
- companies involved in the wind industry were only to a very limited extent specialized in offering more types of products and/or services;
- most of the products and/or service suppliers were subsidiaries or departments of large and long-established companies that did not have wind energy as core activity.

Therefore, the industrial basis and dynamics for wind technology in 2000 can only be assessed as small. This does not confirm the theoretical expectation. As in the case of small hydropower technology in Spain, the very high interest to invest could not be materialised in installed capacity due to social and administrative opposition and lengthy approval processes. This prevented a healthy industrial basis to emerge. But in the same time, it also not enabled the emergence of a politically influential industrial sector, as it happened in Spain and in the United Kingdom with wind technology.

Finally, as regards the *political lobby potential* by means of wind projects ownership, this was also small. The independent private produces were well organised but did not have sufficient political power. In 1998, there were eight regional associations of wind-cooperatives and eight regional interest-organisations of wind project owners. Besides, there was the older national association of wind-turbine operators (Pawex). The inability to influence the governmental position in the contract and price conflict in early 1990s and to induce changes towards a stronger support system after 1998 witnesses their weak lobbying strength. In spite of the great and continuous efforts invested in lobbying activities, small developers did not have the political leverage to improve the prospects for wind energy financial support, in the context where there was also no embedded political will do to so. On the other hand, distribution companies, have always wished a relaxed support system that draws as much as possible on voluntary investments. In the context of industry liberalisation, they have lobbied against the imposition of mandatory quotas for renewables purchase.

The next section makes a summary of the empirical findings presented in this chapter. Further, it draws the conclusion regarding the extent of confirmation of theoretical expectations formulated in Chapter 11 with regard to diffusion patterns and results under the support system mixing political and minimal investment contexts.

12.5 Summary and conclusions on the overall confirmation of the hypothesis

This chapter tested the theoretical expectations of the hypothesis formulated in Chapter 11 for the diffusion of wind technology in the Netherlands in the period 1990-1997. Besides, it also empirically investigated the diffusion patterns for the period 1998-2000 for which no hypothesis was specified.

Diffusion patterns 1990-1997

The extent of confirmation of expectations regarding diffusion patterns can be considered as *satisfactory*. The expectations on diffusion patterns recorded in the period 1990-1997 were ‘confirmed’ for two indicators, ‘confirmed to large extent’ for one indicator, and considered as overall ‘partly confirmed’ for two indicators.

The expectations regarding *project sizes and technological design* choice were assessed as ‘confirmed’. We observed a dominance of very small size projects, while it was expected that investors would prefer to develop mainly small and very small size wind plants. Further, as theoretically expected, it was observed that conventional technological designs of wind turbines were the preferred choice in market adoption decisions.

The expectations regarding the *types of project developers* likely to be interested to invest were assessed as ‘confirmed to large extent’. The support system displayed a mixture of political-type and minimal-type of investment contexts. But only electricity distribution companies and their joint ventures could benefit of the more attractive political type of investment context. Their partners in joint ventures were in many cases small developers. But there were also projects developed with contribution from financial institutions and engineering companies. The presence of distribution companies was larger than theoretically expected under political investment contexts because of two factors: 1) the existence of the environmental voluntary agreement to reduce CO_2 emissions (which actually put them on track with regular investment in renewables) and 2) their regulation as non-profit companies, which allowed them however to make profits not higher than bank interest rate levels (6-9%).

Further, there was no involvement of industrial production companies, which we considered likely to be interested to invest especially in partly-self-generation projects. This is due again to factors exogenous to our analytical framework. There were environmental voluntary agreements concluded between the government and industries of all types to reduce environmental impacts. As renewables were among the most expensive options to do so, they were not chosen by industries. Therefore, looking only at the eligibility of developers for the political investment contexts, it can be considered that the expectations for this part of the hypothesis were confirmed to large extent.

The case study showed that only independent power producers had to confront a minimal investment context. Small developers were the backbone of this group: mainly farmers and cooperatives, but also local authorities, green-minded associations and small private companies. Since 1995/1996 when the Green Funds scheme was introduced, financing agents such as equity investment groups and banks also emerged as investors in wind plants. Hence, the picture of project developers was more diverse than theoretically expected under minimal investment contexts, with the presence of investors such as financing agents that we did not consider as likely to be interested to invest. A characteristic of the business culture of many types of economic actors in the Netherlands is the acceptance to invest in high-risk environments, and to take advantage of any opportunity that offers profits above the regular rates of saving banks. This, in addition to the high environmental sensitivity of many small developers may explain the large number of projects built in the Netherlands under a minimal support investment context. We consider the expectations for this part of the hypothesis also as confirmed to large extent.

The expectations regarding the *drivers to invest* were assessed as 'partly confirmed'. This assessment comes from a mixture of:

- partly confirmed expectations for drivers to invest of independent power producers in minimal investment context and
- confirmation of expectations for drivers to invest of distribution companies and their joint ventures in political investment context.

Small developers such as farmers, cooperatives and associations were driven to invest by a combination of green ideology and the attractiveness of a secondary income stream. But they emphasized their interest in operating profitable wind systems. The commercial co-motivation to invest was not expected in a minimal investment context (Area 4, Figure 11.2 in Chapter 11), especially not at this magnitude and constancy. Besides, since 1995/1996 investment groups and banks also emerged as project (co-)owners. This was made possible by the introduction of the Green Funds scheme, exempting investments in wind projects from income taxes. Their presence could only be commercially motivated.

The large and unexpected presence of commercial investments may be motivated by the business culture and cut-off profit requirements of economic actors in the Netherlands. Equity investors appear to have a high willingness to face investment risks, and high interest in investment opportunities offering even slightly higher profits than generally available in the market. For this type of investment context partly-self-generation projects were also considered likely. But this option did not appear to be interesting for small developers.

In the Netherlands, electricity distribution companies and their joint ventures benefited of a political investment context (Area 3 in Figure 11.2). The owners of these plants had a mixture of commercial and strategic reasons to invest. For this type of investment context partly-self-generations projects were also considered likely. But the option of using part of the output of wind power plants for self-generation is excluded for distribution companies and their joint ventures. Therefore, we viewed the expectation on drivers to invest for the political investment context in which they acted, as confirmed.

Finally, the expectations regarding the *types of financing schemes* were assessed as 'partly confirmed'. This assessment comes from the mixture of 'confirmed' expectations for the period for1990-1995 when predominantly internal financing schemes were observed, and 'not confirmed with comment' for 1996-1997 when the Dutch government introduced the Green Funds scheme.

Given favourable conditions in the Dutch social-economic-institutional contexts, this scheme gave very good results. The not very highly demanding profitability requirements by many types of economic actors, accompanied by high levels of entrepreneurship, environmental sensitiveness, average individual welfare and financial reserves of many private companies and individuals in the Netherlands, created synergies in making large financial resources available also for wind energy plants. Perhaps in other countries the same scheme would not have had the same impact. But in the Netherlands, investments in wind technology shifted to external financing schemes for most developers since 1995. However, in the analytical framework, we derived expectations by assuming that no special governmental intervention affects directly the forms of the indicators of diffusion patterns. We assess the predictability in this particular case as 'not confirmed with comment'.

Diffusion patterns 1998-2000

In the period 1998-2000 the support system changed its risk-profitability profile. The level of aggregated economic-policy risks for distribution companies and their joint ventures increased from 'very low' to 'moderate-high'. For all investors the feasible ranges of profitability increased to 'high' levels when the Green Label trading system was chosen and to 'very high' levels when the Green Premium trade option was taken (Figure 11.3 and 11.4 in Chapter 11).

The main changes in diffusion patterns were at the level of types of project developers. Independent power producers developed more projects than distributors in this three-year period. Small changes were also observed in the indicator of project sizes. Projects had slightly larger sizes than in the previous period. The fact that there are no changes in terms of financing schemes used is because external financing was already available since 1996. As regards drivers to invest the fact that self-generation projects were still not observed is related to the action of the same institutional and regulatory factors as before 1998 (summarised below).

Diffusion results by 2000

In terms of diffusion results, the hypothesis formulated in Chapter 11 expected that the support system could be quite attractive for investors, possibly leading to a modest capacity increase. But after eight years of diffusion, 1990-1997, only 340 MW wind power were installed in the Netherlands. By 2000 the installed capacity increased only to 445 MW. However, there was a very large number of applications that did not receive a positive response from administrative authorities and social approval yet. These totalled a capacity in the range of 1600-2000 MW (Kwant and Ruijgrok 2001). The investment interest includes around 600 MW off-shore. But taking into account that the in-land potential is estimated at around 1500 MW, it may be argued that there is sufficient investment interest to sustain diffusion inland up to the level that the technical and siting potential permits. Therefore, looking at the investment interest, if it wasn't for the strong administrative and social obstacles, a large capacity may have been installed, or at least under development and construction.

The theoretical expectations on socio-economic benefits were confirmed to large extent but those with regard to the industrial basis were not confirmed. It can be hence argued that by 2000 the potential for political lobby from the socio-economic-industrial framework, for a more powerful support system for wind energy was low, from the perspectives of wind system owners, wind-related employment and industrial capacity.

In 2000, the prospects for the sustainability of market diffusion processes were partly favourable, partly gloomy. They were favourable because from the standpoint of financing availability, the prospects for diffusion continuity were good. Even when the Green Funds scheme is cancelled, internal financing schemes are likely to be sufficient for in-land diffusion, since the maximum installed capacity is only estimated at around 1500-2250 MW. But prospects were not very favourable, from the following considerations:

- the cost performances of wind technology in the Dutch resource-landscape-social institutional context did not enable the exploitation of too much resource potential with the available price support;

- the features of the socio-economic-industrial context created by diffusion so far did not have the necessary political leverage to increase the extent of financial support so as a larger share of the technically available potential could be exploited - within the framework defined by siting constraints; and
- the technical performances of market-available technological design limited the potential for installed capacity expansion - within the framework defined by siting constraints; however, the only Dutch manufacturer remaining was concerned with developing technological designs able to function at lower (i.e modest, 8-10 m/s) wind speeds.

Exogenous variables and alternative specifications

Empirical research showed a significant influence on diffusion patterns from intermediary variables of the theory, as well as a series of exogenous factors. The last are mainly of *institutional-regulatory nature*. The regulation of electricity industry based on the 1989 Electricity Law allowed self-generation projects for large consumers. However they did not invest in wind energy projects because the voluntary environmental agreements concluded with the government allowed them to choose for cheaper options, such as co-generation.

In the same time, another environmental voluntary agreement brought distribution companies into the wind business. Another regulatory aspect that strongly influenced diffusion patterns was the introduction of the Green Funding schemes targeting to remove financing barriers of green projects. This induced not only a shift towards external financing schemes, but also an enrichment of the picture of project developers and a slight increase in project sizes.

The technological choice was also under the influence of two main exogenous factors: the rules of local authorities regarding turbine height and, up to 1995, the allocation of governmental investment subsidies that aimed to stimulate (in parallel with market introduction) the domestic wind manufacturing industry. Project sizes were also under some degree of influence. Until 1996/7, distribution companies imposed very low limits on project sizes for which they were willing to give higher contractual prices, although this was against the unlimited legal guarantee on purchase. As regards the plants owned by distributors there was a legal ceiling of 25 MW. But in practice this did not pose restrictions because distributors could invest under the joint venture formula. Besides, during the 1990s, large-scale wind plants were not a clear trend in their investment plans yet.

Beside the role of these regulatory-institutional exogenous variables, empirical research also showed the strong role played in the Netherlands by *business culture and entrepreneurship* of economic actors and financing agents in investment decisions. Green ideology is present among a wide range of economic actors and especially strong among small developers. There is a tradition of cooperative organisation and a spirit of entrepreneurship among cooperatives, as well as individual farmers. Both types of actors are also often strongly green-minded and eager to reap opportunities to increase their income even if the risks and effort invested is sometimes disproportionate to the financial gains. Independent wind developers proved to be willing and quite able to deal with regulatory complexity and uncertainty. The environmental motivations strengthened the decision to invest in wind energy in spite of the low profitability and high risks.

Distribution companies are also open towards dealing with the environmental burdens of fossil fuels use. Some are driven by green ideology motivations, others just by strategic-commercial interests to build a green image in a liberalised industry, or to take a good share in the emerging business of renewable electricity trade. But in any case Dutch energy companies are open towards investments in renewable energy as long as this is not an obligation, but an internally-taken decision which should be appreciated by stakeholders.

The business culture of financing agents has also played an important role in diffusion, especially in the period before 1995 when a helpful hand was needed by independent power producers. Several banks were very responsive to the financial needs of small developers. This was either because of a long-tradition of cooperation, such as in the case of Rabobank, or because of an openness towards ethical investments, such as in the case of Triodos Bank and ASN Bank. Besides, banks in the Netherlands are also opened towards small-scale projects, which is in big contrast with the situation in Spain. Loans are possible even for solitary turbines both as internal and as external types of financing scheme. Another helpful aspect is the interpretation of investment subsidies as reductions from the requirement for equity contribution by project developers. In contrast, in Spain, investment subsidies are considered as reductions from the loan-percentage banks are willing to give.

But the business culture of economic actors also played a role in the non-confirmation of theoretical expectations for capacity increase. The higher than expected interest to invest can be explained also from the perspective of *market expectations* rather than the support system applicable at that time. As Chapter 11 discussed, two new support systems functioned in parallel between 1998 and 2000, making higher levels of projects profitability possible. The fact that new support schemes would be introduced was already known since 1995 when options for a new approach under a liberalised electricity sector started to be discussed. In addition, it was also expected that the Green Label trading system would be replaced by a similar system after 2000, and that the voluntary demand for green electricity by consumers could finance many new plants if the Ecotax on conventional electricity increase as politically intended. Moreover, it was also expected that international trade with renewable electricity would become possible when a EU Directive on renewable electricity treatment is adopted. Given the long delays in obtaining social consent and administrative approval many project proposals were strategically timely forwarded for local approval.

In conclusion, the hypothesis for wind technology diffusion in the Netherlands can be assessed as confirmed to a satisfactory degree by empirical developments. The role of exogenous variables of institutional-regulatory nature in diffusion was significant. But in the same time, country-specific factors related to business culture, the entrepreneurship spirit, the environmental sensitivity of many economic actors and financing agents have a significant position in explaining how a relatively un-attractive support system could lead to the diffusion observed, as well as to the very large potential for diffusion, hadn’t the social and local administrative obstacles been so strong.

13

United Kingdom - support system and diffusion of wind technology during the 1990s

13.1 Introduction

This chapter specifies the hypothesis to be tested for the market introduction and diffusion of wind technology in the England and Wales during the 1990s and tests the selected hypothesis.

The emergence and change of the renewable energy policy in the United Kingdom (UK) was closely linked to the re-structuring of the electricity industry. But it was also strongly influenced by some specific circumstantial factors and developments. The UK was the European first country to privatise its electricity industry and to attempt opening it to competition, through the 1989 Electricity Act. The entire sector of England and Whales was vertically de-integrated, while competition was introduced at generation level through a power pool system. In practice, however the privatisation of the nuclear power plants was not possible. Remaining in public ownership, nuclear plants could only be kept in operation by compelling distribution and supply companies to buy nuclear electricity. In addition they also had to be given price support. For this purpose the British government introduced in 1989 a proposal for a Non-Fossil Fuel Levy on consumers. Although at that time there were no proposals for the greening of electricity supply, supporters of renewable energy seized the opportunity offered by the elegant enshroud terminology - ‘non-fossil fuels’ - and demanded price support for renewable energy too. This marked the beginning of governmental support for market diffusion of renewables in the UK, called the Non-Fossil Fuel Obligation (NFFO).

In the first part of this chapter we analyse the support system used for renewable electricity, including based on wind energy, during the 1990s in England and Wales and its consequences for diffusion[1]. The support system had only an economic component. Policy support mechanisms for market introduction such as investment subsidies, fiscal instruments or soft loans were not used during the 1990s. There was a policy program subsidising research development and demonstration, which will be shortly presented in Section 13.2. But since there was no policy component for market support, as defined in Chapter 2, the description and risk-profitability analysis of support system will be based on the economic governance structure for renewable electricity trade during the 1990s.

The empirical analysis starts in Section 13.2 with a short overview of the main governmental programs and policies for the support of renewable energy technologies during the 1980s and 1990s. Section 13.3 provides a brief overview of the energy resources used for electricity production in the UK. Further, Section 13.4 makes a general description of electricity industry’s structure, as regulated by the 1989 Electricity Act. The description and risk-profitability analysis of the support system for renewable electricity production is made in Section 13.5. This section concludes that Hypothesis 1 will be tested for the case study of wind technology diffusion in England and Wales. The testing of theoretical expectations regarding diffusion patterns is made in Section 13.6. This will be followed in Section 13.7 by a snapshot at the diffusion results by 2000 based on the indicators selected in Chapter 2. The summary of this chapter and conclusions regarding the extent of hypothesis confirmation are drawn in Section 13.8.

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[1] Similar mechanisms were put in place in Scotland - the Scottish Renewable Obligation, and in Northern Ireland - the Northern Ireland NFFO. Three calls of tenders were placed in Scotland and two in Northern Ireland. This chapter only discusses the details of the NFFO program and the diffusion of wind technology in England and Wales.

13.2 Overview of governmental policies for renewable energy

The interest of the British government in renewable resources was awaken by the world oil crisis of the 1970s. But the general attitude among politicians and bureaucrats towards renewable energy resources was one of scepticism. This was, on the one hand, because of the plentiful availability of coal in the UK and confidence in nuclear technology, and on the other hand, because little was actually known in terms of the nature, potential and technological options for the harnessing of these resources. However, the government decided that it was time to get more information on the eventual contributions that renewables could bring to the British energy supply. A research program was consequently lunched in 1974 under the coordination of the Department of Energy[2].

Initially the objective was only to assess the technical and economic potential of renewables and the possible time scales for their contribution. But as the assessment work progressed, and some resources started to be regarded as economically attractive or potentially important over medium-term time horizons, the objectives of the research programs expanded. A more coherent, although still not ambitious, R&D policy on renewables emerged in the second part of the 1980s[3]. The Energy Paper 55 of 1988 describes the British Research Development and Demonstration strategy on renewables as pursuing the goals of stimulating "the full economic exploitation of alternative energy resources in the UK", and encouraging a manufacturing industry able to have a strong position in both the domestic and foreign markets. The objectives set were:

1) to evaluate to what extent different technologies could be important for the UK, designed to run between mid 1970s and mid 1980s;
2) to undertake development projects for technologies having good commercial prospects in close cooperation with the industry, designed to run between mid 1980s and early 1990s; and
3) to demonstrate the technologies having clear economical viability and to prepare the field for commercial introduction.

Phase 3 was designed to run during the 1990s, and had then been viewed as the last step of government's involvement, preparing renewable technologies for unconstrained market adoption by electricity industry or any other interested economic actor.

Nevertheless, already from the end of Phase 2 the policy for renewable energy had to be altered, as a result of the 'unplanned' introduction of a market-deployment component. At the origin of the unexpected event was the decision to the British Conservative government - winning elections in 1987 - to privatise the entire electricity industry and to gradually liberalise its economic activities. The failure to sell the nuclear generation capacity led the government to the solution of subsidising nuclear energy on consumers' bills, in order to enable the nuclear company British Nuclear to participate in the emerging power pool. In addition, it came up with the plan of setting an obligation on distribution companies to purchase all nuclear electricity generated. But the subsidisation of electricity production required the approval of the European Commission, based on the Competition Directive. Consequently, the British Government advanced a request to the Commission to allow for the subsidisation of the 'non-fossil fuel electricity' generation, based on a Non-Fossil Fuel Levy. Approval was granted

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[2] The funds allocated for the program were administrated mainly by the Energy Technology Support Unit (ETSU) of the Atomic Energy Authority, on behalf of the Department of Energy.

[3] As it will be explained, part of this policy was formulated somehow 'ex-post', as certain events had already occurred, but there was still a desire to give them a meaning and place in the policy process.

from the European Commission up to the year 1998, when the market was supposed to be fully liberalised for all consumers. At that moment, the supporters of renewables immediately seized the opportunity and required the benefit of subsidies from the Fossil Fuel Levy fund. The government had no other option than to accept the request, adding ex-post a market deployment component in its renewables' support policy program - a stage it never envisaged to be involved in. The governmentally protected market deployment of renewables started therefore in 1990 in the framework of the Non-Fossil Fuel Obligation - or the NFFO Program.

The British policy program on renewables between 1974 and 1990 can be characterised by the following elements. Firstly, there was modest financial commitment, as compared to other energy technologies. Improvements and innovations in coal and nuclear technologies were considered far more important than alternative renewable technologies[4]. The concern with renewables was more justified from a resource diversity perspective, and the desire to enable British manufacturers to occupy a good early position in the new international markets of renewable technologies. Secondly, the focus was only on economically attractive technologies, regardless the eventual advantage in terms of national resource availability. The UK has the highest wind resource in Europe and a very good potential for energy crops, wave power and tidal energy. However, their support has been erratic, discouraging interest from potential manufacturers and leading to stagnation or unsuccessful developments.

Thirdly, there were too frequent technology reviews, resulting in significant changes of priorities along time. And fourthly, governmental commitment to the renewables' program was not entirely guaranteed. On the one hand, the entrance into Phase 2 or 3 was conditioned by the success on the previous Phase. This induced strong policy risks for (potential) manufacturing companies. On the other hand, the governmental financial contribution was conditioned by industry financial participation. It was envisaged that in Phase 2 the balance would be made by 51% financial contribution from the industry and 49% from the government. For Phase 3 it was required that the industry covers as much as 75% of the expenses. This conditional engagement reflects the weak governmental interest in renewables, which was probably enhanced by the decline in energy demand by 12% between 1973 and 1984, and the excess of oil registered in the beginning of the 1980s in UK (Flood 1986).

Following the events at the end of 1980s related to electricity privatisation and liberalisation, the government reconsidered its research and demonstration program. This was also influenced by climate change concerns starting to emerge at political level. After announcing the withdrawal of nuclear power station from privatisation, the government made known that it set a target for renewables market deployment of 600 MW by 2000. Later, after the publication of the 1990 White Paper on the Environment, the target was raised to 1000 MW. But a clear governmental policy on renewables market diffusion was still missing.

It was only in July 1993 when the new Minister of the Department of Trade and Industry (DTI)[5] finally clarified the general lines of the governments' policy on renewables. The government announced its goal to support market introduction of renewable electricity in a way that its economic performance improves at a fast rate. This was meant to enable the withdrawal of governmental financial support in a 'not too distant future'. The main objectives circumscribed to this goal were to ensure: "diverse, secure and sustainable energy supplies; reduction in emissions of pollutants; and the development of internationally competitive

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[4] For example, in 1984, two nuclear technologies received 232,5 million Euro, while all renewables were allocated only 27 million Euro (Flood 1986).

[5] After the 1992 elections, the Department of Energy was transformed in a Energy Division of the Department of Trade and Industry, and the program "New and Renewable Energy" was established under this new division.

renewable technology industry". The key principle in renewables market support became the "steady convergence under successive orders (…) between the premium price paid to generators of renewable electricity and the market price for electricity" (Etsu 1998). Together with the call for tender for the third NFFO round, in 1994, the government also announced its new target of 1500 MW renewables by 2000.

In this context, the government had no other choice than to continue with the research program. A major technology review was announced, meant to set the research agenda for the following decade. In 1994, the Energy Paper 62 was published bringing disappointing news for renewables' supporters. Renewable technologies were examined from the perspective of their stages in the research process and were classified in three groups: market enablement via NFFO and/or research, development and demonstration; assessment of appropriateness for research and demonstration; and 'watching brief'. Offshore wind energy was placed in the category 'watching brief', and its research funds were cut. On-shore wind energy was placed in the market enablement category and included in the NFFO program.

The new research and demonstration supporting Program was presented as extending probably up to 2005. But its continuation was conditioned by another major review announced for 1999. This condition added yet another layer to the growing pile of policy risks facing potential manufacturing companies. The Supporting Program was conceived in the same fashion as the 1988 research program - the Energy Paper 55. Namely, the governmental financial contribution was envisaged to decline throughout the program's time horizon, and to phase out by the latest 2005, when market forces were supposed to continue with commercial deployment. Further, it was considered that these funds would be compensated by private and industry investments in research and demonstration. The assessment of Program's progress was to take place based on annual reviews through the Renewable Energy Advisory Committee of the Ministry.

13.2.1 Early research on wind technology

The governmentally influenced research work on wind energy was organised in the areas of: resource studies, machine studies, and system studies (wind farms). Research on wind machines was initially focused on large turbines, under the influence of the old generation-transmission company (the Central Electricity Generation Board), which was interested mainly in bulk generation technologies. There were two major demonstration projects commissioned during Phase 2 of the Research Program. One was the 3 MW two-bladed horizontal axis turbine commissioned in 1987 and manufactured by the Wind Energy Group, having the Central Electricity Generation Board as the parent company[6]. The second was the 1 MW three-bladed horizontal axis turbine developed by the second large British manufacturer, Howden Group. In addition, small-scale turbines of variable geometry vertical axis design were also tested, driven by the promise of lower generation costs than the horizontal axis design[7]. Several experimental windfarm systems were also commissioned. The small scale horizontal axis turbines, up to 300 kW, were considered competitive with conventional technologies, as they were already assuming generation costs of around 4,5 €c/kWh. But some attention needed to be paid to improve resistance to fatigue, reliability and environmental performances. It was

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[6] After industry reorganisation, the Wind Energy Group moved into the ownership of the National Wind Power (subsidiary of the large conventional generator National Power) and the construction corporation Taylor Woodrow (WPM July 1996: 25).

[7] The research of this technological option, which enjoyed almost 9 million Euro was however terminated in 1994, as it did not bring the expected results.

only after 1987 when the focus was shifted from large-scale turbines and vertical-axis designs, towards small and medium size turbines and horizontal-axis turbines design.

13.3 Overview of energy resources used

The British electricity industry has had a long-standing reliance on coal, due to the plentiful domestic availability. Until beginning 1960s, coal-based generation accounted for around 80% of fuel input. This was complemented primarily by oil-fired plants, and accompanied by modest contributions from hydropower. Between 1968 and 1973 oil-based electricity expanded to 29%. But after the oil supply crises its share decreased annually, arriving at a contribution of only 1,5% in fuel input in 1998. The position of coal continued to be dominant in the 1980s and 1990s. But its role started to decline with the advent and expansion of nuclear power, and later with the boost of natural gas.

While in 1990 coal still enjoyed a share of 67%, in 1998 this dropped to only 33% in electricity generation. Nuclear power raised between 1960 and 1998 to a share of 26%. An even more spectacular boost in market share was registered by natural gas, from 0,5% in 1990, to almost 30% in 1998. A large part of this capacity was installed by distribution companies following liberalisation that started in 1989. In early 1990s, non-hydro renewable resources entered the picture of resource-base, based on the non-fossil fuel obligation. But during the entire decade they couldn't seize a share higher than 2% - which is mostly given by waste-to-energy, landfill-gas and sewage gas power plants.

13.4 The main characteristics of the electricity industry based on the 1989 Electricity Law

In 1989, the new Electricity Act restructured the industry of England and Wales from the bedrock. The entire sector was exposed to privatisation. The generation and transmission segments were separated, privatised and organised in companies with different ownership. The twelve Area Boards that previously functioned as distribution-retail utilities were privatised in their former organisational structure. But they were required to financially unbundle their distribution and retail accounts. Full competition was introduced from the start at generation level, and a gradual introduction of competition was planned at consumption level.

The system of central planning of electricity generation was replaced by a power pool where sellers and buyers had to trade electricity on a half-hourly basis[8]. In order to facilitate pool competition, the generation segment was broken up into three parts and was partially transferred into private ownership, as follows:

1) the fossil based generators were grouped in two large power plants, National Power and PowerGen; these two plants were privatised and sold to the public;
2) all nuclear plants of the former Central Electricity Generation Board were incorporated in the company Nuclear Electric, which remained under governmental ownership, as selling efforts were unsuccessful;

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[8] The 1989 law regulated the Power Pool as "a day ahead spot market". This means that electricity was traded for the expected consumption in the following day, during each half hour. The management and operation of the pool were placed under the responsibility of the National Grid Company.

3) the legal barriers for the entrance of new generators were lifted, which allowed for the emergence of a group of independent power producers; the twelve newly privatised distribution-retail companies became major shareholders in twelve of the new independent power producers.

In parallel to the power pool, a bilateral contract market was allowed to function, based on financial contracts known as Contracts for Difference and Electricity Forward Agreements. The possibility to conclude such contracts was offered as an alternative for market players to protect from the high fluctuation of pool prices. Eventually most market players chose for this option and more than 90% of the electricity traded through the pool was actually priced through separate ‘contracts for difference’[9] (Thomas 1997). The general length of such contracts was at least 15 years, but some short-term contracts were also signed.

The distribution activities were organised under twelve Regional Electricity Companies. They were initially allowed to own (shares in) new generation companies, on the condition that their purchases from the companies owned will not represent more than 15% of the total volume of electricity they trade. The opportunity to further expand their generation capacity was however later terminated, being seen as endangering competition. But Regional Electricity Companies were entitled to remain shareholders of the already commissioned generation units, for which they signed 15-year purchase contracts for hedging prices.

Retails activities were opened for competition. A series of generators entered this new business line especially on the second half of the 1990s. In 1990 when the new law entered into operation, only customers with consumption rates higher than 1 MW (representing 45% of the non-domestic market) were allowed to choose their retailer. But, in time, the share between captive and free customers was scheduled to change, so that by April 1998 all end-users would be free to choose their retailer.

The policy of the British Government was to protect renewable generators through governmentally guaranteed purchase contracts and price only in the period 1990-1998. But after 1998, when the entire consumption segment was supposed to be opened for competition, the plan was to expose all new renewable capacity to competition based on the spot market or contracts for difference. This intention could however not be pursued. Changes in the international climate politics, the setting of orientative targets by the EU for renewables and domestic lobbying converged towards the adoption of a new support system. This was introduced in 2002 and its main component is a quota obligation on supply companies to generate or trade certain volumes of renewable electricity (see Appendix 13.3). The next section focuses on the description and analysis of the NFFO support system functioning during the 1990s.

13.5 The economic governance structure for renewable electricity. Selection of hypothesis

The law stated that the minister with competencies in the energy field - the Minister of the Department of Trade and Industry - has the authority to impose purchase obligations for renewable electricity on public electricity suppliers. Having in view the new organisation of the electricity industry, the obligee envisaged were Regional Electricity Companies, in charge

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[9] The process functioned as follows: buyer and seller agreed on a price per kWh and when pool prices were higher/lower than that level, they had to compensate each other for the difference.

with distribution and supply. But the formulation in the legal text was so general and vague that it could have been implemented in many ways, as eventually desired by the government. It left room for imposing an obligation such as that applied in Germany since early 1990s: to buy renewable electricity from all generators with license to build such plants, in unlimited amounts, at any time. But it could also be implemented as an obligation to buy renewable electricity for short-term contracts from a restricted number of generation plants, or MW, or types of technologies. As Mitchell (1996: 47) observes, the law did not make any specification with regard to the time horizon of the obligation it enabled, or the capacity level in MW, or the types of resources/technologies that would benefit from it. Consequently, the law could have been implemented in many ways - from a very powerful to a very weak approach. Besides, it was also possible to change the implementation approach in time[10].

The economic governance structure for the support of renewable electricity generation was defined in Articles 32 and 33 of the 1989 Electricity Law. Article 32 provided for the obligation of Regional Electricity Companies, to purchase or generate the amounts of renewable electricity decided upon by the minister. Article 33 provided for the possibility to subsidise the non-fossil fuel generation with the help of a consumer levy.

The government decided in 1989 that it would implement these rules in the form of a purchase obligation on Regional Electricity Companies, referred to as the Non-Fossil Fuel Obligation (NFFO). This was designed as based on a tendering process whereby generators using eligible types of renewable technologies/resources had to compete for limited capacity within specified technological bands. The elected projects were offered two crucial governmental guarantees: a purchase contract with the regional electricity company for a certain maximum period of time, and an inflation-linked[11] price per kWh during the entire contract length. Five tender rounds were organised during the 1990s: in 1990, 1991, 1994, 1997 and 1998.

The guaranteed contractual price was emerging from the tender process and it was made up of two components: the pool price and a technology-specific premium coming from the Non-Fossil Fuel Levy fund. For the first two rounds the purchase contracts with Regional Electricity Companies were guaranteed until 1998. The 1998 deadline was imposed by the European Commission and was linked to the approval to subsidise nuclear power in the UK[12]. This way the de-facto contract length varied between 4-8 years depending on the time when developers managed to put the plant into operation. For the last three rounds, contract guarantee extended to maximum 15 years, as a result of special approval from the European Commission to continue charging the NFFO levy only for renewables. The NFFO 3, 4 and 5 tenders covered a 20 year period. It was estimated that developers would need up to 5 years for securing planning permits, financing, and proceeding with plant construction. The 5 year window would then still allow them to benefit of a guaranteed contract length of 15 years. The tender package guidance notes for applicants explained that it was also possible to put plants into operation later than 5 years if various obstacles, especially planing permits, could not be

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[10] This posed a high political risk for the emerging manufacturing and service industry for renewable technologies.

[11] The contractual price was adjusted by annual changes in the Retail Price Index.

[12] For more details on the context and history of NFFO system design see Mitchell (1995: 1077-1083) or (1996: 46-52).

overcome earlier. If plants remained economically feasible, they could operate with contracts of shorter length[13].

The forms of the three selected elements to describe the economic governance structure for renewable electricity trade are shown in Table 13.1. They are discussed in Section 13.5.2. Before that, we present in the next sub-section few details on the design the NFFO system by the electricity regulator, called at that time the Office for Electricity Regulation. This design was based on the implementation choice of the Department of Trade and Industry for Articles 32 and 33 of the 1989 Electricity Law. The next section contributes to a better understanding of the support system's risk characteristics.

Table 13.1 *The economic governance structure created through the 1989 Electricity Law*

1989 Electricity Law		
Eligible generators: all types of project developers. Eligible technologies: annually decided together with quota to be purchased		
Elements	Characteristics	Forms
Type of demand		legally guaranteed demand but limited at industry level
Pricing principle	Convergence with pool price	
Price design	Price components	pool price and premium from NFFO levy
	Price levels	fixed per contract life-time (inflation-linked)
	Frequency updating	annually adjusted based on inflation index
	Decision mechanism	→ cost-justification in NFFO 1 → competition and last-bid price in NFFO 2 → competition and own-bid price in NFFO 3,4,5.
Contracts with electricity companies	Contract length	NFFO 1 and 2: up to 1998 => 4 to 8 years, depending on the timing of planning consent; NFFO 3, 4, 5 rounds: maximum 15 years
	Price method	see price design

13.5.1 The organisation and criteria of the NFFO tender system

Article 32 of the 1989 Electricity Law left it to the choice to the government whether to impose purchase obligations on individual distribution companies or at the level of the entire distribution segment. The government chose to make all twelve distribution companies collectively responsible for the purchase of renewable electricity with NFFO contracts. In order to fulfil this, distribution companies set up the Non-Fossil Fuel Agency. One of its main tasks was to collect the consumer levy needed to pay for the NFFO contracts, and distribute it to each distribution company. But the law stated that obligees would be held responsible if they failed to prove the purchase of renewable electricity with NFFO contacts. To ensure this does not happen, distribution companies had to scrutinise the project proposals for renewable plants and accept only highly feasible proposals. This was referred to as the 'will secure test'.

The distribution companies were very unhappy with the imposition of NFFO Orders. Although there were no financial burdens on them, since funding came from consumer levies, they claimed it was not compatible with competition principles and the scheme brought them costs (Mitchell and Skea 1991: 12). Besides, they argued that it was administratively

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[13] "Generators are able to nominate the Contract Term during which they will be entitled to receive the Premium Price. This term cannot exceed 15 years." In: "Tender-Pack Guidance Notes for the Fifth Renewables Tranche" elaborated by the Non-Fossil Purchase Agency (NFPA) in January 1998.

burdensome. The Office for Electricity Regulation (Offer) volunteered then to undertake the ‘will secure test’ on behalf of all distribution companies. This test was supposed to examine applications based on a series of criteria - technical, financial, commercial, legal, planning - in order to ensure that the projects proposed will indeed ‘secure’ the distribution companies’ obligation to purchase renewable electricity. Once an application was approved, the legal responsibility for a distribution company’s failure to buy the approved renewable electricity output was transferred to the renewable energy generator himself.

In addition to taking tare of the ‘will secure test’, the regulator decided to ‘interpret’ Article 33, Paragraph (5) of the law regarding financial compensation for NFFO contracts payment in a way that basically transformed the purchase obligation on distribution companies from financially neutral - as intended by law - into financially positive. The law envisaged that distribution companies would be reimbursed for the costs related to NFFO Orders from levies on consumers. The exact level of reimbursement was set as the total avoided costs for each distributor. But the regulator considered avoided costs to be equal to the pool price. This way all the other cost components that would have been part of the ‘total avoided costs’ had to be paid from the fossil fuel levy, becoming therefore economic benefits for distribution companies. The avoided costs brought about by renewable generation plants connected directly to the distribution grid, mentioned in the different documents of lobbying associations and research papers of academics, are: avoided transmission and distribution grid losses, avoided transmission and system charges, and avoided grid reinforcement and expansion costs (Steen 2000). Hence, distribution companies ended-up with financial benefits from the NFFO program, which soothed their opposition to the purchase obligation.

13.5.1.1 The ‘will secure test’

The technical review of the ‘will secure test’ was in principle looking at issues such as grid connection and metering. The commercial review was primarily looking at the adequacy of resources. In the case of wind energy, measurements for at least 13 months were required in order to prove the potential of the proposed site[14]. The legal review looked at some basic requirements such as authorisation to sell electricity to the grid and arrangements for land ownership or rent. The process for planing permission was entirely under the responsibility of developers. However, the will secure test checked the status of proposed projects: whether planning consent was already granted, was applied for, or in preparation for application, or was not needed.

The most important review from the perspective of our analytical framework was the economic review. For the first two NFFO rounds, the regulator checked whether the proposed/bidded price enabled a financial performance for the project that was “normally acceptable to a commercial business” (NFPA 1990[15]). The regulator promised in the Information Notes for Generators, advising them how to prepare project proposals, that it would provide each generator with information concerning the project profitability that it would be prepared to accept. But bilateral communications on this issue remained confidential.

For the last three NFFO rounds, the economic review of the ‘will secure test’ changed its formulation in the regulator’s advice documents. According to the regulator, the ‘will secure test’ had to check “whether, at the applicant’s tender price, the project’s economic

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[14] However, the location flexibility policy (See Section 13.7) introduced in late 1990s in order to deal with planning permission obstacles yielded this part of the ‘will secure test’ superfluous.

[15] “Renewable Generation Projects: NFFO 1991 Tranche. Notes for generators”, November 1990, Non-Fossil Fuel Purchase Agency (NFPA).

performance would give a positive Net Present Value over its project or contract life"[16] (Offer 1994). The issue of commercially normal projects' profitability remained, however, hovering the applicants. The formulation used by the Non-Fossil Fuel Agency in the Tender-pack Guidance Notes for applicants implied that prices bidded had still to ensure some minimum levels of profitability, considered as commercially normal: "It is accepted by the Office of Electricity Regulation that certain projects, which generate projected rates of return below the level which the Office of Electricity Regulation considers to be normally commercially acceptable, may be viewed by generators as worthwhile because they produce other benefits to which their promoters attach significant value. A particular example of this occurs where a project has an important research and development aspect. In such cases, the Office of Electricity Regulation may be prepared to accept projects as passing the 'will secure test' despite their relatively weak economic performance. The Office of Electricity Regulation would require such applicants to set out their arguments for non-financial benefit in a separate submission." (NFPA 1998[17]).

Under all five NFFO rounds, when projects with low profitability (or negative Net Present Value) were accepted by the regulator, developers had to sign a declaration stating that they were aware of this, and agreed to proceed with the project. Acceptance was however still at the discretion of the regulator, on the basis of the arguments presented. Only developers who did not sign the special declaration were allowed to terminate their projects when financial performances were lower than accepted in the 'will secure test'. The number of declarations for acceptance of negative Net Present Values under the 3rd NFFO round was not made public. But under the 4th and 5th NFFO rounds there were seven such declaration passing the will secure test for each call for tender.

The requirements under the economic review of the 'will secure test' have two important consequences from the standpoint of our research model. Firstly, project profitability was a policy design element - although more in the form of soft guideline - of the economic governance structure (the NFFO system). It was hence not just an indirect consequence of the extent of financial support, as assumed in the theoretical framework. Secondly, in terms of our typology of drivers to invest the requirement of normal commercial returns implies that the support system was primarily aiming at solely/strongly commercial projects. But in the same time, the formulation of exceptions from normal economic performance implies that it was also accommodating for strategically motivated projects that, for various reasons, were not able to be sufficiently profitable. This means that strategic reasons such as green ideology, or technology demonstration and learning, or local business opportunity (more attractive than local alternatives), could still operate as main drivers to invest in the NFFO system. Likewise, the 'interpretation' of wind electricity delivered to the local grid[18] as covering self-generation needs could also serve as motivation to invest for projects with low/no profitability. Consequently, it can be considered that the forms of this diffusion indicator were not totally constrained, and will be discussed in Section 13.6.

In the case of wind energy the rate of success in passing the 'will secure test' was very high, compared to the other renewable technologies. We found data only for the last three NFFO rounds, which are presented in Table 13.2. The documents of the regulator advising the

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[16] These explanations were given in the documents that functioned as advice by the regulator OFFER for the DTI Minister to set the NFFO Order size. The text was highly similar in the 1994, 1997 and 1998 documents published by OFFER.

[17] "Fifth Renewables Tranche - Tender Pack Guidance Notes" January 1998, Non-Fossil Purchase Agency.

[18] In the UK during the 1990s there were no wind projects connected to the high voltage transmission grid, mainly due to their small sizes.

Minister for Orders' technology inclusion do not mention for which type of review did wind projects fail. However, they mention the numbers of failures per types of review for all technology bands. It appears that the lowest number of failures for all renewable applications was actually in the economic review: 1 or 2 projects in NFFO-3; 2 projects in NFFO-4; and 2 projects in NFFO-5. A likely reason is that, according to the procedure, after making a first price bid, applicants were allowed to review the economics of their projects, if the proposed plant did not satisfy the Office of Electricity Regulation's expectations of commercially normal profits. The next subsection makes a short discussion on the emergence of contractual prices and presents the results of the five calls for tenders of the NFFO program in terms of number of projects, capacity and prices contracted.

Table 13.2 *Number of projects failing 'will secure test' in NFFO-3,4,5*

Number of projects failing 'will secure test'	NFFO-3	NFFO-4	NFFO-5
Wind Projects	13	4	0

Based on: Offer 1994; 1997; 1998

13.5.2 The capacity with guaranteed contracts and prices for wind electricity in the five NFFO rounds

Under the NFFO-1 call for tender in 1990 there was no differentiation between types of technologies. In this first round, contracts' allocation was based on 'cost-justification' for each proposed plant. The regulator had no experience on the anatomy of production costs for renewable electricity (Mitchell 1996: 49). Hence, there was no direct competition in this round and developers only had to explain to the Office of Electricity Regulation how they came-up with the claimed production costs. The exact level of these prices remained however kept in confidentiality by the government. Prices paid were generally high due to the short period of time when contracts could be guaranteed - until 1998. The highest price paid was 15 €c/kWh but each successful generator was paid his/her proposed price. Around half of capacity approved under NFFO-1 consisted of demonstration systems already in operation.

Under the NFFO-2 round in 1991, applicants for wind projects competed for contracts within a separate technological band. But all successful bidders received the same price/kWh. This was defined by the last successful bidding project, and was referred to as the 'strike price'. With the approval of the cheapest 196 MW of wind projects proposed, the price of 16,6 €c/kWh emerged. This was higher than under the NFFO-1 tender because the time when investment costs could be recovered under guaranteed purchase contract was shorter, having to face the same 1998 deadline set by the European Commission. For winning developers who could put their wind projects fast into operation, the contract length was 7 years. But there were projects with long delays due to permit bottlenecks that could only benefit of contracts as short as 4 years[19]. Under the following three rounds, competition for wind contracts was split further in two project-size bands. But border-sizes were annually changed, as shown in Table 13.3.

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[19] There were 70 MW in 22 projects with NFFO-2 contracts that had to be abandoned. For some projects,the owners were not able to get local permits to put them into operation. For others, the remaining contract length (expiring in 1998) was not sufficient anymore to offer them recovery of investment costs, at the price of 16,6 €c/kWh. As for the NFFO-1 round only 1 project was terminated (with 1,2 MW). But as already mentioned two-thirds of the capacity was already operating and had only to be sold as 'ready-made' plants.

Table 13.3 *Wind capacities with NFFO contracts and prices per kWh*[20]

Tender	Tender year	Number projects for wind	Contracted capacity for wind	Price range €c/kWh	Average price €c/kWh
NFFO-1 (no wind band)	1990	9	28 MW	maximum: 15,1	
NFFO-2 (1 wind band)	1991	49	196 MW	all developers: 16,6	
NFFO-3, >3,7 MW	1994	31	339 MW	6 – 7,2	6,5
NFFO-3, <3,7 MW	1994	24	46 MW	6,8 – 9	7
NFFO-4, >1,76 MW	1997	48	768 MW	5 – 5,7	5,3
NFFO-4, <1,76 MW	1997	17	24 MW	6,2 – 7,5	6,9
NFFO-5, >2,3 MW	1998	33	768 MW	3,7 – 4,7	4,3
NFFO-5, <2,3 MW	1998	36	67 MW	5,1 – 6,9	6,3
Total	-	247	2236 MW	-	-

Based on: ETSU, 1998/1999, "NFFO Fact sheets"

The separation of wind technology band in small and large projects was introduced after a powerful lobby from the British Wind Energy Association, and it was meant to encourage investments by landowners and developers with limited financial resources[21] (IEA 1999: 154). Besides, because of higher costs in the technology-complementary and context-induced cost components (see Section 2.8), small-scale projects needed higher contractual prices to recover investment costs in the same period of time, than larger-size projects. The price-ranges and the average prices per kWh for the last three rounds are shown in Table 13.3. Each generator, whose project proposal was approved, received the contractual price he/she bidded. The maximum price emerged as the Minister of the Department of Trade and Industry was tracing the line setting the wind capacity size of the Order across the price-MW curve drawn by the Office of Electricity Regulation on the basis on all firm bids received. The table also shows the number of projects awarded guaranteed contracts per round for each project-size band, and the total capacity represented by each band[22].

13.5.3 The economic risks associated with the NFFO tender system

The NFFO system can be described as an economic governance structure with legally guaranteed demand for periods of time specified by Order of the Minister of Trade and Industry. For NFFO-1 this was up to 8 years, for NFFO-2 up to 7 years, and for NFFO-3,4,5 up to 15 years. The contracts were signed between the renewable generator and the Non-Fossil Purchase Agency, acting on behalf of the twelve Regional Electricity Companies. In addition, the host Regional Electricity Company was also part to the contract. There were three methods of price design based on which contractual prices emerged, described in the above sub-section. Only under NFFO-2 was there a single contract price for all wind electricity generators. For the rest four rounds each generator received its proposed/bidded price. Contractual prices were set at the moment of contract allocation for the entire period of guaranteed purchase, with annual revisions to account for the inflation rate.

Regarding the risks on cash flows associated with the NFFO system there is general agreement that these were basically absent. All interviewed market experts stated that once a

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[20] Throughout the chapter we used the rate 1 UK Pound = 1,51 Euro.

[21] However, as Section 12.6.1 will argue, small developers did not succeed in becoming a presence in this sub-band because the design of the support system inherently favoured large and financially powerful companies.

[22] The details for the small-scale bands ('small' - as defined by the UK government, not by us in Chapter 4) are highlighted in grey for easiness to spot differences.

contract was allocated this was reliable both in terms of length and price[23]. Empirical literature is also referring to the NFFO system as attractive for investors because of certainty on long-term output purchase and prices that only changed upwards to follow the inflation rate. This was appreciated from the beginning by both companies interested to become developers and by financing agents.

We carried out a close analysis of the legal text for the economic governance structure, consisting of Articles 32 and 33 of the 1989 Electricity Law. Further we scrutinised for contract and price risks:

- all policy statements by the Minister of the Department of Trade and Industry announcing each following NFFO Order[24];
- the Information Notes for Generators elaborated by the Non-Fossil Purchase Agency for each NFFO round explaining applicants the design of the NFFO system, the responsibilities of different parties involved, the requirements of the 'will secure test', and all details regarding price design, procedures to receive payment for electricity sold to Regional Electricity Companies, and contract provisions[25]. In addition, we looked at the information provided in the Tender Packs Guidance Notes explaining applicants how to prepare their tenders (NFPA January 1998);
- documents issued by the Office of Electricity Regulation as advice for the Minister to set the sizes of technology bands for NFFO Orders[26];
- The Statutory Instruments whereby the Minister placed the NFFO Orders on regional electricity companies[27].

We concluded that, from all these documents, the existence or level of economic risks could actually be derived only from the two articles of the 1989 Law and the two types of documents elaborated by the Non-Fossil Purchase Agency.

As regards contracts' length, they were standard for all renewable generators and "not subject to negotiation". An important provision spurring the doubts on purchase continuity was the inclusion of a paragraph stating that "The Contract Term can only be reduced in limited circumstances. This is to ensure the contract continues to meet the requirements of the 'will secure test'. The generator grants Non-Fossil Purchase Agency the sole and the exclusive right for the Contract Term to the 'Contracted Capacity' of the Facility. (…) The generator may not assign the contract to a third party without the agreement of Non-Fossil Purchase Agency and the distribution companies" (NFPA 1995). Such provision eliminated risks on contract interruption or cancellation.

As regards contractual price, a modest price risk emerged under the NFFO 3 and 4 rounds. This was introduced in the 'will secure test' by the Office of Electricity Regulation and was referred to as 'the levy out' clause (Mitchell personal communication 2000). The new clause was explained in the Information Notes for Generators, elaborated by the Non-Fossil Purchase Agency: "If for any reason the Regional Electricity Company's entitlement to the Fossil Fuel Levy is reduced, the generators' entitlement to the 'difference' (difference between contract price and reference/pool price) element of their payments shall reduce proportionately" (NFPA

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[23] Interviews in 2002 with Catherine Mitchell, Cris Naish (ETSU), Gaynor Hartnell (BWEA/CREA), Nicola Steen (AEP), David Porter (AEP), Karen Marshall (OFFER), PowerGen Renewables, Andrew MacDonalds (Renewable Generators Consortium).

[24] DTI, December 1990; July 1993; October 1993; November 1995; December 1995; November 1997.

[25] NFPA November 1990; December 1995; 1996; November 1997.

[26] Orders of: 1994; January 1997; September 1998.

[27] Order 1990 No.263; Order 1991 No.2490; Order 1994 No.3259; Order 1997 No.248; Order 1998 No.2353

1995). This was inserted in order to prevent that the purchase obligation becomes financially-negative for Regional Electricity Companies.

Nevertheless, the levy-out clause did not surface as a concern for developers and financiers[28]. The high competition for contracts (see Table 13.13 in Section 13.7.1) suggests that developers were not concerned with this regulatory aspect. There was sufficient confidence in the political continuity for renewables support within the NFFO framework. The probability of Minister cancelling the implementation of Article 32 in the 1989 Law that allowed distribution companies to charge the consumer levy was very low - at least as regards the already unfolding contracts. In the Information Notes for Generators preparing bids for the NFFO-5 round the levy-out clause disappeared. A more comforting note was inserted in its place, stating that "cash flow (…) may be in part delayed if funds from the fossil fuel levy are insufficient" (NFPA 1997). *In conclusion, we assess the economic risks posed by the NFFO system as very low.* This is represented in Figure 13.1 in the next sub-section, which discusses the issue of profitability of wind projects under the five NFFO rounds.

13.5.4 The profitability of wind projects under the NFFO system

In the previous chapters the issue of project profitability was analysed from three perspectives: a) direct and/or inferred data on project profitability based on information from interviews and publications, b) qualitative assessments by developers and market experts, and b) comparison of average production costs with the average contractual prices during the period studied. In this empirical case study, only the first two mentioned perspectives are taken. The reason is that many NFFO contractual prices under the last three rounds (especially NFFO 5) were bidded speculatively low, in order to secure contracts' approval. Counting on the 5 year grace period to put the plant into operation (enabled by the government to help developers secure planning approval) developers took the expectations on future production costs' decrease as reference for price calculation. Hence, comparing the average contractual prices for NFFO-3,4,5 with the claimed production costs that are distorted by future expectations makes little sense.

However, the first perspectives pose also difficulties. Firstly, should one look at the projects' profitability for the *approved* projects, or for the *installed* projects? The analysis of empirical material suggests that these have often not been the same for several reasons explained below. Secondly, should one look at the profitability of installed projects under the *first owner*, or also under the *following owner(s)* when projects were sold after the developer won the tender? A close study of the British wind market reveals that there was a significant trade with already operating wind plants holding NFFO contracts. As owners changed, the (remaining) profitability of projects also changed. Table 13.4 shows the substantial difference between the wind capacity approved by the government in the five NFFO rounds and the capacity installed by mid 2002.

The main reasons for this difference are: a) the refusal or long procedures for social and administrative approval at local level, which affected projects from all five NFFO rounds; and b) the speculative bidding under the NFFO-3,4,5 rounds, resulting in the impossibility or undesirability to build projects too soon, when contract prices were/are (still) too low; waiting could only help make projects feasible or increase their profitability.

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[28] No empirical study or specialised journal article we are aware of (Wind Power Monthly 1994-2002; Wind Directions; News Review (1993-2002) mentioned that the levy-out clause produced a change in investment strategies or put on hold the design or finance of wind projects. This was also not mentioned as an issue affecting investment decisions by any interviewee.

Table 13.4 *The contracted and the installed wind capacity in the UK, 2002*

Tender	Year	Contracted capacity	Installed capacity by mid 2002[29]	Capacity (projects) terminated by 1999[30]
NFFO-1	1990	28 MW	27 MW	1,2 MW (1 project)
NFFO-2	1991	196 MW	124,72 MW	70 MW (22 projects)
NFFO-3, >3,7 MW	1994	339 MW	98,8 MW	88,4 MW (12 projects)
NFFO-3, <3,7 MW		46 MW	13,2 MW	
NFFO-4, >1,76 MW	1997	768 MW	23,2 MW	97,6 MW (11 projects)
NFFO-4, <1,76 MW		24 MW	4,8 MW	
NFFO-5, >2,3 MW	1998	768 MW	-	n.a.
NFFO-5, <2,3 MW		67 MW	6,5 MW	
Total		2236 MW	292,17 MW	at least 257 MW

To discuss the issue of projects' profitability it is useful to differentiate between: NFFO-1,2 rounds, on the one hand, and NFFO-3,4,5 rounds, on the other hand. This is necessary because of the different the emphasis of governmental policy and, the design of NFFO system. Due to the fact that we are interested in the investment attractiveness of the support system, we focus on the profitability of projects under their first owners (or the project developers). Further, having in view that the approved capacity was based on speculative bidding, it makes sense to concentrate on the *profitability of projects successfully installed*. However, looking at the profitability of approved projects, helps to make a general orientation into the ranges of profitability supported by the policy program.

The profitability of approved projects was not made public by the regulator. All documents of the regulator and Non-Fossil Purchase Agency included a confidentiality assurance for applicants[31]. In the available empirical literature, we could find some data on the ranges of project profitability, returns on equity requirements by different types of developers, and interest rates. Table 13.5 summarises the empirical data. These were complemented by the cooperation of several interviewees. In a communication with the department of renewable energy at the Office of Gas and Electricity Market - the new body replacing the Office for Electricity Regulation - we learned that the regulator used as criteria for the examination of project proposals an 8% level of project profitability (McIntyre 2002). This places the profitability of the NFFO system in the high/very high range - at least theoretically, because as we mentioned many projects bidded at speculative prices. Having in view that we assessed economic risks as very low, this profitability border used by the regulator suggests the placing of the NFFO support system in the optimal investment context. We now look at other pieces of empirical information supporting the idea of a high/very high profitability for wind projects.

[29] Source: for the number and capacity of projects already installed by mid 2002 we used the database of the British Wind Energy Association available at 26 September 2002 at http://www.bwea.com.

[30] Source: ETSU, 1999, NFFO Status Update leaflet.

[31] For example the Information Notes for Generators for the Fifth Renewables Tranche mentioned that "All information supplied by applicants and their representatives will be treated as strictly confidential and will be used only for the purposes of assessing projects and monitoring the performance of contracts awarded to meet the Order (…). Limited information of a non-commercial nature will be made available more generally" (NFPA November 1997: 12). The documents for the other four NFFO rounds contained similar text.

Table 13.5 *Ranges of projects' profitability, returns on equity and interest for wind projects installed during the 1990s in the UK*

Sources[32]	NFFO Number or year	Project profitability	Returns on equity owners	Interest rates banks
ETSU (1993)	early 1990s	15%	-	-
Mitchell[33] (1994)	NFFO-1,2	-	15 - 35%; mostly > 20%	8,3 - 11,2% (up to 13%)
Johns (1997)	NFFO-1,2,3	15 - 20%	-	-
Milborrow (1997)	NFFO-2	8 - 15%	10 - 30%	-
WPM (1998; 1999[34])	1993/99	-	-	7,5 - 10%
IEA[35] (1998-2001)	all NFFOs	"plenty of margin" in NFFO-1,2,3	project finance 8-12 %; corporate finance 15-25 %	-
WPM (2000)[36]	NFFO-1,2,3	10 - 12%	> 12%	11%
	NFFO-4,5	7 - 10 %	on average 9 %	-
(WPM Feb. 1995:27)	NFFO-3	9 %	-	-
Martin Alder	NFFO-3,4 5	will secure: 8-12 %; typical: 8-10 %	often > 20 %	6-7 % late 1990s – 2002

At the launch of the NFFO support system, the government had a target of 1000 MW by 2000. But it did not have a clear policy on renewables market diffusion. The only obvious, but not stated, policy line pursued in the first two NFFO rounds was to attract large companies, especially the newly privatised electricity companies, to form the basis of the British renewable energy industry. For this, the Minister with energy responsibilities purposely allowed for high contract prices - especially in NFFO-2 when the 'strike price' was given to all successful developers. Distribution companies were not enchanted by the governments' decision to impose renewable purchase orders on them in a liberalised industry. The distribution companies argued that one way to compensate for this burden would be to become

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[32] The sources used are scientific publications (Mitchell 1994), conference papers of financial consultants (Johns 1997; Milborrow 1997), articles from Wind Power Monthly journal (WPM September 2000: 39; and 1998), publications by governmental renewable agency (ETSU 1993), the Annual Reports on Wind Energy by the International Energy Agency (IEA 1998; 1999; 2000; 2001), as well as interviews with market experts (Alder 2002; Milborrow 2002; Fletcher 2002).

[33] Mitchell suggests in a specialised journal (WPM February 1995: 20) that the lower end of the commercial returns on equity generally expected in the UK was 15% (in 1995). Assuming an interest rate of 8-9%, and a loan contribution to the capital structure of the project of 25%, this could result in an overall level of project profitability of around 10-11% at the lower end of the so-called 'commercial' range in the UK.

[34] "Private sector developers use interest rates from about 8% upwards" (WPM February 1999: 48).

[35] The Annual Reports of the International Energy Agency mention some average data at industry level for all 5 NFFO rounds. According to this source, when project finance was used, owners had returns on equity of 8-12%. When corporate finance was used, their returns on equity were as high as 15-25%.

[36] One market expert made the following comments "Wind developments in the US and Britain have been financed on normal commercial terms in deals put together by banks or the small handful of project financiers operating in the sector. Lending levels rarely exceed 80% of the project cost and investors put up the remaining 20%, the equity. Given that equity shareholders generally demand rates of return of 12% or more, in Britain the effective profitability for projects as a whole has generally been in the 10-12% range. The intensely competitive nature of the Non Fossil Fuel Obligation (NFFO) market structure, however, drove down project rates of return. The successful bidders in the later rounds were often utilities. These were able to use their own funds and set their own rates of return lower, and profitability dropped to 7-10%." (WPM September 2000: 39).

involved in renewable electricity generation themselves. This way, it was easier for the government to reach its target, if distribution companies received a share of NFFO contracts that would support an atmosphere of cooperation in the industry.

But in order to attract their participation, it was necessary to allow for high payments per kWh because electricity companies were just recently privatised and were still operating with very strict investment criteria. They required very short pay-back time of investment costs - definitely no longer than 5 years[37] - and very high returns on equity - generally in range of 20-35%. But, in addition, they regarded renewable technologies as riskier than fossil-technologies, which placed their expectations on returns in the upper part of the range, during the first two NFFO rounds.

These considerations and the empirical data in Table 13.5 suggest that most wind projects developed under NFFO-1,2 rounds had very high profitability levels. More empirical sources agree that the returns on equity of owners were much higher than in the following 3 rounds. They were more often in the range 20% - 30% while fewer companies accepted returns on equity of 10% - 20%. Taking into account that interest rates were also quite high, generally in the range 8% - 11% (but possibly also higher given the early stage of diffusion), it can be estimated that, ceteris paribus, the profitability of projects with NFFO-1,2 contracts was probably in the range 10% - 17% with some projects reaching 20% or even higher, as suggested in Figure 13.1.

Besides, a market analyst explains that in the UK a project can get ‘project finance’ loans only when its overall profitability is above 9%. For wind technology this should be minimum 10%, when the technology is perceived risky[38], which was the case for the projects under the first two NFFO rounds. In these rounds, slightly more than half of the projects used project finance approach and the other half used different types of internal financing schemes (Mitchell 1994: 308-9). This explanation suggests that more than half of installed projects must have been high - very high profitability plants.

A strong indicator for the very high profitability of NFFO-1,2 wind projects is formed by the phenomenon that emerged already in the first years of the 1990s of selling-off already operating plants. Apparently, the profitability of some projects was so high that it made possible for the initial owner(s) to withdraw with some profits and still enable the buyer to make also satisfactory profits for the remaining guaranteed-contract period. For example, the company Ecogen (owned by American Sea West and by Japanese Tomen Corporation) won nine NFFO-2 contracts (WPM April 1994: 14). Later they sold some projects to British electricity companies. Another example is the purchase of 3 projects by the American company The New World Power (WPM July 1994: 26/30). All 3 contracts were bought in 1994 and expired in 1998, suggesting the large profitability projects must have had when they

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[37] The boards of electricity companies, which approve corporate finance, require the recovery of investment costs in only 3-4 years. A period of 5 years was often already unacceptable (Mitchell 1994: 255). This was a very serious challenge for wind technology which assumes high initial investment costs.

[38] "A lower rate of interest is paid on the debt - currently around 11% in the UK, but these payments have priority. Cover ratios can be linked to another key indicator of financial stability - the overall rate of return on the project. If this falls below about 9% in real terms, meaning net of inflation, most banks regard the level of security on their loan as inadequate as it requires only a small perturbation in the performance of the plant to make it difficult to repay the annual loan instalments. This argument applies to any type of investment, not just wind farms. But these are particularly susceptible to variations in income due to the year-by-year variations in wind strength and risk rises as rate of return falls. When these risks are taken into account, project rates of return for wind plant are usually pushed towards 10%, in order to make the risks acceptable." (WPM February 1995: 27).

were approved. The trade with operating plants diminished substantially for those built under NFFO-3,4,5 contracts.

In July 1993 the new Minister of Department of Trade and Industry clarified the governments' policy on renewables, and set 'price convergence' (of renewable and conventional electricity) as the key principle for the NFFO price design (ETSU 1998). The NFFO-3,4,5 rounds were designed as 15 year long contracts with a 5 year grace period when successful developers could put their plants into operation. The policy statements announced increasingly large capacity orders for wind energy. These raised the interest of increasingly more companies to propose projects and toughened the competition to unexpected levels. The prices bidded under NFFO 3 were much lower than those under NFFO-1,2. The main reason for this was the increase in contract length that allowed investment cost recovery to spread over a longer period. But, still, market experts estimate that an additional reduction - up to 33% - was possible due to reductions in the various cost components that make-up the production costs per kWh (WPM February 1995: 27). Part of this decrease comes, as data in Table 13.5 also suggest, from a reduction in the return requirements by equity financiers (mainly the large electricity companies). As mentioned earlier, under the 4th and 5th NFFO rounds there were 14 declarations for acceptance of lower than 'commercially normal' projects profitability. But the interest rates required by banks also lowered. Technology risk perceptions decreased, as interest in the new business increased both for financiers and developers.

But a negative consequence of the new governmental policy and NFFO design was that many bids were purely speculative, in order to secure contracts. Therefore, while the regulater operated with a profitability criterion of 8%, it means that many projects presented project proposals that resulted on paper on profitability levels above 8% but in fact this may have been lower or even negative. The same thing happened in NFFO-4 round and was a dominant feature of NFFO-5 round. Some developers who made speculative bids hoped that the 5 year window would allow costs to come down to a level that would make their projects (more) profitable, reaching the 8% level or higher levels. Others, especially under NFFO-5 round, were mainly interested to sell the winning contracts to large corporations (Alder 2002).

Another negative consequence of the new governmental policy after 1993 was that the suddenly large orders for wind capacity, as compared to the previous two rounds (see Table 13.4), seemed to have scared the public and local/regional authorities. Especially the countryside inhabitants and local interest groups became scared that the landscape would be flooded with wind turbines in a frenzy drive for new energy, as in Germany and Denmark. This increased the social and local administrative opposition to unexpected levels. Many projects had to be terminated (see Table 13.4) and the process continues with intensity, while others had to confront delays of up to 5 years (Krohn 1998). In 2001, the government has finally introduced a location flexibility policy whereby projects that were refused planning permission at the originally envisaged site were allowed to try to obtain approval at a different site.

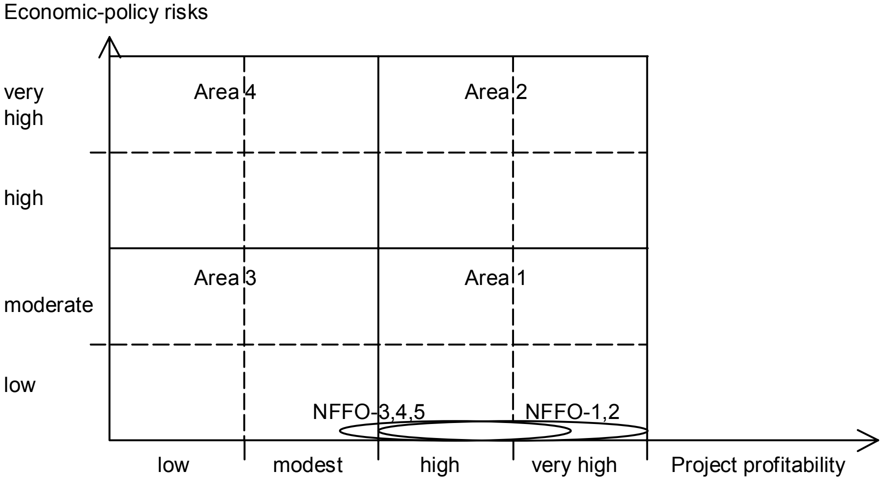
As regards the profitability of projects approved in these last three rounds, some market experts (Alder 2002; Milborrow 2002) mention that this has generally been between 8-12%. But others estimated that this could have still been as high as 16-17% in some cases[39]. As

[39] For example Johns (1997) mentions that in the UK "the general investment criteria of overall project returns (is) between 15 % to 20 %". He estimates that for a large wind plant of 20 MW that benefits of 80 % project finance loans at 8 % interest rate for 12 year can yield a project profitability of 16,7 % under a 15 year NFFO (3) contract for a bid price of 5,33 €c/kWh. The NFFO-3 contract prices were in the range of 6-7,25 €c/kWh, for plants larger than 3,7 MW. There were only 3 wind projects larger than 15 MW put into

concerns the projects installed, it is not clear if and how many projects increased their initially approved profitability, and if and how many suffered a set-back. The following factors can be seen as potentially playing a role in raising the level of projects' profitability from the 'approved' to the 'installed' phase: lower technology-specific costs; increased competition in project design and development phases resulting in lower fees and costs. On the other hand, there are also factors leading to cost increase, such as the reduction in the guaranteed contact length below the 15 year period for which prices were bidded - due to permit delays, legal and consultancy costs - also due to local permit obstacles.

The empirical data summarised in Table 13.5 suggest that for the installed NFFO-3,4,5 projects the profitability has spread so far in the range of 7-12%, as represented in Figure 13.2. The move from the dominance of project finance (for NFFO-1,2 contracts) to the dominance of internal financing schemes (see Section 13.6.4) suggests that increasingly more projects have profitability below or slightly above 9-10%, which is considered the lower limit for the approval of project finance by many banks in the UK. It is not clear what will happen in the 'remaining future' with these contracts: whether they would move more substantially in the below 10% area or would somehow still manage to stay or climb into the above 10% area.

Figure 13.1 *The risk-profitability investment context created by the NFFO support system for wind energy*



In conclusion, in the case of projects with NFFO-1,2 contracts the profitability of projects was higher than for the projects with NFFO-3,4,5 contracts. The projects commissioned under the first two rounds of tenders could reach profitability levels in the *'very high' range* frequently, while those successfully built under the last three calls for tenders were mainly focused in the *'high' profitability range*, possible with a decrease towards 'modest' levels[40]. *Based on these*

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operation based on NFFO-3,4,5 contracts while 41 projects were in total approved in these three rounds (see Table 13.8).

[40] This does not mean that the NFFO system did not result in projects with low profitability. Indeed, the fact that many developers bidded speculatively low prices means that in fact many projects were either not profitable at all or had very low profitability. But this group of projects was not considered as serious investment options by contract owners, unless cost reductions could help pushing the profitability of projects at least in the modest/high range. The projects that were installed, had only exceptionally profitability lower than 7%.

considerations, we select Hypothesis 1 to test for the diffusion of wind technology in the United Kingdom. Section 13.6 will test the theoretical expectations of Hypothesis 1 for diffusion patterns and Section 13.7 concentrates on testing the expectations regarding the diffusion results.

13.6 Diffusion patterns of wind technology in the England and Wales, in 1990-2000

This section tests the theoretical expectations of Hypothesis 1 for diffusion patterns for wind technology in England and Wales during the period 1990-2000. Before discussing the confirmation of these expectations per type of indicator, we present the extent of compliance of this case study with the theoretical assumptions made in Section 2.5.

Based on the presentations made in Section 13.4 and 13.5, it can be argued that the first four mentioned assumptions in Table 13.6 were complied with for this case study. However, the design of economic governance structure whereby the government decided for how much MW capacity it guarantees contracts and prices implies that the fifth assumption mentioned in Table 13.6 was not complied with. This has the consequence that the theoretical expectation regarding one dependent variables - the capacity increase - cannot be tested in terms of installed capacity but the capacity *applied for*. Only the later would show the investment interest created by the support system.

Table 13.6 *Assumtions of the theory and their presence in the case study - wind technology in England and Wales*

Assumptions of the theory	wind in England and Wales
imported renewable electricity is not eligible for the benefits of support system	complied with
electricity industries are liberalised to the extent that market entry of any type of economic actor willing to engage in electricity generation is possible	complied with
the support system remains the same over at least short-medium term	complied with
renewable electricity from partly-self-generation plants may receive the same benefits from the support system as electricity from commercial projects	complied with
there is no governmental limit or requirement on the installed capacity of renewable technology(ies) at industry level	not complied with
there are no direct influences from government intervention on diffusion patterns e.g. on types of developers, types of financing schemes, project size, drivers to invests, technology choice design	not complied with for project sizes and types of developers; partial influence on drivers to invest
no other types of obstacles impede diffusion, such as administrative, social, institutional, technical (grid) obstacles	not complied with

Further, the close analysis of the NFFO Program design and governmental policy revealed that there was governmental influence on the indicator of project sizes and - to a smaller extent - also on that of types of developers. Besides, it was also an attempt - incompletely pursued - to influence also the drivers to invest towards commercial projects (by means of the [8%] profitability requirement). Finally, the strongest assumption of the theory - that no other types of obstacles impede diffusion, such as administrative, social, institutional, technical (grid) obstacles - was not complied with in the United Kingdom. Actually, this was a major reason why there is such a gap between the approved capacity and the installed capacity. We briefly explain below the forms of governmental influence on diffusion patterns.

Governmental influence on diffusion patterns

The governmental policy underlying the design of NFFO-1,2 rounds assumed indirect interference with the forms of the indicator 'types of developers'. As mentioned in Section 13.5.4, the government aimed at bringing the former utilities in the renewables business, and was successful in its objective. In July 1993, when the governmental policy on renewable energy was finally articulated, a change in direction occurred. The new Minister of the Department of Trade and Industry engaged in a 'diversity policy', which was to be stated before all following three NFFO calls for tender. The government aimed in NFFO-3,4,5 tranches to encourage diversity in the types of developers, in technological choice, and in project sizes[41]. The policy to encourage diversity in types of developers was strongly related to price competition. It was feared that if concentration of business and ownership starts too early this would lead to keeping bidded prices artificially high. To ensure diversity the government even announced that it would impose ceilings on the number of projects or total capacity allocated to a single company in a single round. This happened only once and not even effectively[42]. On the other hand, this policy was seen as a means to safeguard diversity in technological choice, to avoid "premature focusing on too narrow a technical base, so excluding the development and demonstration of alternative options" (DTI 1993: 9). Besides, the government wanted to encourage diversity in project sizes because it feared that if only few large projects were approved and they subsequently failed to secure building permits, this would have had consequences for target' achievement.

The diversity policy was not successful in the case of types of developers (see Section 13.6.1). Further, the practical developments in terms of technology choice cannot be seen as related to the stated governmental policy because developers were free to choose their preferred technology after they had been allocated contracts. Since technology choice was not a commitment screened in the 'will secure test' by the regulator, the outcome cannot be hence linked to the governmental policy. As regards, project sizes, these have been eventually indeed strongly influenced by the NFFO design: firstly by differentiating between small-size and larger-size technological bands for wind energy (see Table 13.4), and secondly by ensuring that the selection of projects avoids too large plants.

In conclusion, only the forms of the indicator 'project sizes' were ultimately directly influenced by NFFO design. Indirectly, the governmental policy influenced the picture of 'types of developers' - under NFFO 1 and 2 contracts. As regards the drivers to invest, Section 13.5 already explained that - in spite of setting a minimum limit for the profitability of projects the regulator preferred to approve - regulations allowed developers to bid projects with profitability below this floor level. This implies that the forms of this indicator were not fully constraint as in the case of project sizes.

Table 13.4 shows that from the total approved wind capacity of 2236 MW in the five NFFO rounds, only 292 MW were installed in mid 2002. This raises the question of whether the testing of Hypothesis 1 should be done for the diffusion patterns of the 2236 MW approved or for those of the 292 MW emerged in practice by the time of our analysis.

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[41] This is explained in the information notes for project applicants e.g. "Renewables Energy Bulletin No. 5, Information on the Non-Fossil Fuel Obligation for Generators of Electricity from Renewable Energy Sources, NFFO 3", October 1993, DTI.

[42] The capping of projects happened under NFFO-3 when the largest wind developer National Windpower (of the conventional generator National Power) was approved only 10 projects of those that would have qualified for NFFO contracts seen solely from the price standpoint. But still the approved 10 projects counted for half of the entire capacity approved in the NFFO-3 round (ETSU 1998 "NFFO Fact Sheet").

Our aim is to observe the particularities of the investment *interest* of project developers, eliminating as much as possible the distortion of the picture of developers due to different types of obstacles. Having this in view, we argue that the testing of the hypothesis should be done for the *approved capacity* for the indicators - types of developers and drivers to invest - and for the *proposed projects* for the indicator - project sizes[43]. In order to learn about the influence of exogenous factors, we find it useful to look in the case of project developers and drivers to invest at both the owners of approved projects and installed projects. A preliminary orientation in the topic indicated that the change in ownership was sometimes motivated by obstacles to finance and/or get a construction permit for the project, while buyers of wind projects had sometimes more than commercial reasons to invest. For the other two indicators - types of financing schemes and technological choice - the testing of expectations can only be done for the *installed capacity*, since these aspects where not a criteria of projects approval and they were not even included in project proposals.

13.6.1 Types of project developers and owners

Hypothesis 1 predicted that under optimal investment contexts a large diversity of types of developers could be observed, coming from a wide range of industrial, economic and social sectors and activities. Empirical data regarding the project developers for the *approved capacity* during the five NFFO rounds led to the assessment that theoretical expectations were *confirmed to large extent with comment*.

In the analytical framework, we referred to developers as economic actors that contribute to the equity financing of renewable energy projects. In this sense, developers were the same with owners of projects. In the UK, however the nature of the NFFO system led to the emergence of a group of companies specialised in the preparation of bidds for the calls for tender, who are generally referred to also as ‘developers’. They carry out all necessary steps required in the ‘will secure test’, and all the other steps needed to start with a project’s construction[44]. In some cases, after winning the NFFO contracts they become also owners by providing all the equity needed to finance the project. In other cases they call in for other companies (or economic actors in general) to contribute with equity, becoming hence co-owners of the project. But quite frequently, developers sold the NFFO contracts to other companies. In these cases the developer and the owner of the same project were different companies/economic actors. As Krohn (1998) observes “this ‘developer’ layer is a fairly unique feature of the UK market”. Bearing this in mind we discuss in this section about the types of *developers of approved NFFO contracts*, and about the *owners of installed projects* by mid 2002.

The dominant developers of approved wind projects in England and Wales were large and financially powerful economic actors: electricity companies (former energy utilities), mainly by means of subsidiary companies specialised in investments in renewable power plants, water utilities, industrial groups from a very wide diversity of industrial and economic backgrounds, and wind technology manufacturers.

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[43] Ideally, the discussion of types of project developers and drivers to invest should have also been done for the *proposed* projects. However, this information is not available. We could only found data regarding the *sizes* of proposed projects for the NFFO 3,4 and 5 calls for tender.

[44] Often these steps include: resource measurement, project design, feasibility and impact studies, arrangements for grid connection and infrastructure engineering, land-use permission, local approvals, studies required by financing agents, incorporation of legal advice and possibly others.

Besides, a modest presence of economic actors included in the group of small developers was also observed with around 12% of the total number of projects. However, their participation in the bidding process was stimulated under the last three NFFO rounds by the design of the NFFO support system whereby a special wind technology band was created for small size projects. This way developers were expected to have more chances of winning contracts. For this reason, combined with the governmental policy for the stimulation of electricity companies investments in early 1990s - we considered the confirmation for this indicator as 'with comment'.

In continuation, this section presents the empirical information on which the assessment for this indicator relies. In addition, we also explain how the ownership of wind power plants changed for the installed projects, and which are the factors that influenced project ownership (change) in the United Kingdom.

The Energy Technology Support Unit (ETSU) of the Department of Trade and Industry published (1998/1999) the complete lists with names of project developers who were approved NFFO contracts and the sizes of their projects for all the five rounds. A close look at these lists reveals that there was a large number of companies winning projects, and also some diversity in the types of developers. There was a strong representation of former energy utilities and regional electricity companies. The most active from the beginning were the two largest conventional generators National Power and PowerGen, both of which later established special subsidiary companies for wind energy, respectively for renewables.

Distribution companies Swalec and Manweb were also winners of an important number of contracts (WPM February 1995: 20). But there was also a substantial presence of foreign companies, winning many projects such as Ecogen, M&N Wind, and Cumbria Wind Farms[45]. Further, several water utilities have also successfully developed wind projects. An important number of contracts were won by large new-entrant companies coming mainly from the British construction and engineering industries[46]. For example, Renewable Energy Systems[47], D.J. Construction and Windjen Power are developers with parent companies in the construction industry. Finally, wind turbine manufacturers - domestic and foreign - won 7 % of all NFFO projects. But they did not wish to develop too many plants, to avoid competing with clients[48] (Krohn 1998).

Beside these large companies there were also small developers. Under NFFO-1 there was only one farmer winning a contract (Windelectric Ltd). Under NFFO-2 there were 16 projects approved for small developers, representing 33% of the allocated projects. Most of these developers were farm owners, others were small industrial production companies. But there was also one project approved for a public heath authority and one for a hospital (Michell and Skea 1991: 21-24). With NFFO-3 there were 2 educational centres securing contracts in the

[45] Ecogen is owned by American Sea West and by Japanese Tomen Corporations, while M&N Wind Power is a partnership between the Danish Neg-Micon wind turbine manufacturer and the Japanese financier Nichimen. Cumbria Windfarms is jointly owned by the Danish enYco A/S and the American company Zilkha Renewable Energy of Houston.

[46] Some of these companies, e.g. Windcluster and Wind Prospect, had however a preference for developing small-scale projects, with the idea that these are more suitable for local people participation and long-term integration in the community.

[47] Renewable Energy Systems is a subsidiary of Mc Alpine construction group that would become also an important owner and also a specialised operator, and later a manufacturer of wind turbine technology.

[48] Joint ventures between equity investors in power plants and manufacturers were very unusual events, in contrast to Spain, because the drive for lowest costs and the economic feasibility was more powerful than that for large installed capacity.

small-size band[49], while 4 projects were given contracts for small-systems proposed by private individuals.

In addition, under NFFO 3 and 5 rounds around a dozen of projects were approved for small developers setting up private limited companies (WPM February 1995: 20; WPM April 1998) and one project went again to an educational center. One NFFO-3 contract became latter a cooperatively owned project - the Harlock Hill plant[50]. This was initiated by a subsidiary of the Swedish firm Wind Company whose aim was to introduce co-operative wind system in the UK. The Wind Company was approved in total five NFFO-4 contracts. Another project became a community owned plant - the Haverigg II plant, financed with the help of the Wind Fund opened by the Triodos bank. Hence, small developers had a modest representation in the approved contracts, with around 12% of the total number of projects. Nevertheless, overall it could be argued that there was a satisfactory degree of diversity among the types of developers who were approved NFFO contracts.

The situation of ownership of *installed projects* is however very different. Although precise empirical data on ownership market shares for wind capacity in the UK are difficult to find or calculate, all empirical studies and market experts' opinion we consulted argue that there is a clear dominance of the former energy utilities and their subsidiaries[51]. The leader is the National Wind Power company, descending from the large conventional generator National Power[52]. By mid 2002 it owned almost 40% of the wind capacity installed in England and Wales. Other important owners are Powergen Renewables, Scottish Power, and Yorkshire Power.

The remaining capacity is owned either by corporations from the British construction and infrastructure engineering industries, and to a smaller extent by foreign companies. None of the 18 projects approved for manufacturers were installed by them: some were sold to new entrants and to electricity companies, and some await perhaps progress. By 2002, there were only 2 community projects operating, 1 project owned by the educational Center for Advanced Technology, and 2 projects owned by farmers.

Consequently, while there was some diversity in the types of developers who were approved NFFO contracts and they had more balanced market shares in the approved capacity, the installed wind capacity is characterised by predominant ownership of electricity companies - with the remaining share being owned by large corporations. The small developers experienced difficulties in finding financing. In some cases, they sold ownership shares to larger companies, mainly electricity companies. In other cases they sold large companies the entire project (Naish and Hartnell 2000). Others did not receive planning permission and abandoned their contracts.

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[49] These projects belong to Loughborough University of Technology and the Center for Alternative Technology. The Earth Center received a NFFO-4 contract for a 9 kW turbine (DTI 1998/9).

[50] The cooperative was called Baywind Energy. Approximately 1100 people contribute to it, of whom 600 locals. The Triodos Bank provided the project finance loan for the purchase of the turbine ("The Wind fund", downloadable at http://www/windfund.co.uk/wfgen1.htm on 5 June 2000).

[51] The analysis of installed capacity ownership was based on empirical literature discussing this (Anderson 1997; Krohn 1998; IEA Wind Energy Annual Reports 1998, 1999, 2000, 2001; Windpower Monthly journal articles from 1994 to 2002; and Mitchell 1994, 1999). They all argue that former utilities are behind the overwhelming capacity of wind projects installed. These also emerged from all interviews carried out in the UK, listed at the end of the chapter.

[52] NWP was since 1991 a joint venture of National Power and the construction corporation Taylor Woodrow (33% shareholding). In 1996 Taylor Woodrow withdrew (WPM March 1996: 26). In 2002 NWP was a subsidiary of Innogy plc., the largest electricity supplier and a leading integrated UK energy business.

We identified the following *factors* as influencing the picture of types of developers for the installed wind projects:

- governmental policy to encourage electricity companies' involvement in renewable energy in early 1990s;
- the design and competitive nature of the NFFO system, which led to very high project development costs, placing an important barrier for small developers[53];
- the business culture of the domestic financing agents raising financing difficulties for small projects and small developers; the presence of electricity companies as co-owners is often required including for large companies coming from other industrial backgrounds (non-energy-core companies); commercial banks dominate, few banks are interested in ethical investments, and voluntary soft-loans are ruled out;
- the business culture of small developers: low importance attached to the (voluntary) environmental performances and image by production companies and commercial/ small consumers; low entrepreneurship among small developers with regard to new technologies and in particular renewable energy technologies;
- the business culture of electricity companies, who did not see (at least during the 1990s) joint ventures with small developers as interesting[54];
- the business culture of private individuals does not favour community enterprises and cooperative ventures, but rather investment in stocks and shares; capital ownership is more popular than cooperative ownership; but here come the obstacles from the:
- the institutional context for the stock ownership of small projects/companies by private individuals: very high administrative costs for legal structure setting and investments.

In Appendix 13.1, we explain in detail the action of these factors on the picture of types of project developers. The next sub-section tests the theoretical expectation with regard to the motivations of project developers to invest.

13.6.2 Drivers to invest

Hypothesis 1 predicted that under optimal investment contexts commercially motivated projects would predominate. Based on the empirical data, theoretical expectations can be considered as *confirmed* for this case study.

The issue of drivers to invest needs to be seen in relation to that of types of developers and owners[55]. As wind plants and contracts are traded, and as approved projects are terminated either due to social/local opposition for construction or to financing obstacles, the 'motivational landscape' also changes. Looking from the perspective of project developers who have not become owners (by 2002 when analysis was made), the discussion on reasons motivating their decision to carry out such an activity is only in some cases transparent. These project developers for the governmentally *approved capacity* can be differentiated in three groups: developers who were only interested to sell the contracts or operating-plants later; large developers who intended to remain owners but did not succeed to put their plants into operation; and small developers.

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[53] When projects are rejected, the high project development costs are lost.

[54] This started to change after 2000 only for the largest wind power investor, National Wind Power - see Appendix 13.1.

[55] The empirical data for this section come overwhelmingly from articles of the Windpower Monthly Journal and the DTI's electronic journal "News Review" at its website http://www.dti.gov.uk.

As regards the first group, these were specialised companies driven by commercial reasons. They were financially strong companies - or owned by such corporations - and managed to get many projects approved[56]. This group is an outcome of the NFFO system design and a special feature of the British wind industry. Companies were becoming specialised in preparing project proposals because this way they could design low cost, competitive projects.

In the second group there were many large developers who have not (yet) managed to build their projects. The main obstacles for these projects were: to obtain local/social approval; or to make the project economically feasible - when they bidded too low prices in the tender. But as nothing happened with these projects, so far, and we also could not find any indication in the available literature on the motivational aspects, we cannot comment on the drivers to invest for this group.

The third, was the group of small developers who have not yet managed to put their plants into operation. For them, the major barrier was finding finance. But they also experienced local approval refusals. Some were still struggling with these two barriers in 2002. When their projects were discussed in empirical studies and specialised journals, three reasons that we classified as strategic came to the fore - income diversification for farmers and land owners (WPM July 1995: 6) local business opportunity, and self-generation ‘interpretations’[57] (WPM June 1995: 16). The highest number of projects regarded by their developers as self-generation investments appear to have been approved in the NFFO-2 round, where 8 projects were viewed this way (Mitchell and Skea 1991: 21-24). In addition, there were three educational centers winning contracts, for which learning was the main reason to proceed with the investment. But by 2002 only one of them was on the list of operating projects.

At this point it is useful to remind that among the NFFO-4,5 applications there were 14 developers who signed declarations accepting lower than ‘commercially normal’ profitability on their projects in the ‘will secure test’. Information is not available if they were finally selected for contracts, but this suggests that there were projects where non-commercial drivers were important reasons to invest. Consequently, for two of the three groups of project developers the picture appears to be dominated by commercial motivations, with a small presence of strategic and self-generation reasons to invest. But due to incomplete information it is not possible to draw a conclusion regarding the drivers to invest of developers with approved projects. For this reason, we combined the analysis with that regarding the divers to invest for owners of installed capacity.

Looking from the perspective of the economic actors *owning installed wind capacity* in 2002, the drivers to invest are slightly more transparent in the empirical literature and studies we examined. In early 1990s, equity investors were primarily driven by commercial reasons to invest. But since mid 1990s, a trend started whereby projects were still mainly commercially-driven, but had also various strategic overtones.

For the projects owned by electricity companies and their subsidiaries, a slight enrichment of the motivational pallet could be observed in time. In early 1990s[58], electricity companies

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[56] In this group, electricity firms and foreign companies had a substantial presence.

[57] Although these plants had to sell the electricity to the grid based on NFFO contracts (and hence were not self-generation plants in the strict technical sense of being directly connected to the consumption place), the fact that their production could cover at least partially their consumption needs was seen as an extra stimulus to invest.

[58] The NFFO process assumed five calls for tenders. However, as discussed in the section regarding types of developers, there was a continuous activity of trade with wind projects and ownership consolidation. It is

viewed renewable energy projects as “lucrative short-term investments” requiring notoriously high returns on equity (Mitchell 1994: 254). There were several electricity companies more interested in wind energy than others (e.g. National Power, PowerGen, Sweb, and Manweb). But they still did not have the intention to invest after the NFFO system stopped and no other obligation system replaced it[59].

In the second part of the 1990s, the number of electricity companies investing equity in wind projects increased. In parallel to this, two main strategic drivers emerged on the background of their investment decisions. Firstly, the approaching full liberalisation of electricity trade at consumption level in 1998 made electricity companies aware of the importance of *green image* to attract customers[60]. Secondly, some companies became more aware of the fact that the growth of the wind industry is un-stoppable (both domestically and abroad) and realised that an *early-market positioning* could only bring them benefits in the long-term (Krohn 1998). Some electricity companies established special subsidiaries, whose main activities were in the sphere of consultancy, project development, construction, or maintenance-operation. Others added such activities to their existing subsidiaries specialised in ownership of wind plants.

These developments suggest that their investments in wind projects were no more purely commercial. But they were building ‘roots’ in the new industry, being hence also driven by early market positioning interests. The fact that electricity companies lowered their requirements for equity returns (see Table 13.5) suggests that there was more than only a profit interest behind their decision to invest. The other large companies owning wind projects were mainly commercially driven in their action. They were very often also vertically integrated with activities along the value-chain of wind projects life-cycle, like electricity companies. As equity investors in many British and (some also) foreign wind projects, looking to improve their position in the emerging and increasingly promising wind industry.

As regards small developers, in mid 2002 we were aware only of 6 projects successfully installed, as already mentioned in the previous section. The investors in the two community projects - at Harlock Hill and Haverigg - were mainly co-motivated by self-generation interpretations, the attractiveness of an environmentally friendly business (WPM June 1998) and, for local people also the chance of good local business opportunity[61]. The 2 operating plants owned by farmers and landowners were co-motivated by the fact that they could benefit of a second income stream from their land, while still using the land for grazing and cropping[62]. The fact that this business opportunity was also an environmentally friendly activity added to their list of incentives. By 2002 we were aware of only one example of

therefore more appropriate to look at the drivers to invest as a story along a continuum, rather then as snapshots for the 5 years of NFFO tenders.

[59] Mitchell wrote in 1994(269) that in the UK “Regional Electricity Companies appear to have short term attitudes to renewable energy generation as an investment; no long-term vision of a future environmentally friendly industry. Only SWEB wanted to become accustomed to new technologies now so that they would not be left behind.”

[60] Even if the wind electricity produced under NFFO contracts was not for sale for green consumers, it could still work to attract green-minded consumers on grounds that the company is interested in environmentally friendly production and cooperates towards the governmental goal for more renewable energy in the system.

[61] These are referred to in the literature as ‘community of interest’ since share investors are not only local people. In order to come up with all financing necessary, developers had to offer shares for purchase also to people outside the region where the project was located.

[62] For example Cornwall Light and Power is one of the first small private companies developed by a farmer and still owned by him. This is a farm-diversification project and the site is still used for grazing (Source http://www.bwea.com).

commercial company considering its co-ownership of a large wind plant as a self-generation investment[63].

The small engineering company Century Steels installed one small project, driven by a strong green ideology motivation[64]. In addition, we can add to the list of projects with strong strategic overtones those of company Wind Prospect, the projects being prepared under the Wind-Works program of National Wind Power, and the NFFO-5 projects that small developers opened for ownership participation to local people. Income diversification and energy self-sufficiency with clean resources are the main logos in attracting community ownership for their projects. Especially in rural areas the possibility to benefit of a new income stream is extremely important, since the crisis facing the British farming industry starting in late 1990s. And, finally, remarkable is the very poor representation of demonstration projects. Due to the competitive nature of the NFFO system, companies rarely wanted to invest in new turbine designs or operate turbines just for learning. Demonstration projects of British technology were facilitated to large extent by separate financial lines from the extensive government R&D programs. The only project was that of the Center for Alternative Energy, operating a 600 kW demonstration turbine of the British manufacturer Wind Energy Group.

Consequently, by early 2000, the general trend was towards more strategic drivers on the background of commercial motivations, towards improved market positioning in the wind industry, green image, and better community integration through income diversification. The predominance of commercial motivations to invest accompanied by increasingly strategic overtones among a series of different owners resemble the motivational picture theoretically expected under the optimal market environments, which confirms this part of the hypothesis.

13.6.3 Project sizes

Hypothesis 1 predicted that under optimal investment contexts mainly medium and large size projects would be seen. Empirical data presented Table 13.8 *confirm* this expectation for the last three rounds, for which information on proposed project sizes was available. Most of the capacity proposed for NFFO 3,4,5 tenders came from wind power systems with medium (above 5 MW), large (above 15 MW) or very large capacity (above 25 MW).

The NFFO system assumed substantial governmental influence on project sizes. Firstly, in order to stimulate investments by small developers, the government organised in NFFO-3,4,5 rounds separate competition bands for small-size systems. The upper limit for the special small-size band changed with every round, as shown in Table 13.4. Secondly, the government had a policy to encourage diversity in project sizes, and avoid approving too large plants. This was motivated by the fact that if only few large projects were approved and they subsequently failed to secure planning approval, this would have had consequences for target' achievement.

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[63] This is the cosmetics company The Body Shop, which owns 15% of a 22,4 MW wind. This capacity is covering all its consumption at the production headquarters in Sussex. The company stated that its ultimate goal is "energy self-sufficiency in the UK by means of renewable resources" (WPM November 1994: 13).

[64] "Renewable Energy Case Study No. 24 - Century Steels Wind Turbine" ETSU, January 1995, available at http://www.bwea.org/ref/steels.html.

Table 13.7 *Project sizes for wind systems approved in the UK, 1990-1998*[65]

Sizes/number projects	1990	1991	1994	1997	1998	Total	Share
very small: < 1 MW	3	16	9	1	2	31	12,5%
small: 1 - 5 MW	4	17	17	20	34	92	37,4%
medium: 5 - 15 MW	2	15	24	28	14	83	33,6%
large: 15 - 25 MW	-	1	4	8	11	24	9,7%
very large > 25 MW	-	-	1	8	8	17	6,8%
Total number	9	49	55	65	69	247	100%

Table 13.8 *Projecst proposed by developers in NFFO-3,4,5 rounds*[66]

Project sizes / Number (MW all projects)	1994 (NFFO 3)	1997 (NFFO 4)	1998 (NFFO 5)
< 2,31 MW	37 (32 MW)	35 (56 MW)	46 (84 MW)
2,32 - 11,5 MW	129 (874 MW)	62 (440 MW)	32 (256 MW)
11,6 - 23,2 MW	26 (412 MW)	32 (500 MW)	26 (421 MW)
23,3 - 116,2 MW	6 (223 MW)	22 (860 MW)	16 (646 MW)
> 116,3 MW	-	1 (205 MW)	3 (235 MW)
Total projects proposed	198 (1541 MW)	152 (2061 MW)	123 (1642 MW)

Table 13.7 shows the project sizes for the *approved* NFFO contracts using the operationalisation for wind plants proposed in Chapter 4. The governmental influence of project sizes led to 71% of the approved projects having small and medium small sizes, that is between 1-15 MW. Only 16,5% of the approved projects had sizes larger than 15 MW. Table 13.8 shows the sizes of projects as proposed by developers, before selection by government. The classification in this table is the one used by the electricity regulator, and it differs from our operationalisation shown in Table 13.7. However, comparing numbers of proposed and approved projects it is possible to observe that the sizes of approved projects were indeed smaller than the sizes of proposed projects. Especially in the NFFO-4,5 rounds the sizes of proposed projects increased, as well as the number of large and very large plants. The proposed capacity under NFFO 3,4 and 5 was mainly in the forms of project above 11 MW, while we considered plants as medium size above 15 MW. The trend is therefore clear towards medium, large and very large size plants towards the end of the 1990s as the dominant investment preference of developers.

13.6.4 Types of financing schemes

Hypothesis 1 predicted that under optimal investment contexts external financing schemes would be the predominant financing tool - project finance, with the likely presence also of institutional finance. Empirical studies and interviews indicate that for the wind plants holding NFFO-1,2 contracts, project finance was the main financing approach, while for the NFFO-3,4,5 contracts the plants installed by mid 2002 used mainly internal financing schemes. These

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[65] Source: database wind projects of the governmental renewables agency ETSU (Energy Technology Sustainable Unit), “NFFO Fact Sheets” 1998/1999. This database lists projects according to their Declared Net Capacity. We transformed them in Installed Capacity because that is the unit that we used throughout the study for all technology types and all case studies. According to regulators definition, 1 MW Installed Capacity = 0,43 % MW Declared Net Capacity (DTI, REB-7, 1997: 19).

[66] Source: OFFER 1994/7/8. The regulator defines project sizes in terms of Declared Net Capacity, in order to take into account the fact that intermitent resources such as wind energy do not allow the plant to function continuously at full capacity. We transformed Declared Net Capacity MW sizes into Installed Capacity MW sizes, by dividing the former with the 0,43 coefficient considered by the regulator in the case of wind energy.

findings *partly confirm* the theoretical expectations. The following paragraphs discuss the types of financing schemes used during the 1990s, the main financing parameters, and how they changed in time.

Mitchell[67] (1994: 308-309) underpins the financing schemes for 25 of the 35 wind projects put into operation by 1994. For these plants, project finance was the dominant formula, used in 15 cases. The rest were internal financing schemes: 5 with debt-corporate finance, 2 in-house corporate finance, and 3 private finance.

Similarly detailed information was not available for the period after 1994 in other empirical studies. We are only aware of the financing approach for the only four NFFO-5 wind projects installed by mid 2002. Two of them were owned by utilities and were financed based on the in-house corporate approach. The other two projects were owned by a subsidiary of an American company and they used project finance (Alder 2002). Speaking more generally, other market experts[68] mention in several specialised publications that in-house- and debt-corporate finance has become the main investment approach for projects with NFFO-3,4,5 contracts installed until mid 2002. The shift of project finance to the background of the financing picture has two main reasons.

On the one hand, some developers/owners accepted to go ahead with projects whose profitability was below the general limit of 9-10%. For these, project finance was either not acceptable by banks, or it assumed too high interest rates and extra fees. When these were reducing the equity returns too much for project owners, internal financing schemes became more attractive[69]. On the other hand, some owners could have well used project finance, having projects with overall profitability generally considered acceptable by banks. However, by using an internal financing scheme they could increase the (volume of) equity returns[70]. But, as Alder (2002) observes “the mix of finance methods will be ultimately affected by the projects that receive planning consent”. Therefore, most of the internal financing schemes used for NFFO-3,4,5 projects were either in-house or debt corporate finance, since the main owners were large corporations. Few projects were also using private finance. Further, there was only

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[67] In her doctoral dissertation Mitchell (Mitchell 1994) made an in-depth study on the types of financing schemes used in the UK for projects with NFFO-1,2 contracts. We rely to large extent on her empirical findings for this section. But we also searched for their confirmation in other empirical sources and interviews with market experts.

[68] Sources: IEA 2000: 178; IEA 2001: 210; WPM, December 1994: 21; WPM, February 1995:20; WPM September 1998; WPM September 1996; WPM September 2000: 39; WPM February 1994: 26; Chris Naish 2000; Gaynor Hartnell 2000; Ian Fletcher 2002; Steen 2000.

[69] In Appendix 13.1, we explained the main traits of the business culture of the British financing community, with their preference for electricity companies and long-established corporations. Section 13.5.4 mentioned the general profitability criteria for project finance, with the lower limit of 9-10%. The perception on technology risks by commercial banks improved in the second part of the 1990s, lowering the risk premiums for this component (WPM September 1998). But the fact that wind is an intermittent resource remained in the view of commercial banks a risk for project’s cash flow. This risk premium is normally reflected in interest rates, being higher the lower projects’ profitability is. In addition, the studies on project’s technical, legal, economic, and planning feasibility that banks normally require to assess the suitability of project finance loan attract always high administrative and bank fees. If there was no possibility for cost-reduction at the level of other components, these extra fees and risk premiums induced reductions in the equity returns owners could have yielded, leading to their decision to better use in-house or debt corporate financing.

[70] A report of the Ernst & Young financial consultant suggests that large companies who are able to use debt-corporate finance with large contribution of debt, at low interest rates, and with long-term loan reimbursement are able to increase their returns on equity by up to 4-8% (Source: Article “Report underlines importance of financial parameters” based on Ernst & Young report: “Sensitivity of the costs of renewable energy to financial parameters” on 29 May 2000 at www.dti.gov.uk/NewReview/nr35/html/report.html)

one project based on participation finance - the Haverigg II project under community ownership, which runs four turbines in Cumbria.

As regards changes in banks attitude to wind plants investments, it could be observed that range of interest rates charged by banks for project finance loans decreased during the 1990s. As it can be seen in Table 13.5, the upper end of the range was 11-13% in the first years of the 1990s (Mitchell 1994). Towards the end of the 1990s there were developers able to get loans for 6-7% interest rates. But the reduction was not the same for all types of developers/owners and all projects sizes. Commercial banks remained faithful to their general lending criteria whereby smaller-size projects, smaller developers and new entrants in the energy sector were imposed higher interest rates. When equity was provided by a well-established company, interest rates for project finance could be in early 1990s only 1-2% above the average level of interest rate in the market (around 6%). The more developers/owners were 'risky' in the eyes of financing agents, the higher were the interest rates imposed. At the end of the 1990s established developers could receive interest rates of 6-7% for project finance loans while 'risky developers' could still be charged 8-10%.

With regard to sizes, interest rates for projects above 3 Million Euro were quite high, between 2-4% above the average market level for conventional investments (Mitchell 1994: 317). Projects incurring more than 15 Million Euro could obtain project finance loans at lower interest rates. These size-related and client-related lending criteria have not changed throughout the 1990s, which makes loan availability still a problem in the UK. The only improvement regards the benefit of larger plants and powerful corporation of lower interest rates for project finance loans[71] (assuming that project profitability is satisfactory for the bank).

But an improvement was recorded in terms of the debt-equity ratio required by banks for project loans. The governmental division for renewable energy mentioned that wind plants build on the basis of NFFO-1,2 contracts with project finance loans used between 50% and 80% loans[72]. Mitchell (1994) also argued that for the early 1990s the requirement of banks for equity contribution was higher than in other European countries. Towards the end of the 1990s however increasingly more projects used 80% bank loans and 20% equity (Alder 20002). But the 20% equity requirement is very strict and there appears to be no exception to it (WPM September 2000: 39). Requests for higher equity contribution are however still made, leading to debt-to-equity ratios as average level in the industry of 75%-25% (IEA 2000: 178). Debt maturity has been generally linked to the length of guaranteed contracts. Under NFFO-1,2 this was generally 6 years (Mitchell 1994), while under NFFO-3,4,5 this was mostly 12-15 years[73].

Institutional finance by venture capitalists was not used yet in 2002 in connection with the NFFO support systems. In the UK, venture capitalists are willing to take high risks but prefer projects with unpredictable returns on equity that are in any case highly likely in the range of 35-40% or higher. They also prefer to invest in projects that can offer them the option to exit after a short time, generally 3-5 years[74]. The long term 15 years contracts of NFFO-3,4,5 with

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[71] Governmental experts (Fletcher in IEA, 2000: 178) mention that the average interest rates for wind projects at national level has been typically 1,5% above the London Inter-Bank Offered Rate (LIBOR) in the last years of the 1990s. However in our opinion, looking at this average figure alone, obscures the understanding of the differentiation between developers types and project sizes made by banks, and of the remaining financing obstacles.

[72] "Renewable Energy as Commercial Activity – a Guide for Lenders, Investors and Advisors", brochure of DTI and ETSU, 1994.

[73] "Early wind projects in the UK secured loans for just ten years. Today 12 to 15 years is more common." (WPM February 1999: 48).

[74] Acton 1996: 15; Zemke [Alchemy] November 2001.

predictable cash flows were not the types of investments they normally wish to engage in (Johns 1997). Third-party finance was also not used during the 1990s, but it was initiated in early 2000 by National Wind Power.

Consequently, project finance started by being the dominant approach for projects with NFFO-1,2 contracts, but it moved to the background, as less frequently used approach for the projects with NFFO-3,4,5 contracts. During the 1990s, commercial banks' perception on wind technology improved. But banks remained the same inflexible with regard to their general lending policies regarding client type and project size.

The assumption on capital structure preference

In the analytical framework we considered that project finance would dominate because we assumed that developers will try to minimise their equity contributions whenever possible. Given the same profitability of a project, the smaller is the equity contribution of the owner the higher are the returns in one unit of equity. Besides, we also considered (based on financing literature) that companies would try whenever possible to minimise the use of cash reserves or place (too many) non-core or technologically risky projects on their balance sheet. But in the United Kingdom the perception of wind technology changed in time into core-business and reliable technology. Besides, the main owners of wind projects are electricity generation (and distribution) companies. After successful privatisation these do not have cash shortages and are interested in businesses that can offer them large volumes of profits, making in-house corporate finance or debt-corporate finance more desirable, as compared to project finance.

These findings, combined with the empirical observation in Chapter 9 that small hydropower diffusion in optimal investment contexts also did not lead to the predominance of project finance do not support our assumption in Chapter 3 that the first choice of developers would be to use non-recourse finance. However, the assumption was fully confirmed in the case studies of wind technology diffusion in Spain and in the Netherlands, and biomass technology diffusion in Spain. In conclusion, the empirical results with regard to the assumption in capital structure preference made in Chapter 2 are mixed.

13.6.5 Technology choice

Hypothesis 1 predicted that under optimal investment contexts, the adoption of new and/or existing technology designs with substantial contribution potential to diffusion expansion is likely on a more frequent basis. Practical developments *do not confirm* this expectation.

Table 13.9 presents the years of market entry and the sizes of the turbine types used by British developers and owners. The projects built up to 1994 based on NFFO-1,2 contracts used in proportion of 83% foreign turbines (Wind Directions 1994: 13). These were to a large extent Danish turbines Vestas, Bonus and Nordtank. But also Japanese Mitsubishi turbines were used, while several projects were based on the Dutch Windmaster turbines. In three projects the choice went for the British (early model) two-bladed turbines of the Wind Energy Group. With the severe price convergence policy introduced in 1994, the search for lowest cost turbines accelerated.

By 2001 there were turbines from 11 manufacturers installed in England and Wales. Some manufacturers managed to introduce more types of turbines on the British market, in terms of their installed capacity, especially the Danish companies. But there was diversity in owners' choice not only in terms of manufacturer brand, but also with regard to the technical characteristics that we selected in Chapter 4 to describe the grid-friendliness of wind technology.

Taking into account the first two performance perspectives considered in Chapter 4 - grid friendliness and efficiency - Table 13.10 shows that almost 60% of wind capacity installed in England and Wales by mid 2002 under NFFO contracts used conventional designs. But there were also companies that chose for more technically advanced designs with modest improvements in grid friendliness and efficiency. Their market share was around 37%. There were only three (Enercon) turbines with synchronous generators adopted that we considered as diffusion-optimal from grid-friendliness standpoint.

Table 13.9 *The years when the wind turbine designs were for the first time adopted in the UK*[75]

Manufacturer / kW-turbine	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Vestas	400	225	-	-	500	-	-	600	660	1900	1750
Bonus	-	300	450	-	600	-	500	-	-	1300	-
WEG	-	300	500	-	-	-	600	-	-	-	-
Mitsubishi	-	-	300	-	-	-	-	-	-	-	-
Windmaster	-	-	300	-	-	-	750	-	-	-	-
Nordtank	-	-	450	500	-	600	-	-	-	-	-
Zond	-	-	-	-	500	-	550	-	-	-	-
Enercon	-	-	-	-	-	500	-	-	1500	-	-
Wind World	-	-	-	-	-	-	500	600	-	-	-
NEG-Micon	-	-	-	-	-	-	-	-	-	1500	720; 950
Nordex	-	-	-	-	-	-	-	-	-	600; 1300	800

Table 13.10 *Technical characteristics - from the perspective of grid-friendliness and efficiency - for the turbines commissioned in the United Kingdom by 2002*

Manufacture	Wind turbines based on the horizontal axis technological principle					
	Capacity owned [MW]	Number turbines owned	Voltage control type	Rotor speed type	Generator type	Technology design / Market share in 2002
WEG[76]	14,6 (5%)	47	Stall control	Constant speed	Asynchronous	59,5% conventional designs
Bonus	130,4 (45%)	248	Stall Control	Constant speed	Asynchronous	
Nordtank	27,7 (9,5%)	54	Stall control	Constant speed	Asynchronous	
Neg-Micon	3,6 (1,2%)	5	Stall control	Two speeds	Asynchronous	36,7% modest improvements in grid friendliness and efficiency
Nordex	6,3 (2%)	9	Stall control	Two speeds	Asynchronous	
Vestas	60,2 (20%)	123	Pitch control	Variable speed (limited range)	Asynchronous,	
Mitsubishi	31 (10,5%)	103	Pitch control	Variable speed	Asynchronous	
Windmaster	8,7 (3%)	23	Pitch control	Variable speed	Asynchronous	
Enercon	3,5 (1,2%)	3	Pitch control	Variable speed	Synchronous	1,2% grid diffusion optimal designs
Wind World	5 (1,7%)	9	n.a	n.a.	n.a	n.a
RES	1 turbine demonstration		Pitch control	Variable speed	Asynchronous	1 MW Scotland

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[75] Based on the list of projects installed by mid 2002 available at the website of the British Wind Energy Association http://www.bwea.com.

[76] There was only 1 turbine of two-speed rotor design in demonstration at the Centre for Alternative Technology since 1996 (WPM July 1996: 25).

As regards the third performance perspective chosen for analysis - turbines' ability to exploit very low wind speeds - such technological designs did not emerge on the market. The situation in the UK presents some particularities, which suggest that they were not a technological priority during the 1990s. Firstly, the competitive nature of the support system pushed developers towards the areas with richest wind resources, in order to result in as low as possible production costs per kWh. This led to a market demand for turbines able to function well at high wind speeds and highly versatile patterns of wind regimes. Most plants were installed at sites with average annual wind speeds of 9-10 m/s or higher. Developers collected from the international market the technology designs that performed well at high wind speeds[77]. When small projects were built for the special small-size technology band, these were based on low-capacity mature designs of established turbine manufacturers, who could offer them cheaply because they were running out of market anyway, with the general drive towards ever-larger turbines. Therefore, there was no market demand for innovative technology able to reach nominal power at lower wind speeds, of 8 to 5 m/s.

Secondly, innovations in this direction are probably perceived as not so urgently needed in the UK because of large availability of high quality wind resources. Milborrow et al. (1999) explain that the predominantly hilly British countryside landscape leads to ground-level speeds higher than 4,5 m/s in large areas. The governmental renewable energy agency mapped wind resources (ETSU 1999) revealing that the overwhelming British territory is blown by average annual wind speeds higher than 5 m/s at 25 m above the ground. Current wind turbines operate on 40-50 m hub heights or higher, where average annual wind speeds are often 8-10 m/s. Johns (1997) mentions that around 20% of the UK land has mean speeds above 7 m/s[78].

There was nevertheless an innovation developed by the blades' manufacturer Aerpac UK especially for the British market. This innovation consisted of blades with superior load resistance, making possible the exploitation of the very high and variable wind speeds in the United Kingdom, as compared to the European continental countries. The new Aerpac blade design was adopted by almost all plant owners. This can be described as a new design wich brings substantial potential contribution to diffusion expansion, since it makes possible the exploitation of wind sites that existing blade models could not cope with. This can improve indeed substantially the exploitable wind resource potential. But having in view the predominance of conventional designs and the reduced used of technologies with modest grid-friendliness performance improvements, while sufficient choice was available on the international market, we assess this indicator as *partly confirmed*. The next sub-section summarises the extent of confirmation of expectations regarding diffusion patterns under Hypothesis 1.

13.6.6 Conclusion regarding the extent of confirmation of Hypothesis 1 for diffusion patterns of wind technology in England and Wales, 1990-2002

Section 13.6 looked at the diffusion patterns of wind technology in England and Wales in the period 1990-2000 in order to test the first part of Hypothesis 1. The empirical forms for diffusion patterns are summarised in Table 13.11. The extent of confirmation can be assessed as only *partly satisfactory*. The forms of two indicators were 'confirmed' - drivers to invest and project sizes. The expectation regarding types of project developers was 'confirmed to

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[77] The UK-based Aerpac manufacturer of blades contributed to serving this market demand through an innovation that increased blades' resistance to powerful wind gusts (Anderson 1999).

[78] Even with conventional technological designs, such sites are considered to have very good economics.

large extent with comment'. For the indicators - types of financing schemes and technological design - empirical findings have only 'partly confirmed' the hypothesis.

Looking at the approved wind capacity, there was a satisfactory degree of diversity among the *types of developers*. Many projects were approved for former generation and distribution utilities, but there was also a good representation of large domestic new entrants from other industrial sectors and foreign companies. Manufacturers also won 7% of projects and around 12% went to smaller developers. The ownership of installed projects has gone however mostly in the hands of the former energy utilities and their subsidiaries. This picture confirmed to large extent the expectation under Hypothesis 1.

As regards the *drivers to invest*, the projects installed based on the first two rounds of contracts were overwhelmingly motivated by commercial reasons. However, in time, a series of strategic overtones emerged behind the decision to take ownership into wind capacity. For large developers the main strategic drivers have been the interest in early market positioning in a new growing industry affecting their core business, and green image. Smaller developers have been mainly motivated by the possibility of income diversification, the environmentally-friendly nature of the business. For few others, the idea that the invested shares cover their own electricity consumption was also a driver to invest. Overall, the motivational picture confirmed that hypothesised for an optimal investment context. But demonstration projects were striking absentees from this picture.

Table 13.11 *The theoretically expected and the empirically registered diffusion patterns for wind technology in England and Wales, 1990-2000*

Empirical developments	Theoretical expectations
Types of project developers	
- for approved capacity: predominance of diverse large developers: electricity companies, industrial groups, water utilities manufacturers; small developers modest presence	all types of developers (confirmed to a large extent with comment)
Type of financing schemes	
- NFFO 1 and 2: overwhelmingly project finance; - NFFO 3,4,5 mainly internal financing schemes	predominance external financing schemes (partly confirmed)
Drivers to invest in wind projects	
predominance of commercial motivations to invest accompanied by increasingly more strategic interests	predominance commercial projects (confirmed)
Project sizes	
- for proposed capacity NFFO 3,4,5: mainly medium, large and very large projects	medium and large size projects would predominate (confirmed)
Technological designs	
- 1,2% of capacity: diffusion-optimal grid-friendliness; - 36,7% of capacity: modest efficiency improvements - 59,5% of capacity: conventional wind turbines	the adoption of new and/or existing diffusion-optimal technology designs is likely more frequently (partly confirmed)

Further, the indicator of *project sizes* was directly influenced by governmental policy, in order to avoid approving too large plants. The patterns of proposed projects under NFFO 3, 4 and 5 suggest an increasing investment interest in large and very large size wind farms, as expected under Hypothesis 1. The indicator of types of financing schemes showed a shift in preference from the use of projects finance under NFFO-1,2 contracts when very high profitability was more frequently possible, to the dominance of internal financing schemes (especially corporate finance) in late 1990s, when profitability moved to the high range and even modest levels.

Finally, the discussion of *technological choice* showed that conventional technology designs dominated and diffusion optimal designs from grid friendliness standpoint only had a

1,2% market share. However, an innovation was adopted that improved the market adoption potential of wind technology for the particular circumstances of wind regimes in the United Kingdom, leading to the assessment of partial confirmation. This consisted of stronger blades making possible reliability and good performance in conditions of highly variable and strong winds. Section 13.7 looks at the forms of the selected indicators for the analysis of diffusion results after 10 years since the introduction of the economic governance structure for the support of renewable electricity.

13.7 Wind power capacity and the prospects for sustainability of diffusion processes at the end of 1990s

This section tests the expectations on installed capacity increase and looks at the prospects for the sustainability of market diffusion processes as they looked like at the end of 2000.

13.7.1 Proposed and approved capacity for wind technology

Hypothesis 1 expected that optimal investment contexts would be able to induce *large increase in installed capacity,* operationalised as at least 1000 MW, if the support system retains its characteristics for at least a short-medium term period, of 5-10 years. This case study covered a period of ten years, 1990-2000. Due to that fact that the support approach of the government was to decide for how much capacity it guaranteed purchase contracts and price support, the indicator of *installed* capacity cannot be used to test the expectation regarding the first dependent variable of the hypothesis. Instead, we look at the wind power capacity *proposed* for approval by economic actors under the calls for tenders. Data on this issue were only available for the NFFO 3, 4 and 5 rounds.

The summing up of the numbers of projects mentioned as ‘firm bids received’ in Table 13.12 indicates a very large capacity of around 5200 MW. From this tremendous investment interest, the government selected 2012 MW. After all five calls for tenders 2236 MW were approved[79]. The capacity represented by the number of firm bids received in competition *confirms* this part of the hypothesis.

Table 13.12 *Wind project proposals received and approved*[80]

NFFO tender / Number of projects	Requests for tender packs	Applications submitted	Passed ‘will secure’ test	Firm bids received	Wind projects approved
NFFO 3	371	236	209	198 (1541 MW)	55 (385 MW)
NFFO 4	227	176	162	152 (2061 MW)	65 (792 MW)
NFFO 5	199	127	123	123 (1642 MW)	69 (835 MW)

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[79] There were strong debates between the industry regulator and the Ministry regarding the size of the order and especially its technology composition. The regulator was exceedingly concerned with the impact on consumers of NFFO costs. It always proposed options for NFFO orders where the cheapest technologies had the strongest representation and wind capacity was very small. However, inside the Ministry there were decision-makers looking more favourably upon wind energy, who eventually managed to raise the size of Orders for wind energy (Steen 2000). In NFFO-3 the rate of approval was 25%, in NFFO-4 it raised to 38%, while in NFFO-5 it was the highest, with at 51%.

[80] Sources: OFFER publications as proposals for NFFO Orders to the DTI; and DTI/ETSU, "NFFO Fact Sheets 1998", London.

Taking into account the assumptions made already before the size of each Order was decided, that only 50-70% of projects would be implemented, the approved capacity was expected to lead to the 1500 MW target that the government set in 1993[81]. However, while being generous in terms of contracted wind capacity, the failure of the government to accompany it by an institutional framework that is able to facilitate the implementation of approved contracts resulted in only a tiny fraction installed by 2002, of around 300 MW[82]. In Appendix 13.2, we explain the obstacles for the implementation of wind projects with NFFO contracts. The next sub-section looks at the indicators for diffusion results in 2000.

13.7.2 The prospects for sustainable diffusion processes

Hypothesis 1 expected that under optimal investment contexts, the supported technology has good prospects for the sustainability of market diffusion processes in the long term. Both the industrial basis and dynamics, and the socio-economic benefits from diffusion were assessed as potentially large after short-medium term diffusion under optimal investment contexts.

In Chapter 2, we argued that the prospects for sustainable diffusion processes need to be analysed from three angles: cost performances, technical performances and socio-economic-industrial context. In Section 13.7.2.1, we discuss the progress in cost performance improvements and the sources of cost reductions, based on the four categories of cost factors distinguished in Section 2.8. In the same framework we also refer to the diffusion continuation prospects from the perspective of wind resource potential and the technical performances of wind technology in the electricity system. In Section 13.7.2.2, we test the theoretical expectations with regard to the socio-economic-industrial context created by diffusion under an optimal investment context.

13.7.2.1 Cost performances, technical performances and remaining resource potential

The progress in cost performances of wind technology in the England and Wales by 2000 was substantial. The lower part of the range of production costs per kWh reached the cost competitiveness threshold with 3,8 - 4,3 €c/kWh at wind speeds 9-10 m/s[83]. For regions with wind speeds higher than 8 m/s, production costs were possible in the range of 4,3 - 6,4 €c/kWh[84]. The NFFO contract prices with values for the larger size band between 3,7 - 7,2 €c/kWh enabled hence profitable projects at sites with larger than 7 m/s speeds, when the costs (influence of factors) in the other categories could be minimised[85]. This implies that the NFFO system has left the wind potential with wind speeds below 7 m/s mostly economically not feasible (see Figure 13.2).

In Chapter 2 we differentiated among four categories of costs: technology-specific, technology-complementary, context-induced, and resource quality/availability. Empirical

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[81] The capacity approved for contracts was higher than that considered desirable by the government, because it took into account that not all projects would proceed due to local permit barriers. Generally, the assumption of the regulator for wind projects was that only 50% (in NFFO-2,4,5) or 70% (in NFFO-1,3) of approved capacity would be finally installed.

[82] Prior to the NFFO program there were only 10 privately owned single turbines of 65-95 kW and several turbines of less than 5 kW installed. In addition there were 10 demonstration turbines with capacities between 130-3000 kW (Mitchell 1994: 40).

[83] Sources: Wind Power Monthly (February 1999: 48; and Milborrow in WPM January 2002: 31) and Milborrow in BWEA 1997).

[84] Based on Milborrow (in BWEA 1997).

[85] Milborrow mentions that competitive production prices are possible also at 7,5 m/s but only under certain locations / investment circumstances.

research shows that, the main source of production costs reduction was the use of high quality and availability wind resources, followed by substantial reductions in technology specific costs. The evolution of technology-complementary is not clear, while that of context induced costs has been so far sinuous, as summarised in Table 13.13. We explore below the changes in these categories of cost factors for wind technology the UK.

Table 13.13 *Cost performances of wind technology in the United Kingdom by 2000*

Evolution cost sources	wind technology in the UK, 1990 - 2000
technology specific	24 % reduction (in 1990: ~ 1000 - 950 €/kW; in 2000: 650 €/kW; up to 770 €/kW)
technology-complementary	not clear[86]
context induced	high sinuous evolution
resource quality and availability	See Figure 13.2
lowest production costs per kWh	3,8 - 4,3 €c/kWh, at wind speeds 9-10 m/s
price support NFFO 3,4,5 large plants	3,7 - 7,2 €c/kWh (2,43 - 4,8 pence/kWh)

Technology-specific costs

Empirical research showed that significant *reductions* were achieved *in technology-specific costs*. Blades were generally purchased from the UK Aerpac company, which was able to produce at competitive costs due to good demand from abroad. The costs per kW of wind turbines installed in the UK decreased with around 24% reduction during the 1990s. The costs of wind turbines sold on the UK market in early 1990s were in the range 1000 - 950 €/kW. In 1995, some of the lowest cost NFFO-3 projects were built with turbine costs around 750€/kW (WPM February 1995: 27), while in 2000 prices varied between 650 - 770 €/kW[87].

However, the technology-specific cost reductions were achieved not by British manufacturers but by means of imported technology. During the 1990s, the British manufacturing industry has slowly perished. This was due to three main reasons. Firstly, the design of the NFFO system undermined the chances of success of the domestic manufacturing industry. This was in early 1990s still in its infancy, and it was taken by surprise by the NFFO-1,2 Orders, which - by being also made in consecutive years - were too large for its supply capacity. Besides, the stop-and-go nature of the support system, with the five calls for tenders at unpredictable times and for unpredictable capacity sizes, represented a serious disincentive for domestic manufacturers to increase their production capacity. The wave-like pattern of demand was also given as a main reason by foreign manufacturers for not being so eager to install production facilities in the UK, as they did for example in Spain.

Secondly, the price convergence policy behind the NFFO-3,4,5 rounds encouraged the search for the most cost-efficient technologies. Having faced an unfavourable start, British manufacturers could also not deliver too low prices. Besides, the interruptive and unpredictable nature of demand was not an incentive to invest in R&D for innovative lower cost designs. Thirdly, local opposition also undermined the success chances of the few deals reaped by British manufacturers. Some turbine producers who managed to sign purchase contracts with winning developers could not proceed with production because developers failed in obtaining local permits for construction. Even when local permits came with delay this still induced serious disruption in their production activities. These factors contributed to

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[86] Information was not available with regard to the evolution of cost components in the category of technology-complementary factors.

[87] Based on overall investment cost data in IEA (2001: 206) combined with information at BWEA website "Wind energy economics" cost split, with wind turbines accounting for 64 % of total investment costs. Including information from IEA (1998; 1999; 2000).

the decline in the British wind manufacturing industry, making foreign manufacturers the winners of the NFFO support system.

Context induced cost category

As regards the context induced cost category, cost components in this category have been high at the start of the diffusion processes, with a *sinuous evolution in time*. On average the cost-components that we include in this category represented between 5% and 8% in total investment costs[88]. Inside this category some components experienced increases, others remained the same, while still others lowered their level. Reductions took placed to large extent due to lower financing costs and lowering requirements for returns on equity. But also due to the lowering of consultancy costs, project management and project development costs, and insurance, as result of more competition and experience. But legal costs remained substantial, accounting to 2% of total investment costs at the end of the 1990s (BWEA 1997). Since the nature of the NFFO system did not change, lawyers' advice remained important in preparing bids.

One cost component that increased its level in the context-specific was related to planning approval. The association of wind generators estimates that developers incur costs between 15.000-75.000 € per project for all administrative fees and studies needed to get planing permission (WPM March 1997: 4). In addition, extra costs have voluntarily emerged for some companies, in order to stimulate local approval and embeddness. The most 'generous' and active in this direction has been the largest capacity owner National Wind Power. It engaged already in early 1990s in a 'good neighbourhood policy' to stimulate local interest. This policy resembles the approach used in Spain by project developers to secure local permits[89].

Besides engaging local people and companies in construction and maintenance works, and offering direct benefits, such as land rents and local taxes, the company also engaged in a policy to set-up community funds for various applications. These can vary between 45.000 to 150.000 € per project. In some cases, the company endowed local schools with computer equipment. For other communities it sponsored, energy efficiency advising schemes and the delivery energy efficiency and sustainable energy workshops to pupils at local schools. At one of its largest plants (33 MW) the company opened a fund to finance a land management project. This aims to support wildlife and archaeology studies, and improve natural habitats[90]. Hence the costs related to local permits form the main component in the context-induced cost category for which increases were registered. They vary from project to project and for different companies, but overall they have a slightly increasing weight.

Resource quality cost factors

As regards the cost-category of resource quality (wind speed m/s) and availability (hours/year nominal speed - see Chapter 4) the almost 300 MW installed by 2002 used the best wind sites in England and Wales. The remaining NFFO contracts - if implemented - can also only be used for sites with highest wind speeds and annual availability, as Figure 13.2 suggest. The main criterion used by the government for selecting among (eligible) proposed plants was that of production costs per kWh. The government considered that this way it would achieve fast and long-lasting price convergence. However, we argue that the idea that further wind diffusion would continue to take place at the low prices of the last three NFFO rounds is illusory. By

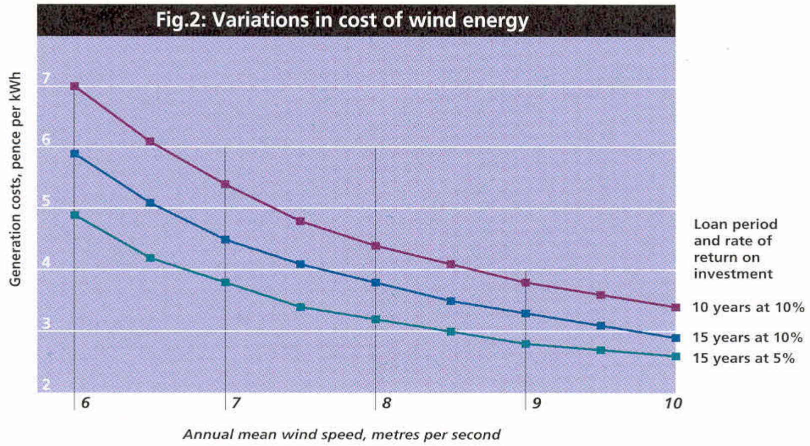
[88] By comparison, they represented 5% in Spain and only 1% in the Netherlands, on average (Sources: ETSU 1993; BWEA 1997; http://euwinet.iset.uni-kassel.de at 8.10.2001).

[89] The difference is that this policy is not required by local authorities but comes from the company' initiative.

[90] Source: company's website at http://www.natwindpower.co.uk, October 2002.

squeezing production costs, the government induced, on the one hand, the search for the cheapest wind technology globally available, and, on the other hand, the clustering of projects "in roughly the same windiest areas in the country" (Krohn 1998).

Figure 13.2 *Production cost curves in the UK, for different wind speeds and levels of projects' profitability*



The cost of wind energy with different wind speeds and rates of return on capital (Source: David Milborrow, energy consultant)

Source: Milborrow in BWEA 1997

Looking at Figure 13.2, the price convergence policy harnessed the possibility to develop projects in the lower-right area of production costs curves. The average price bidded in the NFFO-2 call for tender was around 13 €c/kWh - if the difference given by shorter (8 year) contract length is eliminated and prices are recalculated for 15 years contracts (Krohn 1998). This lowered suddenly to the range 4,3 - 6,5 €c/kWh (2,9 - 4,3 pence/kWh) for NFFO-3,4,5 rounds in the band of larger project sizes. But the cost potential above 6,5 €c/kWh (4,3 pence/kWh) could remain largely un-explored. Even if the expected technology cost reductions could make it possible to install a large part of the approved 2236 MW capacity (assuming all other barriers removed), the high quality resource areas with wind speed of 7-10 m/s would be eventually exhausted. If technology costs do not make even further spectacular jumps downwards, the prices of NFFO-3,4,5 contracts cannot be sustained in the long-term. Market diffusion would then increase only if higher contractual prices are possible.

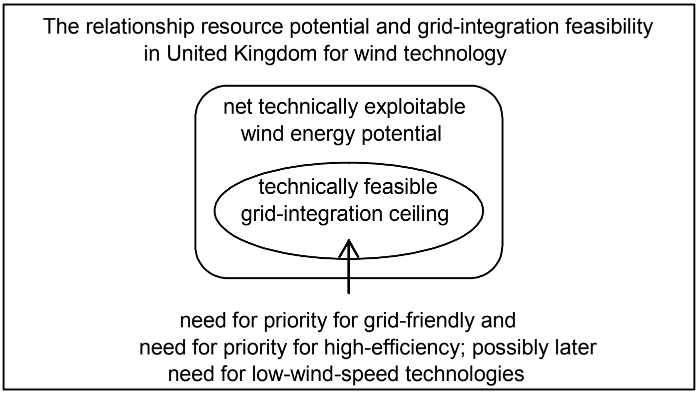
Consequently, the speed of technology cost reductions will only influence the speed of upwards climbing of production costs along the curves described in Figure 13.2. But the direction is inevitably upwards. The position (height) of the curve will be defined by the interaction between the support system characteristics and the investment preferences / requirements of project developers and financing agents. Based on this we argue that the price convergence achieved by the British support system was indeed the maximum that current cheapest technologies can achieve at the most resource rich sites. But if diffusion of wind technology is to be sustained in long term, with substantial capacity increase, prices need to go up again in order to exploit lower resource sites.

In conclusion, the cost factors in the category - resource availability and quality - have constituted the main sources of cost reductions during the 1990s, followed by reductions from the category technology-specific costs (see Table 13.13).

Relationship: technical performance - resource availability

In terms of relationship technical performance - resource availability, we distinguished between two situations in Chapter 4. The first was when the exploitable wind potential is higher than the possibility for its grid integration. The second situation occurs when the wind potential is lower than the opportunity to integrate wind energy in the grid system.

Figure 13.3 *The relationship between resource potential, grid integration ceiling and type of technological designs needed with priority in the United Kingdom*



We represented the in Figure 13.3 the relationship between resource potential, grid integration ceiling and type of technological designs needed with priority in the United Kingdom. In the UK, the on-land technically available potential is very high, considered the largest in Europe. This adds to an even larger off-shore potential. The 1994 governmental renewable energy policy paper[91], considered accessible, at or below the production cost of 15 €c/kWh, a potential of on-shore wind resources that could generate around 340 TWh/yr. This is higher than the total electricity consumption of the UK in 1992, which was slightly above 300 TWh/yr. The off-shore wind potential accessible at the same production cost, was estimated at 380 TWh/yr. It was considered as 'accessible resource', the theoretical potential exploitable 'by a mature technology' after certain physical constraints have been taken into account such as national parks, lakes, housing areas, roads and other built areas. Based on this the Maximum Practicable Resource was estimated at 55 TWh/yr (Milborrow et al. 1999), taking into account regulatory, sociological and environmental constraints, for which "subjective judgements are often required" (DTI 1994: 9). This potential is further likely to be constrained by the difficulty to obtain local permits. As Figure 13.2 suggests, for contracts' length of 15 years prices need not increase so much. But it would be necessary to allow higher levels of projects' profitability - around 10% - to keep a wider range of developers interested in the market.

Consequently, the theoretically available on-shore and off-shore potential is at least double than the total electricity consumption, which would make grid-friendly turbines more important in owners' technological choice. But the practicably accessible potential on-land is around one-sixth of the total consumption, which considering also the difficulties in getting local permits would make high efficiency turbines also strongly desirable in owners' choice. By 2002, as Table 13.10 shows, grid-friendly turbines had only an insignificant 1,2% market

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[91] Energy Paper Number 62, 1994:8, Department of Trade and Industry, "New and Renewable Energy: Future Prospects in the UK", London.

share, while the designs that are generally slightly more efficient in harnessing wind energy than conventional designs had a modest market share of 36,7%. The need for grid-friendly turbines is indirectly acknowledged when the government argues that a system integration of wind energy higher than 10% of total consumption (i.e. only around 32 TWh/yr) would require serious grid reinforcement. This is becoming increasingly imperative as large off-shore wind farms were being planned.

Section 13.7.2.2 looks at the features of the socio-economic-industrial context of diffusion in 2000, comparing them with theoretical expectations and discussing their political lobby potential.

13.7.2.2 The socio-economic-industrial context for diffusion continuation

In 2001/2002, a new support system was introduced in the UK, which aims to increase renewables' contribution to 10% of total electricity consumption. Its core element is a Renewable Obligation on supply companies. They are obliged to buy a certain amount of renewable electricity or green certificates per year, which increases annually. But there are also other support schemes making-up the new support system. These are shortly described in Appendix 13.3. There is no special technology band for wind energy, which has to compete with all other renewables. But this new support system can be seen as a frame based on which wind energy can further increase its market share.

The implementation of the new support system does not have, however, consequences for the already allocated NFFO contracts. The decision of the government was to allow all economic actors holding NFFO contracts to go ahead with investments, whenever they are successful in receiving planning permit and financing. They would still benefit from the 15 years contracts and the contractual prices won in the call for tenders[92].

Table 13.14 *The features of the socio-economic-industrial diffusion context for wind technology in 2000 - theoretical expectations and empirical findings*

Diffusion context likely to emerge		Theoretically expected	Wind in the UK
Socio-economic benefits		Large	*Small but increasing*
Local	Direct: ownership	Likely present	Confirmed since late 1990s
	Indirect: more attractive (than usual) benefits from ~ land rents ~ local taxes; ~ local economic or social welfare investments	Likely high	Confirmed since late 1990s
	Indirect ~ local employment	Technology specific	Low; but increasing
National	Ownership individuals (shares)	Likely present	Not confirmed[93]
	Employment in industry	Likely high	Not confirmed
Industrial basis and dynamics		Large	Large
Number companies offering products / services for wind electricity plants		Large	Large
Types of companies involved in industry		Large presence of corporations from a wide diversity industrial sectors	Confirmed
Degree of specialisation in renewables		High	Partly confirmed

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[92] These NFFO financed wind power plants will not be eligible for support under the new support system implemented after 2002.

[93] As discussed in Section 13.6.4 there were no projects based on institutional investments yet during the 1990s while only 2 projects used participation finance based for community/cooperative projects.

This section looks at the extent to which the older support system created the necessary socio-economic-industrial context for a smooth continuation of diffusion for wind technology based on the new support system. The situation for the selected indicators for diffusion results in 2002 is summarised in Table 13.14.

The socio-economic benefits from diffusion have been assessed as small but with a tendency for increase since 2000 (induced by the NFFO support system). The industrial basis and dynamics could already be assessed as large, before the entry into application of the new support system. These assessments mean that the theoretical considerations regarding socio-economic benefits were *not confirmed*, while those regarding the industrial basis and dynamics were *confirmed*. The next paragraphs present the empirical information on which these assessments rest.

Socio-economic benefits

The socio-economic benefits from wind energy investments by 2000-2002 can be described as *small but in process of improvement*. In early 1990s developers proposing wind plants for planning permission were not concerned with the issue of indirect *local* socio-economic benefits. Small developers had their interests such as income diversification and saving electricity bills by means of green self-generation. Large companies had their commercial interests. But both categories had little (in mind) to offer to local communities. Beginning with 1994, with increasing refusals for planning permission, few companies developed strategies to increase their chances for local permits.

As mentioned earlier, the National Wind Power has been so far the most generous, allocating special funds for local community spending, and trying to maximise local employment in their projects for the development of rural economy. Community funds are aimed at schools' and day-care centers' endowments, educational purposes - with special attention for pupils' training into energy efficiency and sustainable resources, recreational group activities both for youth and elderly, and projects of special local interest. But it is important to note that, under the strong price convergence policy of NFFO, very few developers could afford such spendings. The lowering profitability of projects under the last three rounds offered little room for investments towards local integration of wind farms. Only few financially strong companies, such as former utilities with good financial reserves from privatisation, could afford this.

In addition to community funds, National Wind Power also introduced recently the WindWorks scheme offering ownership shares to farmers and local people. This was warmly received by communities, as well as by the branch organisations National Farmers' Union and Countryside Agency. By 2000/1 increasingly more developers, were designing ownership schemes offering the possibility of local people to have a share from the profits of wind farms locate in their area. For these reasons, we assess the indicators of direct and indirect local socio-economic benefits as small but increasing since late 1990s.

As regards *employment*, due to the fact that the design of the NFFO system basically undermined the British manufacturing base, and that the planning obstacles allowed only a very small fraction of approved NFFO contracts for wind to be installed, employment in the wind industry was quite low in the UK. A detailed study on wind energy related employment (Jenkins 1996) estimated that, in the year 1994-1995, there were around 1300 full time equivalent direct jobs. Of these, about 1000 jobs were serving the domestic market. In addition, it is estimated that the 1300 direct jobs created 900 more jobs in other economic sectors - indirect jobs. In the manufacturing sector, including production of components, there were only 300 direct jobs. An important feature of wind related direct employment in the UK is that for many people, wind energy represents only a portion of their work. “They also carry out work in other areas as part of their jobs” (Jenkins 1996).

Consequently, beside the smallness of the employment base, this was also to a large extent resting on other industrial and economic sectors. This suggests, on the one hand, a small degree of specialisation in the wind energy business (indicator for the industrial basis and dynamics). On the other hand, it suggests a weak potential for trade union political lobby for sustained support of wind technology market diffusion, since if the wind-related tasks disappear from the job description of these employees, for most people this would not mean job losses. In the second part of the 1990s wind related employment has not increased. The British Wind Energy Association estimated that in 1998 around 2000 jobs were directly and indirectly linked to wind energy development in the UK (Krohn 1998). In conclusion, wind related employment in the UK can be rather assessed as *small/modest*.

Industrial basis and dynamics

In contrast to employment - which reflects the *installed* capacity increase, the industrial basis reflects also the groups of stakeholders - not yet involved because of project implementation obstacles, but directly interested to become involved in the wind business. The NFFO support system led to the enlargement of the group of stakeholders, with the *approval* of the 2236 MW wind capacity.

The number of companies offering services and products for wind plants investments registered in the database of the British Wind Energy Association increased from less than 50 in 1996, to 136 at the end of 2000, and further to 216 in mid 2002. The increase in late 1990s was mainly induced by the many contracts allocated in the last two NFFO rounds in 1997 and 1998. The increase since 2001 has been mainly motivated by the prospects for off-shore investments in the frame of the new support system.

Table 13.15 *Number of companies offering services and products for wind plants investments in 2002*

Types of industrial activities	Companies in 2002
Project Developers & Consultants	100
Offshore wind / goods & services	48
Civil Engineering	29
Operators	28
Legal services	21
Manufacturers turbine components	18
Finance houses	15
Electrical Engineering	13
Manufacturers turbines >50kw (producing in the UK)	2
Manufacturers other components (including blades)	4
Small System Suppliers	4
Insurance	4
Total companies industrial basis	216

Source: BWEA database, June 2002

As Table 13.15 shows most companies offered services of project development and consultancy. These services were on high demand under the NFFO system, which required careful preparation of project proposals. But under the new Renewable Obligation they remain crucially important, since it poses high economic risks on projects’ operation phase, as briefly described in Appendix 13.3. High quality expertise was available in the areas of: site exploration, performance and financial evaluation, planning applications, and environmental impact statements (IEA 2001: 212). Other particularities of the British wind industry are the high number of companies specialised in legal services, and the presence of financial houses offering equity finance. Their numbers were considerably higher than those of wind technology manufacturers.

Since late 1980s there have been only 4 manufacturers of turbines with production facilities on UK ground and 2 companies producing wind blades. In the 1987 the Wind Energy Group tested its first large two-bladed horizontal turbine (see Section 13.2.1) and it continued its activity until 1998 when it was bought by the Danish Neg-Micon company. The Howden Group was successfully producing and exporting small-scale turbine designs in mid 1980s. But it withdrew in 1989, due to perceived lack of domestic market[94].

The third manufacturer, Carter, became an UK subsidiary of an American company in early 1990s. But it failed to win sufficient sales and in 1996 it also left the market. Finally, the Renewable Energy Systems which entered the wind industry (from the British construction industry) as a project developer, operator and owner, it manufactured its own first wind turbine of 1 MW and put it to testing in 1998 (IEA 1999: 153). Hence, in 2002 there were only 2 turbine manufacturers with production facilities in the UK.

Beside them there were also 2 blade manufacturers. One was Taywood Aerolaminates, the sister company of the former Wind Energy Group, which was also taken over in 1998 by the Danish Neg-Micon company (Krohn 1998). The second was a branch on the British Howden manufacturer, which was taken over in 1996 by the Dutch Aerpac company and transformed into an internationally successful blades production company - Aerpac UK. Although 95% of its blades' production went to export in late 1990s, the company remained based in the UK "due to the expectation that sooner or later the domestic market will take off too, and being aware of the very large wind potential of the country" (Anderson 1999). But the UK manufacturing industry produces a wide range of components such as castings, towers and pitch bearings. In 2002 there were 18 companies producing technology components. The prospect of intensified off-shore investments increases the medium-term expectation of growth through demand from the domestic market (IEA 2000: 180).

Consequently, the numbers in Table 13.15 suggest that there was (potential) very high competition in 2002 for project development and consultancy services. For other essential services such as wind farms civil engineering, electrical engineering and operation there was modest competition, with between 13 - 30 companies offering such services. A special feature of the UK wind industry is that it seems to be dominated by a set of large corporations offering more services in the life-cycle of wind plants, which were often (co-)owners of installed wind capacity. Data regarding how many services/products each of the 216 companies in Table 13.15 were not available. However, some empirical sources mention that there is a substantial degree of vertical integration in the British wind industry (IEA 1998: 150). As regards the horizontal integration of the companies registered in the wind energy business with other renewable technologies, direct data were again not available. It seems, though, that many of them offered similar services also to developers and owners of other types of renewable technologies or other business areas.

The considerations on employment involved some empirical studies which suggest that most employees do not work full time jobs in the field of wind energy. In conclusion, the national industrial dynamics for services related to wind energy plants can be assessed as large. Although the industrial basis for products manufacturing was small, the presence of companies arranging imports of wind technology was large.

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[94] The Wind Energy Group and Howden had a strong R&D base and were successfully exporting turbines that were among the largest and technically advanced at the end of the 1980s. This performance was to large extent the result of governmental R&D program and support.

The potential for political lobby from the socio-economic-industrial context

As regards the potential for political lobby related to wind-industry employment, wind project systems owners and the industrial basis for wind technology services, this needs to be analysed in retrospect, as a change of support system had already occurred when this study was done. Lobby from the wind industry played an important role in the shape of the new support system. As mentioned in Section 13.4, when the government launched the NFFO system in 1989 it intended to keep it in place only until 1998. Afterwards, when full liberalisation of the consumption segment occurred, any form of governmental support for new renewable electricity capacity (outside the NFFO contracts) was to stop.

However, there were three driving forces that eventually created synergies towards the introduction of a new support system for renewables. Firstly, the 1997 Kyoto target for greenhouse gas emission reduction and the domestic climate program required some contribution from renewable resources[95]. Secondly, the European Union was preparing a Directive for the harmonisation of support systems for renewables and specific national and EU targets for renewable electricity. In this framework the option of support withdrawal was not politically feasible anymore for the British government. And thirdly, the lobby from the associations representing the interests of renewables industry was constant and powerful towards a new and more effective support system. Consequently, in 1998 a 10% renewable electricity target was set for the year 2010 by the government, with an intermediary target of 5% by 2003.

The political lobby was exercised mainly by the trade associations representing individual renewable technologies[96], of which British Wind Energy Association was very active, and by Association of Electricity Producers[97]. The British Wind Energy Association represents a wide range of stakeholders, from companies already doing business in the wind industry, to companies with small current involvement but large interest for future business, and to academia. What is interesting in the British context is that at the end of the 1990s this was very weak from the standpoint of direct lobby from the employment segment. But it was very high from the standpoint of economic actors (of many different types) with interests in the British wind industry.

The NFFO system created a lot of interest from many types of economic agents and financing agents into the wind energy industry. On the one hand, there were the many developers winning NFFO contracts for 2236 MW wind capacity, as well as all developers whose proposals were rejected into the tough competition. One the other hand, there were all the companies seeing a large business potential in the manufacture, construction, operation and maintenance of the very large approved capacity. Beside them there were also many potential financing agents, both loan and equity providers, attracted by the long-term fixed price contracts for a technology proving to be increasingly reliable.

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[95] The Kyoto target of the UK is to reduce greenhouse gas emissions by 12,5% by 2008-2010, compared to the 1990 level. But the domestic climate target is actually higher proposing a 20% cut in CO_2 emissions by 2010, compared to 1990. The British government wishes moreover to be prepared for meeting CO_2 reduction targets beyond 2010, which are expected to be even more drastic.

[96] Other organisations are: British Hydropower Association, the Biogas Association, Energy from Waste Association, Photovoltaic United Kingdom, and British Biogen.

[97] The members of the Association of Electricity Producers use almost all types of energy resources and generating technologies. The resources used include wind, hydropower, wave power, landfill gas, animal wastes, municipal and other types of wastes. But some also use coal, gas, oil and nuclear. Company types vary from small family associations and cooperatives to major corporations. Among the main tasks are lobbying, and responding to consultations in the policy-making process.

The stake created by the NFFO system in wind industry overlapped with evolving awareness on the potential for further market diffusion, having in view the very large exploitable wind potential in the UK, and the new political challenges on the UK government for climate change and EU related targets for renewable electricity. Consequently, a strong political lobby from a large diversity of economic actors emerged under the NFFO system, and increased in late 1990s. This was chiefly focused on the reduction of obstacles for local planning permits, and on ensuring that a new support system is put in place that ensures continuation of wind electricity diffusion.

The lobby was successful in many of its objectives, such as the location flexibility policy adopted at the end of 2001 and the design of a new planning system for renewable energy plants. It was also successful in exempting renewable electricity from the Climate Change Levy entering into operation in 2001, and in introducing many design features in the Renewable Obligation on supply companies that are attractive for investors. In other objectives of substantial importance for further diffusion, the lobby was not successful. For example it failed (so far) in the attempt to introduce special technology bands for on-shore and offshore wind technologies in the Renewable Obligation. It also did not manage to avoid the financial penalties on intermittent electricity supply introduced under the New Electricity Trading Arrangements law entering into operation in 2000 (see Appendix 13.3), although discussions were ongoing in mid 2002.

However, simultaneously with its successes, the lobby group has substantially increased in size. As diffusion prospects improved, more companies - especially powerful domestic and foreign corporations from the energy, equipment, marine and construction industries - joined the British Wind Energy Association. Its membership increased from around 160 companies in 2000, to more than 200 corporate members in mid 2002 and a total of 500 members[98]. This ball-rolling effect could lead to further improvements in the general regulatory framework surrounding wind electricity production, towards a larger and smoother diffusion of wind technology in the UK. Based on this analysis the potential for political lobby induced by the NFFO system can be viewed as large.

In conclusion, the prospects for the continuity of diffusion processes created by the NFFO system could be summarised as follows. Firstly, good cost performances were achieved. They were reached mainly by means of using the richest wind energy locations and substantial technology-specific cost reduction. However, the NFFO price support could enable (assuming no administrative and social obstacles) only a partial exploitation of the available wind resources, namely those for wind speed higher than 8 m/s. An increase in price support may enable the exploitation of lower wind speed resources. The possibility for higher prices per kWh than allowed in the NFFO contracts emerged with the adoption of the new support system in 2002[99].

Secondly, the adoption of a post 2000 support system was initially (in early 1990s) not considered by the British government. However, in time a series of domestic and international factors contributed to the extension of governmental support for renewables. The domestic industrial basis and group of stakeholders emerging from wind diffusion based on the NFFO

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[98] Farmers and their associations became also increasingly vocal in their interest to take a share from the British wind energy as a secondary income stream in a period of crisis in the agricultural sector, due to the mad- cow disease and the foot-and-mouth disease epidemics.

[99] Some market experts (Adler and Fletcher 2002) expected in 2002 that many approved NFFO contracts for wind would be abandoned because the new support system - the Renewable Obligation based on tradable green certificates - gives them opportunity for projects with higher profitability.

system, contributed also to the decision for renewables support and to the improvement in price support as compared to that enabled by the NFFO support system. The issue of socio-economic benefits did not play a role in support system prolongment.

Thirdly, with regard to technical performances, no concern was observed for the market adoption of grid friendly turbines. We considered that such designs would be needed to adopt with priority in order to expand the grid-integration ceiling and the diffusion adoption potential of wind technology in medium-long term. But technological designs with synchronous generators (considered 'diffusion optimal' from grid friendliness perspective) are currently still more expensive than the conventional designs or those with only modest grid-friendliness improvements. Under a support approach - such as the NFFO system and the new Renewable Obligation system - that puts pressure on production costs, investors are not allowed the option to adopt the more expensive diffusion optimal designs. The next section summarises the main findings of this chapter and draws the conclusion regarding the extent of confirmation of Hypothesis 1.

13.8 Summary and conclusions regarding Hypothesis 1

In this chapter we studied the diffusion of wind technology in England and Wales since 1990. We started the empirical analysis with a general orientation in the British policy for renewables, the energy resource base, and the organisation of the electricity industry. Following that we described and analysed the economic governance structure put in place for the support of renewable resources through the 1989 Electricity Law. The economic governance structure is known as the Non-Fossil Fuel Obligation and consisted in five calls for tenders. Based on price competition, the government allocated at the end of these five rounds a total of 2236 MW wind power capacity. Its analysis is concentrated in Section 13.5, where we look first at the economic risks and then at the ranges of profitability for wind projects enabled under the five calls for tender.

We concluded that the *economic risks were very low* while the range of profitability moved from the *very high/high profitability* range, to the *high* profitability range, which went further down the *modest* range for some projects. Based on this we selected to test Hypothesis 1 for the case study of wind technology diffusion in England and Wales in the period 1990-2000. In Chapter 3 we formulated Hypothesis 1 as follows.

A support system leading to a national investment environment of low to medium economic-policy risk and high to very high levels of project profitability will induce *diffusion patterns* that are characterised by:

- the involvement of all types of project developers, having
- predominantly commercial motivation to invest, using
- predominantly external financing schemes, in
- mainly medium and large size projects, based on
- the use of all types of technological designs of which new and/or existing diffusion-optimal technological designs are likely to be more frequent.

Such diffusion patterns will result in:

- a *large installed capacity* increase in short-medium term; and
- *good prospects for the sustainability* of market diffusion processes in the long term for the renewable technology envisaged.

Diffusion patterns

Section 13.6 analysed the diffusion patterns of wind technology. The extent of confirmation of the theoretical expectations regarding diffusion patterns can be assessed as only *partly satisfactory*. For two indicators - drivers to invest and project sizes - the expectations were 'confirmed'. For the indicator - types of developers - they were 'confirmed to large extent with comment'. The expectations regarding the types of financing schemes and technological designs were only 'partly confirmed'. We summarise here the main observations regarding the indicators for which the expectations were not fully confirmed.

As regards the indicator *types of project developers*, due to developments induced by the design of the support system, a distinction had to be made between project owners and project developers. The analysis of project developers winning contracts in the tender process reveals a dominance of large and financially-strong companies, with some diversity in their industrial background, and a modest presence of small developers. However, the picture of project owners (providing equity financing for approved projects) reveals the overwhelming dominance of few electricity companies. The market entry of electricity companies for the first two calls for tender, as well as the winning contracts of small developers under the last three calls for tenders were stimulated by governmental policy. For these reasons, the inset 'with comment'.

The expectations on *financing schemes* were only partly confirmed. Slightly more than half of wind projects built on the basis of contracts approved in the first and second calls for tender used project finance. In the last three rounds, however, the price convergence policy was emphasised and projects used in slightly more than half of cases internal financing: mainly in-house corporate and debt-corporate financing schemes. There were two main reasons why companies used more often corporate financing schemes since mid 1990s. Firstly, some developers/owners accepted to build projects with profitability between 7-10% while banks have generally a limit of 9-10% above which they consider to give project finance loans. Secondly, some owners could have well used project finance loans if they wanted so, having projects with profitability considered acceptable by banks. But, by using corporate financing schemes, they could increase equity returns.

In terms of *technological design*, the domination of conventional designs was observed, instead of the expected frequent adoption of diffusion optimal designs. The main reason is related to the fact that the severe cost convergence policy obliged developers to search for the lowest cost wind technology. From grid friendliness standpoint, diffusion optimal designs are more expensive than the conventional designs. By contrast, in Spain, the high/very high profitability options enabled developers the adoption of the more expensive grid friendly designs, while keeping profitability of projects still above their minimum requirements. However, a blade innovation was adopted that improved the market adoption potential of wind technology for the particular circumstances of wind regimes in the United Kingdom. This led to the assessment of partial confirmation.

Diffusion results

Hypothesis 1 expected large increase in installed capacity, sufficiently strong socio-economic benefits of the respective technology, and a large supportive industrial basis and intensive industrial dynamics. The assumption was that no other obstacles would impede market diffusion processes. Section 13.7 reviewed these indicators of diffusion results by 2000-2002, as well as the cost and technical performances reached by wind technology. The extent of confirmation of the expectations on diffusion results of Hypothesis 1 can be assessed as *satisfactory*.

In this case study, the government decided on the wind power capacity at industry level, for which guaranteed purchase contracts and price support would be approved. This implied that instead of testing the expectation of Hypothesis 1 against the indicator of *installed* capacity we used the indicator of *proposed* wind capacity. Empirical data regarding this were only available for the last three calls for tenders - NFFO-3,4,5 - and they confirmed the expectation. Around 5000 MW of wind power were proposed in these three calls for tenders, showing a tremendous interest. After five calls for tenders there was 2236 MW of wind capacity approved under NFFO contracts. But by 2000, there were only around 300 MW wind energy installed in England and Wales. This is mainly due to administrative-social obstacles, and the fact that many bids were just speculative, proposing projects below the economic feasibility limit.

As regards the theoretical considerations regarding socio-economic benefits, they were considered as *not confirmed,* while those regarding the industrial basis and dynamics were assessed as *confirmed*. By 2000 there was little involvement of local population in terms of direct ownership in wind projects in the regions with good wind resources. However, the largest wind energy developer (National Wind Power), as well as some other companies, were preparing financing and investment schemes aiming at the involvement of local people in the projects for which they held NFFO contracts[100]. In the same time, more attention started to be given by large developers with regard to indirect local benefits aiming to increase local interest in wind energy projects. The industrial basis appeared to be large by 2000, with numerous service companies, though very few technology production companies. The industrial basis was drawing on companies from a very wide diversity of industrial backgrounds. However, the degree of specialisation of these companies in the wind energy business appeared rather modest, mainly due to the fact that most wind capacity was planned but not implemented due to the obstacles mentioned.

Cost-performances have improved significantly in the period studied. This occurred mainly by means of using the very rich resource sites. But reductions in technology-specific costs also occurred. Finally as regards the technical performances, diffusion of grid-friendly technologies may be viewed as diffusion optimal in the context where the wind resource potential is much larger than the grid integration ceiling. However due to the pressure of price support, their market adoption was not stimulated.

Exogenous factors and alternative specifications

The reduced presence of small developers (especially in terms of *installed* capacity) and the market leadership of electricity companies were explained from the following perspectives:

- support system related factors: governmental policy to encourage electricity companies' involvement in early 1990s; the competitive nature and design of the support system;
- business culture of financing agents: commercial banks dominate the domestic market; they require the participation of electricity companies and rarely approve loans to small developers or individuals; there is also a scarce presence of ethical banks; commercial banks have inflexible requirements on client types, loan volumes they are willing to finance, and minimum profitability levels of projects;
- business culture of small developers: low entrepreneurship with regard to new technologies and low environmental interest among small developers;

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[100] These considerations do not refer to what may happen under the new support system revolving around the Renewable Quota Obligation.

- business culture of electricity companies: little interest from them to make joint ventures with small developers (in contrast to the Netherlands);
- institutional factors: the structure of the British financial market with few sources of equity; the institutional context makes stock ownership of small projects/companies by private individuals very expensive and complex.

In conclusion, in this case study where we tested Hypothesis 1, we obtained some mixed results. The independent variables of economic-policy risks and ranges of project profitability *did not appeared to have a strong explanatory powe*r with regard to the diffusion patterns of the supported technology. The extent of confirmation of the theoretical expectations under Hypothesis 1 was ‘partly satisfactory’ for diffusion patterns. However, they did appear to have explanatory power with regard to the indicators for diffusion results, as in their case the extent of confirmation of theoretical expectations was ‘satisfactory’. Beside the influence of the two independent variables, we identified a set of factors influencing the indicator of types of developers, measured in terms of *installed* capacity. They are mentioned above.

The next chapter concludes this study with considerations on the validity of the theoretical framework proposed, the answers to the seven specific research questions formulated in Chapter 1 and a set of policy lessons.

Appendix 13.1

Factors influencing the involvement of types of project developers and their project implementation success

The emergence of former electricity utilities as dominant owners and the presence (as secondly large) of powerful industrial companies - both foreign and domestic - at the expense of small developers can be seen as a result of three key concurring factors: the business culture of financial community and the general context in the financial market; the design of the NFFO system; and the governmental policy behind the NFFO-1,2 rounds to stimulate entry of former utilities.

The last factor was already discussed in Section 13.5.4[101]. The government achieved its plan of involving electricity companies in the wind market. However, the high payment policy brought about also the entrance of foreign companies, and the beginning of the process of ownership consolidation as a result of trade with operating projects and approved NFFO contracts. Once having entered the market, the highly competitive design of the NFFO system in combination with the business culture of the British financing community overlapped towards making electricity companies and financially strong corporations the inevitable main owners of wind projects.

Mitchell (1999) analysed the consolidation in wind plants ownership for the projects with NFFO 3 and 4 contracts by 1999. Data, reproduced in Table 13.A.1 show that only 3 of the 31 NFFO-3 projects with capacity above 1,6 MW maintained their ownership after 5 years. Four of the companies buying these projects were new entrants, and there were in total only 6 companies owning all 31 projects (larger than 1,6 MW) with NFFO-3 contracts. Projects with NFFO-4 contracts recorded lower trade-dynamics. But this can be explained by the fact that only 2 years passed after the tender when the study was done. In 1999, there were 23 companies owning the 48 larger-sizes project approved under the NFFO-4 tender. The interest in trading wind plants from the smaller-size band was lower.

The phenomenon of ownership consolidation was, therefore, on the one hand enabled by the high profitability of projects with (especially) NFFO-1,2 contracts. But, on the other hand, it was very much related also to the second factor that we identified as playing a key role in the dominance of large companies in the UK: the business culture of financing community and the general context in the British financial market. This acted in two main ways. Firstly, in the UK very few banks are interested in ethical investments (Mitchell interview 2000) and the backbone of loan financing is formed by commercial banks[102]. These banks are easily willing to approve loans when projects are (co-)owned by an electricity company, a water utility or another large company with well acknowledged commercial experience (Mitchell 1994). But commercial banks are highly inflexible with regard to projects proposed by new entrants in the industry with limited commercial background and small companies. For them it is very

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[101] What could be added here is that under NFFO-1,2 not all electricity companies invested in wind energy. Some saw wind technology as unreliable and preferred wastes incineration as a technology resembling more that of fossil-fuels they were used to (Mitchell 1994: 257). But beginning with NFFO-3, increasingly more electricity companies proposed and won projects, as the reliability and performance of wind technology became obvious to them too (IEA 1998: 150). Some were still struggling in 2002 to receive local building permits, but others already sold their projects to financially stronger companies - often National Wind Power.

[102] As Archer et al. explain (1999) “There is no history of non-profit making regional banks in the UK (…) and [voluntary] soft loans are very difficult if not impossible to come by in the UK”.

difficult to obtain loans, especially project finance loans, even when they dispose of the available money to provide as equity.

Table 13 A.1 *Consolidation in wind projects' ownership in the UK*

Wind projects	Total number projects	Number original developers	Number projects still owned by original developers in 1999	Number owners in end 1999	New owners in end 1999
NFFO3 (1994)					
> 3,7 MW	31	21	3	6	4
< 3,7 MW	19	18	14	16	2
NFFO 4 (1997)					
> 1,7 MW	48	24	18	23	5
< 1,7 MW	17	8	7	7	-

Source: Mitchell 1999

Commercial banks often place as a precondition for loans' approval the participation of a company that in their view is trustworthy both financially and in terms of in-house technical and commercial skills. This is what basically happened with the many projects developed by small and new entrants facing the financing problem. Large companies bought either some shares in their ownership or entire the plant, when the remaining equity returns for the initial developers were to small to go ahead with the project. Besides, banks do not view favorably developers that have a large number of equity shareholders (Archer et al. 1999). This aspect of business culture is an additional obstacle for investments by communities or cooperatives.

Secondly, most commercial banks have thresholds for the investment costs of projects they are willing to finance. They seldom agree to give loans to projects that assume costs below 7 Million €, because the total financial benefits from interest rates would be too low[103]. Banks become really interested to finance only when projects are above 37 Million €. In addition, there is a gap in the British financial market. Projects below 1-2 Million € could be (and have been) financed by small companies, communities and private developers. But there appears to be no clear financial source for projects with costs in the interval 2 - 7 Million € (WPM February 1994: 26). Local and regional banks have their own threshold-rule and do not generally loan more than 1,5 Million € per project[104].

As regards equity financing Mitchell (1994[2]) mentions that "the UK has very few sources of capital (essentially building societies and banks) and they are very inflexible about the way they lend". Due to the poor competition in the financing market, they usually require high returns on equity when approached to form joint ventures with small developers, lowering substantially their own equity returns.

The third factor acting in favour of ownership dominance of large developers is given by the very design of the NFFO support system. This requires a series of studies and preliminary work to be done in order to pass the will secure test - the technical, commercial, economic and legal reviews. But the system is also highly competitive and in order for applicants to secure good winning chances, consultants and lawyers need to be involved, which increases total costs for project preparation. The Association of Independent Electricity Producers estimated that these costs are between 45.300 € - 60.400 € per project (WPM July 1995: 25;29). Large corporations may afford to loose this money, especially electricity companies that emerged with large financial reserves after privatisation (WPM March 1997: 21). But for small

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[103] In the five NFFO rounds banks financed few projects with lower than 8 Million € investment costs.

[104] Many local banks have been simply not willing to consider wind projects in early 1990s, or were only willing to give private/corporate loan and not project finance loans (Mitchell 1994: 290).

developers the risks of project failure are hardly acceptable. Besides the NFFO system did not guarantee planning permission, and this proved to be the key obstacle for wind diffusion in the UK. Assuming that projects were approved NFFO contracts, the risk of failure to install the contracted capacity was also an important deterrent for small developers to invest.

Other factors that can be pointed out as working against the emergence of small developers' ownership are the business culture of small developers themselves, and the institutional context for legal organisations.

Market experts argue that in the UK the business culture of private individuals does not favor community enterprises and cooperative ventures, but rather investment in stocks and shares[105]. Capital ownership is more popular than cooperative ownership. Although co-operatives are commonplace in agriculture, this ownership vehicle is seldom considered an option for other types of economic activities (Archer et al. 1999). It is generally considered that feasible approaches in the UK would be either developer-led community enterprises or wind investment funds where individuals and small companies could buy stocks (WPM January 1999). In both cases specialised wind farm developers would take responsibility for the design, management of financing operations, construction, and operation of the wind system. These ventures could even group together several small wind projects and reduce costs through economies of scale.

However, even these investment approaches could face difficulties due to other cultural particularities. For example Mitchell (1993) argues that the UK does not have companies, such as in Germany and the US, specialised in bringing together investment opportunities in renewable energy and potential stock buyers. Although there are in principle firms and bank networks specialised in institutional investments, they were just not used for renewable technologies. In addition, other market experts (Archer et al. 1999) observe that in the UK "individuals are less willing to invest in wind energy projects than in other European countries such as Denmark, Germany Sweden, Finland and Austria". In addition, they argue that in the UK there is no background of environmental awareness amongst ordinary citizens as compared to the countries mentioned.

During the 1990s only one community project and one cooperative project were developed in the UK[106]. The latter was a developer-led project based on a NFFO-3 contract - the Harlock Hill plant. This was initiated by a subsidiary of the Swedish firm Vindcompaniet (Wind Company) whose aim was to introduce co-operative wind system in the UK[107]. In the NFFO-4 round the Wind Company won contracts for 4 other small-size projects for which it was preparing to get planning permission. But later the Wind Company was bought by the Danish turbine manufacturer Neg-Micon who took the decision to sell the NFFO contracts and concentrate on its core business - turbines production (WPM July 1999: 25). With this, a serious endeavour to stimulate community ownership was given a hard blow. The community

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[105] "Cultural differences here play their part. The population of the UK is nowhere near so homogeneous as that, say, of Denmark and getting a local community to co-operatively invest in a wind project would be expecting the unlikely." (WPM July 1995: 4). "One of these barriers [to community involvement] is cultural. Unlike some other European nations, the British are slow to mobilise themselves into groups to develop projects." (WPM July 1995: 29).

[106] Both projects had profitabilities in the low end of the range, 7-9% (Edwards et al. 1999; WPM June 1996). Many individual investors in these two schemes benefited of a tax relief under the Enterprise Investment Scheme, which raised their profitability from 7% to 8-9% (WPM June 1996: 27). This scheme was not available for corporate investors.

[107] "Windkompaniet, a small Swedish company specialises in forming wind plant ownership co-operatives among local people (…) Its British subsidiary, The Wind Company UK Ltd (...) has gone to great effort to inform the local population of its plans and get them to support the project" (WPM April 1995: 22).

project was developed with the help of the Dutch ethical bank Triodos, under a NFFO-5 contract (Haverigg plant). This opened in 1998 a Wind Fund in the UK to give the opportunity to individuals and companies buy shares in wind projects. The Wind Fund provided finance in the form of 100% equity, which in our typology was referred to as participation finance. The Triodos Bank took care of all phases before and after the placement into operation of projects.

As regards the institutional context, there are several difficulties for the organisation of institutional investment companies, community ventures and cooperatives in the UK. The organisation of legal ownership for these types of developers is quite expensive, complex and inflexible[108]. It is estimated that, the legal and financial costs of developing projects under community ownership are around 151.000 € per project (WPM December 1995: 29). Besides, there is tight regulation on shares' trading and strict control on shares' advertising. Small-scale projects cannot be publicly quoted in the UK, while the 1986 Financial Service Act does not allow investors to advertise stocks. Only investment funds from private individuals' savings managed by specialised equity gatherers can be used for small projects (Mitchell 1994: 292).

In the first years of 2000s, the ownership picture started to experience some changes. Several developers decided to invite private individuals and local people at project location to buy shares in wind projects. The company Wind Prospect[109] opened 5 projects to community participation. Several new small companies with NFFO-5 contracts for small-scale wind systems were also considering to invite local people to buy shares for community ownership (WPM, January 1999). The National Wind Power developed a special program Wind-Works program to enable small developers develop, finance, construct and operate small scale systems - of 1,2 or 3 turbines. This assumed 'third-party financing' by the corporation, having in view that "the difficulties of financing individual small wind projects, each costing typically 1,5-3 million €, proved insurmountable"[110]. The National Wind Power retains majority ownership of such systems. But farmers and landowners are enabled to get additional income in a period of serious farming crisis in the UK, which raised overwhelming interest among them.

In conclusion, the NFFO system led to the domination of electricity companies as wind capacity owners. This was on the one hand the outcome of government's policy to encourage their involvement by high profitability in the first two competition rounds. But on the other hand, the design of the NFFO system and the business culture of the financing community led to an unstoppable ownership consolidation by electricity companies and other large corporations, in spite of the government's policy to encourage developers' diversity since 1993. Small developers had a scanty presence in the approved capacity and an insignificant presence in the installed capacity. Even if beginning with the 3rd NFFO round a special wind technology band was introduced for small-scale projects, large developers were still the overwhelming winners of contracts. Only in NFFO-5 did the number of small new entrant developers increase in this small-size band. But very few managed to materialise their projects in installed capacity.

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[108] Edwards et al. (1999) explain that "legal structures for these operations can be costly to establish (e.g. a Public Limited Company), while a separate tier of business (e.g. an Investment Club) adds complexity and a loss of local control".

[109] Wind Prospect emerged as a joint venture between the developer Windcluster, the Dutch ethical bank Triodos and the Dutch engineering consultancy E-Connection. Wind Prospect states it aims "to develop wind energy projects in partnership with local communities, whilst offering farmers an opportunity to diversify. (…) We encourage local ownership and investment and contract with local companies wherever possible." (Source: http://www.windprospect.com)

[110] Information at http://www.nationalwindpower.org.

The picture of wind projects' owners can be seen as the outcome of the following corroborating factors:

- the governmental policy to encourage electricity companies' involvement in early 1990s;
- the business culture of the domestic financing community and the structure of the British financial market;
- the design and the competitive nature of the NFFO support system;
- the business culture of key economic actors: small developers and electricity companies;
- the institutional context for legal ownership of small projects/companies by private individuals.

The analysis of the factors leading to the very restricted involvement of small developers in the wind power generation industry suggests that beside an adjustment of the support system itself, pervasive intervention would be needed to adapt the financing market and the institutional/legal context for a new business approach towards small developers. But some cultural barriers need to be addressed at the level of small developers, as well.

Appendix 13.2

Main obstacles in the implementation of wind power projects with NFFO contracts

Of the 2236 MW wind capacity approved, only 292 MW were installed by mid 2002, that is 13%. The principal culprits for the slow capacity increase are local/social opposition and financing difficulties. The issue of financing obstacles was already discussed. Hence, we concentrate in this paragraph only on the local/social opposition issue.

By 1999, projects amounting to 257 MW were terminated mainly due to planning permits refusals. The rate of success in local approval was very small in the following years. Only at the end of 2001 has the government introduced the location flexibility policy of NFFO-approved wind projects. This was estimated to give new chances to around 350 MW of wind projects with contracts that were declined planning permission at the originally proposed site. The new policy allows even for their placement offshore (IEA 2001: 209). Another policy change consists in the placing of wind plants larger than 50 MW on a different approval mechanism. For such large plants the Ministry can directly give building permits, while local authorities are only given a consultation position.

But this intervention in planning and local approval came very late. The government received since early 1990s criticism for the incompleteness of its planning guidance to local authorities. But it rejected this criticism. In 1990 and 1991 when the first two rounds of contracts were awarded, there was basically no planning guidance for wind energy plants at all. A draft note on Planning Policy Guidance Note 22 for renewable energy was only adopted only in February 1993. The plan was criticised mainly for failing to define the role of planners and to give adequate guidance regarding the visual and noise impacts of wind/renewable plants, which were the most frequently invoked local complaints (Mitchell 1995: 1089).

Presumably also due to poor guidance, many early projects were placed in Areas of Outstanding Natural Beauty (at least 17 sites by early 1996). These were often hill-tops or coasts of high landscape value, where high wind speeds could make projects economically feasible or more profitable under the price convergence policy (WPM March 1996: 20). This gave raise to a series of bitter confrontations between wind energy developers and various interest groups. But the government continued to claim its approach was the right one and to refuse giving more specific planning guidance to local authorities. It considered that local decision-makers are in a better position to assess projects based on their suitability to the local conditions and interests (WPM December 1994: 23).

In addition to planning bottlenecks, critics of the government also mention the failure to explain to local authorities and to debate publicly the need for wind energy and for renewables in general. The incumbent planning regulations are based on the principle of local value (Mitchell 1999). People and local decision-makers perceived wind energy as bringing regional and global benefits in terms of reduced emissions and considered them to have no local merit. They did not see - and the government did not explain them - the local economic benefits, and the strategic advantage of being able to generate electricity at local level from the perspective of security of supply, since these plants are generally linked to the regional distribution network. Besides, another factor inducing social and local opposition was the design of the economic support system itself. Firstly, the wave-like pattern of contract approval generated concerns that wind diffusion happened too fast and the countryside was to be flooded with wind farms (Mitchell 1995). Secondly, the principle of price convergence drove applicants towards a restricted set of areas with high wind resources, lowering the chances that too many would receive building permits. When a support system allows for contractual prices to vary in a wider range, planning authorities gain greater flexibility in planning and zoning for wind projects (Ainslie 2000).

Thirdly, the treatment of land access in the 'will secure test' can be viewed as quite weak. On the one hand, because it sufficed with the allowance of projects' proponents to show evidence "that the landowner is prepared to enter into negotiations in respect of the site and access thereto" - when land ownership/rent contracts were not yet available. This provision was actually not really 'securing' the construction of the plant, as the regulator intended. On the other hand, the flaw in the 'will secure test' was that it did not allow from the beginning for the freedom of developers to move projects if planning permission was denied at the initially proposed location.

Looking solely at the issue of social opposition, its 'location' is not very clear. That is to say, the extent to which opposition has been genuinely *local* (in the sense of the NIMBY attitude) or fuelled by various interest groups and influential opinion-makers is debatable. On the one hand, there is evidence of many projects being refused due to *local* social opposition[111]. On the other hand, many public opinion surveys conducted by independent organisations suggest that "the overwhelming majority of residents, in areas with a wind farm, are pro-wind-power, both in theory as a renewable energy resource and in their area"[112] (Simon 1996). The public surveys carried out by developers showed also substantial public support. For example, surveys made in the period 1992-1998 by the owner of largest share of wind capacity National Wind Power at locations around wind farms suggest that 61% of interviewees supported wind energy, while only 32% declared to be against it (Macken 1999).

The wind industry argues that the idea of strong social opposition in the UK does not reflect the real situation, and that it is fuelled by access to media of opponents of wind energy especially associations claming that they defend the countryside landscape and culture such as Country Guardian, Council for the Protection of Rural England, Countryside Agency, and English Nature. In addition, opinion-makers such as artists, novelists, and even Prince Charles made also strong statements against wind energy that enjoyed wide media coverage[113]. As these were coming on the background of a poor public awareness on the multiple benefits of local renewable energy, it is possible that indeed local social opposition was to larger extent 'injected', rather than of the inward NIMBY type. And very often the injection of opposition to wind turbines was based on emotional calls based on systematic mis-information and exaggerations that eventually discredited many opponent groups and individuals. But social opposition was in some cases also rational. For example, one opposition group was complaining that while a large conventional generator (Scottish Power) was reaping profits from the NFFO program with wind energy plants, it was in the same time planning to expand its coal burning capacity generating 19 times more CO_2 emissions than those saved by its wind capacity (WPM November 1995: 6). Ultimately, the local administrative obstacle and social opposition appear to have had much to do with the insufficient and inappropriate governmental intervention in facilitating projects' implementation, as well as with the defective design of the economic support system for renewables.

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[111] Many articles of the Windpower Monthly journal (since 1994 to 2002) report on projects refusals due to social opposition.

[112] This is the main conclusion of a study on 13 public opinion pools conducted between 1990-1996 by independent bodies. These surveys interviewed 3550 people living close to a wind plant or a proposed site.

[113] For example in 1994, tens of members of the literature world started a campaign against wind turbines referring to them as an assault on the British "literary and artistic heritage, being perpetrated in the name of so-called environmentally friendly power generation." (WPM April, 1994: 13). In the same year Prince Charles mentioned in a documentary on his life and ideas "I'm dead worried that they're going to go too far like they have in Denmark. The whole place is knee deep in these damn things" (WPM August, 1994: 6). Besides, newspapers were publishing that, in the opinion of real estate experts, wind farms would devalue property between 35% - 50%, or more (WPM July 1996: 8).

Appendix 13.3

New support system for renewable electricity post 2000

Towards the end of the 1990s, the need for a change in the British support system emerged. This was the result of two main overlapping factors. Firstly, the British electricity industry was preparing for re-organisation of its structure and trade system, since the liberalisation model launched in 1989 failed to lead to competition in the wholesale market. The new Utilities Act and the New Electricity Trading Arrangements started to be discussed in 1998. The old NFFO support system for renewables was not compatible anymore with the new regulatory framework of the electricity industry because two main elements of the support system were supposed to disappear: the obligee and the pool price. Secondly, the Kyoto target for greenhouse gas emission reduction and the domestic climate program required some contribution from renewable resources. In 1998 a 10% renewable energy target was set for the year 2010 by the government - with an intermediary target of 5% by 2003.

After 2000, a new system has been shaped to support the commercially viability of renewables, consisting of three elements. The central element is a quota Renewable Obligation on electricity supply companies with a 25 year horizon. The second is the exemption from Climate Change Levy for renewable electricity consumed by business and industrial consumers. The third element is a special governmental program to support medium term technologies, offering subsidies for research, demonstration, investments in commercial plants, infrastructure building, decentralised used of renewables and local planning. The plants that were awarded 15 years contracts under the NFFO 3,4,5 calls for tender will preserve them and remain separated from the all these support schemes.

The Utilities Act of 2000 amends the provisions of the 1989 Electricity Act on renewable electricity. It empowers the Department of Trade and Industry to impose electricity supply companies an obligation to supply a certain amount of renewable electricity to their customers. The Renewable Obligation imposed on suppliers since April 2002 aims to lead to 10% renewable electricity by 2010 and it is envisaged to be in place until March 2027. Green certificates have a price cap of 4,5 €c/kWh, which is also referred to as the 'buy-out price'. This was introduced to appease the worry of the Treasury, Office of Gas and Regulation and some officials from the Department of Trade and Industry that the Obligation will lead to too high costs for consumers.

Suppliers can meet their obligation by means of: generating renewable electricity, buying physical streams of renewable electricity, buying green certificates, or 'buying out' their obligation. But obligees cannot borrow the green certificates. The buyout payments are recycled to suppliers who fulfilled their obligation - in proportion to the extent that they have done so. A supplier can pass over the costs of meeting its obligation only on its own customers. Since 1999, in the UK all types of consumers are free to choose their supplier. This stimulates obligees to be active players in the Renewable Obligation market and avoid paying the buy-out price that could have considerable impacts on their overall competitive position. The renewable electricity consumed by a generator or exported cannot receive green certificates. It is estimated that in order to comply with this profile an annual capacity of slightly below 1000 MW should be annually built (PIU 2002). A review of the workings of the Renewables Obligation is planned for 2006/2007. The quota obligation is not split among technological bands, creating competition among renewable technologies in different stages in technical-economic development.

Expectations on diffusion patterns post 2002

An attractive aspect of the Renewables Obligation is that it has a quite long time-horizon. The preservation of the obligation up to 2027 offers investors some confidence in demand. But compared to the NFFO system, market and price risks have emerged. It will not be easy to predict how much capacity would various interested developers be willing to build and what kind of contracts would obligees be willing to offer to renewable generators. It is also highly uncertain how will the three price components evolve - wholesale market prices, green certificates prices, and the politically set Climate Change Levy.

These risks attract negative impacts on the financiability of projects. Especially in the first years, it is likely that most investments will be done based on corporate finance or private finance. When banks agree to give project finance loans, they will be likely to ask higher interest rates, due to risk premiums, and to require a larger equity contribution from project developers. Overall, this means that large and financially self-reliant companies will be the main project developers under the Renewables Obligation scheme. Small developers will be perhaps under increasing pressure to sell or merge with large developers (WPM November 2001). In early 2002, many utilities were planning very large-scale renewable power plants and long-term investment strategies, of the order to hundreds of MW. The most targeted resource was wind energy - increasingly in the form of off-shore projects, due to slow progress in smoothing regional planning procedures and local acceptance.

In conclusion, beginning with 2001/2002, a new support system has been put in place in England and Wales[114]. The centrepiece of support is a Renewable Obligation on suppliers, which regards exclusively new renewable capacity. The projects that were awarded contracts under the NFFO 3, 4, and 5 calls for tenders, will be honoured but their output cannot be traded under the Renewable Obligation. It is estimated that if all projects awarded contracts during the 1990s overcome the current obstacles, they will provide 5% of electricity consumption (Doddrell 2001).

If the Renewable Obligation of England and Wales is successful in leading to 10,4% renewable electricity consumption by 2010, the United Kingdom has chances to overcome its political target, with consumption reaching 15% renewable electricity. The economic and financial mechanisms to support renewables seem sufficiently powerful for the achievement of this target. Much of this will depend however on overcoming planning and public acceptance obstacles, and on the trade off between supporting renewables and supporting nuclear energy that the government will have to decide eventually.

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[114] Scotland and Northern Ireland are revising their new renewable energy policies along similar lines, based on market mechanisms.

14

Summary and conclusions

Part IV of the book consists of Chapter 14 where we give a summary of the main theoretical considerations, and discuss the relevance of empirical findings for the analytical framework of the study. Further, we draw some conclusions regarding the policy lessons and recommendations emerging from our research.

14.1 Problem statement and the analytical framework

We started this study from the observation that analysing support systems that address the economic and financing obstacles for the diffusion of renewable electricity technologies places policy analysts with a serious challenge. There is an increasing wide diversity in the types of support instruments that may be used to address these obstacles. But there is an even larger diversity in the possibilities to combine such instruments into national support systems. Besides, the composition of support systems may also change in time. The empirical information summarised in Appendix 2.1 illustrates this, by mentioning the support instruments used simultaneously in late 1990s, and prepared for implementation, in several industrialised countries.

A review of the current approaches in the (still limited) scientific and empirical literature regarding support systems' analysis and their impacts on renewable technology adoption led us to formulate several critical observations. The general criticism was that current studies do not explain how the observed results of market adoption were achieved, and they also do not address the issue of what do those results mean for long-term continuity of diffusion.

More specifically we observed that, firstly, the way support systems are described and analysed is not (sufficiently) helpful in understanding the consequences for diffusion. Classifications and analyses of support schemes' characteristics are often made from the perspective of policy makers. Secondly, the way financial aspects of support systems are described is not sufficiently suggestive with regard to the attractiveness of potential adopters to invest. Thirdly, the studies on adoption effectiveness of support systems are overwhelmingly short term oriented. Research so far has been interested in which support systems can achieve a larger extent of adoption. But no attention was paid to the conditions necessary to sustain diffusion in the long term and the role that government policy may play. Too often the potential of governmental intervention is overestimated, such as the potential to improve cost performances. Fourthly, the studies on adoption potential of support systems performed so far do not offer satisfactory answers regarding the mechanisms that relate to the types of support systems with the adoption results observed.

Drawing on these observations, we sharpened the theoretical focus of the study. We chose to place emphasis on underpinning the diffusion patterns and mechanisms that relate the characteristics of support systems to the adoption results in short-medium terms of system operation and consequences for long-term diffusion prospects. But in the same time, we aimed to specify a new analytical approach to the study of support systems, as well as an approach to the analysis of the long-term diffusion. The *central research question* of the study was formulated as follows:

> *What are the consequences of the design of policy support systems - aiming to address the economic and financing obstacles faced by renewable electricity technologies - for the patterns and extent of short-medium term adoption, and for the prospects for sustainability of diffusion processes in the long term?*

In developing the analytical framework, it was assumed that no other obstacles such as administrative, social, environmental or institutional would prevent economic and financing agents from implementing their investment decisions. These types of barriers are generally country- and technology-specific. Support systems were conceived as having two components: economic and policy.

The economic component refers to the support schemes that directly concern the trade arrangements for renewable electricity. They can be governmentally protected, in which case they are generally rooted in the legal framework governing the functioning of electricity industry, or equivalent sets of regulations. But they can also be based on the voluntary purchase of renewable electricity by various types of economic actors. The support schemes taking the form of trade arrangements were encapsulated into the concept of *economic governance structures* for renewable electricity. We chose three elements to describe them: type of demand for renewable electricity, legal price design, and contractual parameters (contract length and contractual price methodology).

The policy component refers to the forms of governmental support that improve the economics of renewable electricity plants, either by reducing costs or by making purchase more price-attractive, or contribute directly to the reduction of financing barriers. This type of schemes were referred to as *policy support mechanisms* and were divided into three groups: subsidies - such as investment, production and loan interest rate (soft loan) subsidies; tax instruments - such as reductions or exemptions of fiscal expenses; and schemes that facilitate bank financing - such as governmental technology performance insurance schemes, or governmental letters of credit support.

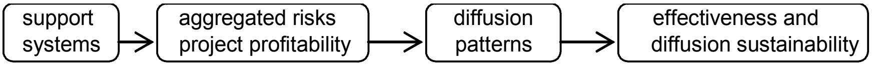
In supporting renewables' market introduction and diffusion, some governments may choose for legally protected economic governance structures. Others may prefer to use only policy support mechanisms and to stimulate voluntary trade, guided by political targets. But very often combinations of these schemes can be found in practice, in which case we refer to them as economic-policy support systems.

The research model holds two dependent variables:

1) effectiveness of market introduction of renewable technologies; this was considered in terms of MW capacity increase in short-medium term, operationalised as between 5-10 years; and
2) prospects to sustain their diffusion in the long-term; this was analysed in terms of cost and technical performances relative to the available (remaining) potential, and the features of the socio-economic-industrial context of diffusion that support systems are likely to induce after short-medium periods of time since implementation.

Given the very large diversity of support schemes that could be used, and the even larger variety of possible ways to combine them, we proposed to translate any support system in terms of two characteristics: 1) aggregated economic-policy risks and 2) overall profitability of projects. It was considered that support systems influence the market diffusion patterns of renewables by means of these two characteristics, which in their turn will influence the extent to which a support system could be effective and market diffusion processes can be sustained in the long term.

Figure 14.1 *Analytical framework for market diffusion potential*



The risk-profitability space was divided into four areas. They were labelled as follows (see also Figure 14.2 further below):

- optimal investment context with low/moderate economic-policy risks and high/very high profitability of projects (Area 1);
- entrepreneurial investment context with high/very high economic-policy risks and high/very high profitability of projects (Area 2);
- political investment context with low/moderate economic-policy risks but modest/low or even below cost-recovery profitability of projects (Area 3);
- minimal investment context with high/very high economic-policy risks and modest/low or even below cost-recovery profitability of projects (Area 4).

The details regarding the operationalisation of the risk and profitability characteristics are presented in Chapter 5. Further, drawing partly on a review on diffusion theories and partly on empirical literature, we selected five indicators of diffusion patterns: types of project developers, types of financing schemes used, projects' sizes, drivers of developers to invest, and choice for technological design of investors. These indicators were selected because we assumed that with their help one can derive expectations regarding both the rate of installed capacity increase and the prospects for sustainability of market diffusion processes. In terms of methodology of theoretical inquiry, we took three analytical steps towards the formulation of the theory's hypotheses[1].

The first step was to make clear typologies for the five selected indicators for diffusion patterns. Eight types of financing schemes were differentiated that were grouped in two categories. The first is that of internal financing schemes whereby project developers are in the same time the main financing agents. Six types of financing schemes were placed in this category. The second is that of external financing schemes, when project developers contribute to less than half of the financial resources to the capital structure of the project, and the rest comes either from loans issued by banks or institutional investors.

We differentiated among two main groups of project developers: large developers and small developers. In the group of large developers the following types of economic actors were included: energy utilities/electricity companies, long-established financially-powerful corporations, and publicly-owned companies. In the group of small developers we included medium/small-size industrial production companies, small new-entrant firms, cooperatives, communities, associations and individuals.

The drivers to invest were classified as commercial, strategic, and (partly-)self-generation. Strategic drivers could be quite diverse, ranging from early market positioning, green image, and local business opportunity to ideological reasons. In practice developers base their investment decisions on more considerations, simultaneously. But the typology enables a clearer analysis. Projects' sizes were labelled and operationalised differently for wind energy systems and for biomass electricity plants, as presented in Chapter 5. This indicator was not discussed for small hydropower technology, as the sizes that may be regarded as 'small' hydro plants are politically defined.

Finally, the technological choice of developers was discussed in terms of the potential of the respective designs to contribute to capacity increase of that technology in the long term in the electricity system, improving this way the prospects of sustainable diffusion processes. Several technical characteristics and features were selected in Chapter 4 for each of the three technologies included in empirical research. Based on state of the art technical literature, they

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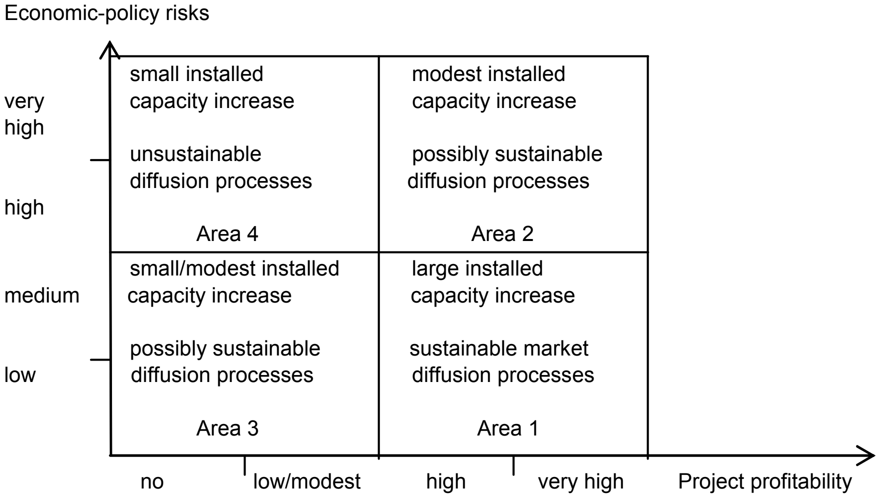
[1] These steps were actually merged in the analysis made in Chapter 3.

appear to have the potential to directly reduce diffusion obstacles with answers in the technical sphere. This way the market adoption of these technological designs may contribute to the increase in the technically, economically and/or socially feasible diffusion potential of that renewable resource in the electricity system, on a long-term basis. We differentiated between conventional designs, and technological designs with substantial or modest potential for contribution to diffusion expansion.

The second step in the theoretical inquiry was to suggest some probabilistic relations among the forms that the five selected indicators for diffusion patterns could take. In the third step, probabilistic relations were suggested between the various forms of the five indicators of diffusion patterns on the one hand, and different degrees of aggregated economic-policy risks and levels of projects' profitability on the other hand. These two analytical steps were taken by combining theoretical and empirical literature, with our observations of the research field. In the last step, hypotheses were formulated with regard to the effectiveness and sustainability of market diffusion under support systems resulting in different risk-profitability investment contexts, represented in Figure 14.2.

Figure 14.2 *The diffusion potential of different investment contexts*



The expectations on the dependent variables were inferred from the forms of diffusion patterns. But we only formulated hypotheses with regard to the expected installed capacity increase in short-medium term and the features of the socio-economic-industrial context of diffusion. In addition to these, we considered in Chapter 2 that the prospects for the sustainability of diffusion processes in the long-term are also influenced by the technical performances and production costs of renewable technologies. However, since these are country-specific and technology-specific, we argued that they need to be studied empirically, in relation to the (remaining) resource potential.

In Chapter 2 we distinguished four sources influencing production costs: technology-specific costs and performances, context-induced costs, technology-complementary costs and resource quality and availability. Of these, only the first and the second categories of cost factors may be influenced by governmental policy. The other cost factors are defined by national resource availability, quality and spatial distribution in relation to grid and consumption points. This renders the potential for governmental impact on cost performances limited. Empirical analyses looked at how costs in the four categories influenced the level and speed of production costs decrease.

It was argued that, when in a country technology specific costs cannot be lowered any further and context induced costs have deflated to normal business terms, the production costs for remaining resource sites will only depend on geographical conditions and resource potential. The further capacity increase of the respective renewable technology will then be defined by the extent of price support the government is willing to accept and sustain. But while political forces define the border of diffusion through the extent of price support, market forces may create (through diffusion patterns) a socio-economic-industrial context of diffusion that can exert political pressure on the extent of renewables support.

We viewed the diffusion context as favourable for diffusion continuation when:

- investments produce socio-economic benefits that would be too politically costly to put a halt on, and when
- a large and politically influential national industrial basis emerged, able to lobby in favour of price support maintenance or even increase.

The socio-economic-industrial context of diffusion was analysed on the basis of several indicators. To differentiate them from diffusion patterns, we referred to them as indicators for diffusion results: socio-economic benefits - direct and indirect at local level; benefits at national level; the number and types of companies offering services and products for renewable plant investments; and the degree of specialization of companies in activities along the life cycle of renewable plants.

Finally, we looked empirically at the extent to which the technical performances - at industry level - of the technological designs that dominate investors' preference may help or not the expansion of the diffusion potential. In the empirical part of the book, the theoretical expectations were tested on eight case studies, mentioned in Table 14.1.

Table 14.1 *Case studies for hypotheses testing*

Hypothesis	Case studies
Hypothesis 1	• wind technology in Spain, 1995-2000 • small hydropower technology in Spain, 1995-2000 • wind technology in the United Kingdom, 1990-2000
Hypothesis 2	• wind technology in Spain, the 1980s-1994 • small hydropower technology in Spain, the 1980s-1994
Hypothesis 4	• biomass electricity technologies, Spain, the 1980s-1994
Specification hypothesis for political-optimal investment contexts (Areas 1/ 3)	• biomass electricity technologies in Spain, 1996-2001
Specification hypothesis for political-minimal investment contexts (Areas 3/4)	• wind technology in Netherlands, 1990-1997

A case study was defined by the market introduction of a specific type of renewable electricity technology, in one country, where an economic-policy support system remained located in the same risk-profitability investment context for at least a short-term period, of around 5 years. This way we tested Hypothesis 1 in three case studies, Hypothesis 2 in two cases and Hypothesis 4 in one case. But in two cases the risk-profitability investment contexts spread over more than two of the four theoretically differentiated areas, which led to the specification of hypotheses for combinations of investment contexts. In the next section we present the research results and discuss the validity of our theoretical expectations.

14.2 Research results and theory validation

In this section we answer the seven specific research questions, by bringing together the theoretical considerations, empirical findings and lessons learned in empirical research. For the research questions 5, 6 and 7 for which theoretical analyses led to the formulation of hypotheses, we also discuss the empirical validation of theoretical considerations.

14.2.1 Research question 1 - The risk-profitability characteristics of economic-policy support systems: can they be traced?

The first research question was "How can support systems concerned with the economic and financing obstacles of renewable electricity technologies be systematically described and compared from the perspective of investors?". There is a large diversity of trading arrangements and policy instruments that could be used and there are numerous possibilities to combine them, leading to different sets of incentives and disincentives to invest in renewables. We answered the first research question (in Sections 2.3.2. and 2.3.3) by translating any support system in terms of aggregated economic-policy risks and ranges of project profitability. This approach enables ex-post and ex-ante analysis of diffusion potential, making also international comparisons possible. But a series of difficulties and challenges are facing the proposed approach, empirically. We highlight them below.

14.2.1.1 Economic-policy risks

Based on the ex-post empirical research conducted in this study we argue that the risk-profitability representation of support systems is feasible and helpful in understanding their attractiveness for investors for international comparison, and national changes in time. Nevertheless, a series of challenges can be signalled in relation to the tracing of the economic-policy risks associated with support systems based on the four-area approach proposed in Chapter 2.

Firstly, some support systems may create, purposefully or un-intently, different investment environments for different types of developers, resulting in risks that spread over two areas of the four theoretically differentiated (see Chapter 11). Secondly, some support systems may create different investment environments for different types of projects, in terms of the use of electricity. Projects covering (partly-)self-generation can be supported by different economic governance structures, or a different set of policy support mechanisms, than commercial projects. This happened with non-hydro renewable projects in Spain based on the 1980 and 1994 economic governance structures (see Chapter 6).

Thirdly, under some support systems, risk cannot be so easily narrowed down, because the general legal framework is only broadly formulated. For example, risk-relevant aspects of implementation can be left to developers' choice, or to agreements between various actors in the industry, or market forces. This can result in the risk-range crossing again over the theoretically differentiated borders of the four risk-profitability investment contexts (see Chapter 6). Fourthly, in some countries two or more separate support systems might co-exist. This was the case also in the Netherlands in the period 1998-2000 when a system relying on the voluntary trade of green labels and one relying on voluntary green premium payments from consumers co-existed (see Chapter 11).

Fifthly, in spite of its aspiration for parsimony, the proposed analytical framework cannot escape complexities when the support system itself is complex. When a support system relies on a large number of policy support mechanisms, such as that present in the Netherlands (especially since 1996), the interpretation of aggregated economic-policy risks becomes very laborious. Each support scheme needs to be analysed - both in itself and in context. Afterwards one has also to look at their interaction, keeping track to the role of each scheme in the profitability of projects (see Chapter 11). Sixthly, beside the cases signalled, some support systems may be difficult to analyse based on the framework proposed, because they create different investment environments for different project sizes. When risk differences are too large, diffusion will most likely take place based on projects with lower risks (see Chapter 6).

In conclusion, the analysis of economic-policy risks can be sometimes more laborious, when regulations in support systems are too detailed, segregating between forms of diffusion patterns (e.g. types of developers, project sizes, or drivers to invest as we encountered in empirical case studies). Support systems can also be complex, overlapping or vaguely regulated. However, empirical research suggests that economic-policy risks are traceable. The effort may be especially rewarding in ex-ante analysis and international comparisons of support systems' diffusion potential. However, in these cases the researcher has to rely strongly on the analysis of the legal text. When there is awareness on possible ways of tacit interpretation of legal texts or business culture practices that could affect risk perception, this can be included in the final risk assessment. But such steps should be done carefully as there is not always certainty that the unwritten rules will operate to the same extent when the playing field is a new type of business activity for concerned actors.

14.2.1.2 The ranges of projects' profitability

As regards the tracing of likely ranges of projects' profitability there are also a series of challenges. They are mainly concerned with data accessibility.

Firstly, data on profitability are often strongly guarded by companies, especially when profits are high. When they are lower than the level considered normal, companies are more willing to discuss numbers. Often they view researchers as a potential campaigning tool for increase in governmental financial support and access to financing. In these cases more details on the economics and financing aspects of projects are offered. But obtaining numbers for projects' profitability remains a challenge.

Secondly, when profitability numbers for the operating plants cannot be obtained, the valuation of this characteristic has to rely on qualitative assessments. If for a case study too many developers are willing to give only qualitative assessments, this has the disadvantage of introducing distortions due to variations in business standards and preferences. Different types of developers could put different labels for the same number. For example, a 6% project profitability can be assessed as 'high' by a cooperative, and low by an electricity company or a large corporate investor. This disadvantage amplifies when international comparisons are made due to variations in business standards across countries. Besides, it is also possible that developers' qualitative assessment may be distorted by the non-commercial values of the project. The approach that could be used when the profitability of operating renewable plants is stated confidential, is to inquire on the minimum acceptable level or range of profitability for which the company generally operates commercial projects.

Thirdly, it may be useful to look at the balance between the range of production costs and the extent of financial support from the economic-policy support system. This can be used as a back-up analysis accompanying the above approaches, or as a last-resort approach. However, there are difficulties facing also this approach. Production costs spread on very large areas, especially in case of wind and biomass technologies. One way to narrow down this is to look at the economically feasible potential under the given support system, from the perspective of the four cost-categories providing input for the overall production costs per kWh, as we discussed in Chapter 2. Comparing this with the financial support available, offers hints for a qualitative assessment by the researcher regarding the likely ranges of projects' profitability.

But tracing the financial support can also be difficult under some support systems, for example when contractual prices are bilaterally negotiated. Or when more support schemes are used, such as various types of investment subsidies and fiscal instruments, and they are not applicable to all developers or to the same extent for all developers. Fiscal exemption or reimbursement schemes bring an extra problem when data are not available regarding their equivalent in terms of production costs reductions. All these difficulties where encountered for the case study of wind diffusion in the Netherlands. As the analysis done in Chapter 12 shows, this approach is very laborious. But for ex-ante type of research on diffusion potential of support systems it is actually the only one feasible to get insight into the likely ranges of the profitability characteristic.

Fourthly, the levels of projects' profitability may change when there are long delays between the time of project proposal/approval and the time when the project starts operating. If there are structural obstacles such as administrative and/or social obstacles for project construction affecting a large number of developers, the picture of projects' profitability at industry level may change. In some cases technology cost reductions might bring increases in profitability during the long waiting time. This was expected by developers of wind plants in the United Kingdom, for example. But in other cases the extra costs incurred in the approval process might lower profitability, and this happened in the case of small hydropower plants in Spain when various additional studies and consultation processes had to be financed. Besides, changes can also occur in other cost-components, especially in the context induced cost-category discussed in Chapter 2[2].

Another challenge is methodological and regards the situation when the range of projects' profitability is too large, spreading for example from low to high. In such cases one can look at how many projects are likely to be in the low/modest area of profitability, and how many in the high profitability zone. If there are indications that there is/will be a concentration in only one area, then the hypothesis formulated for that area can be tested. When projects are significantly spread over the profitability scale, then a specified hypothesis may be formulated, as we did for the case of biomass electricity technology diffusion in Spain since 1995.

Consequently, there are three approaches that can be used to derive the likely ranges of profitability in ex-post analysis of support systems diffusion potential. But in case of ex-ante analysis, only the last one is available to the researcher: to look at the balance between the range of production costs and the extent of financial support from the economic-policy support system. The serious challenge with this approach is to be able to anticipate correctly the (possible) changes in the four categories affecting production costs and their complex interaction: technology-specific costs, technology complementary costs, context induced costs, and resource quality and availability (while in the case of biomass plants also resource price should be accounted for). In international comparative research it is preferable to avoid comparisons of qualitative assessments, since profitability perceptions (just like risks) can also be culturally biased. In the next sub-section we discuss the validity of our theoretical expectations regarding diffusion patterns and answer research questions 5, 6, and 7 and diffusion results.

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[2] A particular situation regards biomass technologies since they use resources that have a price and an associated risk. Changes in biomass price on the separate market for biomass resources (e.g. the market for straw or forestry wastes) can affect the resulting profitability of biomass electricity plants.

14.2.2 Research questions 5, 6 and 7 - Diffusion patterns, diffusion results and theory validity

In Chapter 1 we formulated research questions 5, 6 and 7 as follows:

5. How do investors behave - potential owners and financing agents - under different types of support systems?
6. What are the consequences of investors' behaviour under different types of support systems for the patterns of renewable electricity technologies' diffusion?
7. What are the consequences of the patterns of adoption of renewable electricity technologies for the extent of their adoption in short-medium term, and for the prospects of sustainability of diffusion processes in the long term?

These questions were theoretically addressed together, in Chapter 3. It was argued that the risk-profitability characteristics of support systems influence the patterns by which the supported technology diffuses in the market. In Sections 3.3 and 3.4, we discussed the forms that the five selected indicators for diffusion patterns are most likely to take in the four risk-profitability investment contexts. Based on these, theoretical expectations were formulated in Section 3.5 regarding diffusion patterns. They are mentioned in Table 14.2.

Table 14.2 *The influence of economic-policy support systems on RET diffusion patterns*

Minimal investment context (Profitability: cost-recovery / low / modest Risks: high / very high)	Entrepreneurial investment context (Profitability: high / very high Risks: high / very high)
- internal finance schemes only - small developers predominate - mainly partly-self-generation and strategic projects - very small size projects predominate - adoption of new and/or existing diffusion-optimal technological designs not likely	- internal finance schemes predominate - large developers predominate - balanced presence of partly-self-generation, strategic and commercial projects - small and medium size projects predominate - adoption of new and/or existing diffusion-optimal technological designs likely to a small extent
Political investment context (Profitability: cost-recovery / low / modest Risks: low / moderate)	Optimal investment context (Profitability: high / very high Risks: low / moderate)
- internal finance schemes predominate - small developers predominate - balanced presence partly-self-generation, strategic and commercial projects - small size projects predominate - adoption of new and/or existing diffusion-optimal technological designs not likely	- external finance schemes predominate - large diversity in types of developers possible - mainly commercial projects - medium and large size projects predominate - adoption of new and/or existing diffusion-optimal technological designs, likely to be more frequent

Further, it was assumed that, in their turn, diffusion patterns would influence the features of the socio-economic-industrial context for the respective technology, emerging from diffusion. These features play a role in the prospects for sustainability of market diffusion processes in the long-term together with the progress booked on cost and technical performances of the market adopted technological designs. Section 3.6, formulated the theoretical expectations with regard to the ranges of installed capacity increase in short-medium term, the socio-economic benefits likely to be induced locally and nationally, as well as the size and dynamics of the national domestic industry for the renewable technology supported. The expectations with regard to the features of the socio-economic context are reproduced in Table 14.3. The hypotheses predicting the values of the dependent variables have been represented in Figure

14.2. In this section we discuss first the empirical findings with regard to diffusion patterns, and then those concerning the hypothesised diffusion results.

Table 14.3 *Expectations regarding the features of socio-economic-industrial contexts*

Diffusion results in short-medium term		Area 1	Area 2	Area 3	Area 4
Socio-economic benefits		large	modest	modest / small	small
Local	Direct: ownership	likely	likely small	likely	likely small
	Indirect: more attractive benefits than usual from ~ land rents; ~ local taxes; or ~ local economic or social welfare investments	likely high	likely modest	not likely	not likely
	Indirect ~ local employment	Technology specific (construction and operation works)			
National	Ownership individuals (shares)	likely	not likely	likely	not likely
	Employment in industry	likely high	likely modest	likely modest / small	likely very small
Industrial basis and dynamics		large	modest	modest / small	small
Number companies offering products / services for renewable plants		large	modest	modest / small	small
Types of companies involved in industry		large presence of corporations from diversity of industrial sectors		mostly industrial companies with activities in conventional energy technologies	
Degree of specialisation in renewables		high	modest	modest / small	small

14.2.2.1 Diffusion patterns

Empirical research carried out in eight case studies for three technologies in three different national contexts suggests an *overall satisfactory explanatory power* for the influence of independent variables - risks and profitability from support systems - on the forms of diffusion patterns. Table 14.4 presents the results for the extent of confirmation of theoretical expectations regarding diffusion patterns.

Table 14.4 *The overall extent of confirmation regarding diffusion patterns per case study*

Diffusion patterns / case studies	Hypothesis 1	Hypothesis 2	Hypothesis 3	Hypothesis 4
Wind in Spain 1995-2000 (H1)	good	-	-	-
SHP in Spain 1995-2000 (H1)	good	-	-	-
Wind in the UK 1990-2002 (H1)	partly satisfactory	-	-	-
Wind in Spain 1980s-1994 (H2)	-	partly satisfactory	-	-
SHP in Spain 1980s-1994 (H2)	-	good	-	-
Biomass: Spain 1980s-1995 (H4)	-	-	-	good
Specified Hypothesis (H 3/4) Wind in Netherlands 1990-97	-	-	satisfactory	
Specified Hypotheses (H 3/1) Biomass in Spain 1996-2001	good (H 3/1)	-	good (H 3/1)	-

In five case studies, the extent of confirmation was assessed as overall *good*, in one case study it was considered *satisfactory*, while in two case studies it emerged as *partly satisfactory*. In Tables 14.5 and 14.6 we mention in more detail the results of empirical research on diffusion patterns across the eight case studies. Further, Table 14.7 lists all exogenous factors and factors that constitute alternative specifications of the intermediary variables considered - encountered as affecting the forms of each indicator of diffusion patterns. In the same time, we also mentioned the factors affecting the diffusion result of installed capacity increase in short-medium term. In Table 14.7 we mentioned with an (X) the cases when the respective factors affected diffusion patterns/capacity in the case studies in Spain, with an (Y) when they affected diffusion in the Netherlands and with an (Z) when this was observed in the United Kingdom. This was done to facilitate the observation of factors' action across national contexts.

Table 14.5 *The extent of confirmation of expectations - types of developers and financing schemes*

Hypotheses and case studies	Types of developers	Types of financing schemes
Hypothesis 1 (wind in Spain 1995-2000)	confirmed to a large extent with comment	confirmed
Hypothesis 1 (SHP in Spain 1995-2000)	confirmed	not confirmed
Hypothesis 1 (wind in the UK 1990-2000)	confirmed to a large extent with comment	partly confirmed
Hypothesis 2 (wind in Spain 1980s-1994)	confirmed	confirmed
Hypothesis 2 (SHP in Spain 1980s-1994)	confirmed	confirmed
Tailor made Hypotheses 1/3 (biomass in Spain 1996-2001)	confirmed to a large extent	confirmed
Tailor made Hypothesis 3/4 (wind in Netherlands 1990-97)	confirmed to a large extent	confirmed 1990-1995, not confirmed with comment 1996-1997 (both Areas 3 and 4)
Hypothesis 4 (biomass: Spain 1980s-1995)	confirmed to large extent	could not be tested

Table 14.6 *The extent of confirmation of expectations regarding drivers to invest, project sizes and technological choice of developers*

Case study / Hypothesis	Drivers to invest	Project sizes	Technological choice
Hypothesis 1 wind in Spain	confirmed to large extent with comment	confirmed with comment	confirmed
Hypothesis 1 SHP in Spain	confirmed	cannot be tested (politically defined)	confirmed
Hypothesis 1 wind in the UK	confirmed	confirmed	partly confirmed
Hypothesis 2 wind in Spain	partly confirmed	partly confirmed	not confirmed
Hypothesis 2 SHP in Spain	not confirmed	cannot be tested (politically defined)	confirmed
Hypothesis 4 Biomass in Spain	confirmed to large extent	confirmed	confirmed
Hypothesis 3/4 wind in Netherlands 1990-1897	partly confirmed	confirmed	confirmed
Hypotheses 3/1 biomass in Spain 1996-2001	confirmed to large extent	confirmed	confirmed

The factors mentioned in Table 14.7 can be divided in four groups according to their role[3]:

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[3] In Chapter 3 we proposed a series of probabilistic relations among the forms of the five indicators for diffusion patterns. We considered as core indicators the types of developers and the type of financing schemes. It was argued that as they change, the forms of the other three indicators can also change in certain ways. But Table 14.7 only refers to the indicators likely to be directly influenced by exogenous factors, and does not include possible indirect influences.

A. a small set of factors that appear to *more systematically affect the forms* of individual indicators of diffusion patterns across case studies; these were marked on upper grey area in Table 14.7 (the first six factors mentioned);
B. a set of factors that affect *mainly the extent* to which the forms of one or more predicted indicators appear, influencing this way sometimes also the rate of installed capacity increase, or factors influencing directly only the investment interest of economic actors and financing agents towards higher or lower *rate of installed capacity increase*; these are all the factors for which a sign (X, Y or Z) was placed under 'installed capacity'; the empirical results regarding installed capacity increase are mentioned in Table 14.8;
C. a set of factors that act in the form of improving *the framework for certain forms* of indicators to be observed; or - on the contrary - they add to small extent to the creation of a framework that does not stimulate certain forms of indicators to emerge or to be observed to larger extent; we assess that from theoretical standpoint their action is not significant; these factors were marked in lower grey area in Table 14.7;
D. a set of factors that represent direct or indirect *governmental intervention* with diffusion patterns; these are mentioned in the last three rows of Table 14.7.

All these factors may be important from policy design point of view, to improve the effectiveness of support systems. We address the issue of policy lessons in Section 14.3. From theoretical standpoint, the virtue of having an as lean as possible theoretical explanation is as such very important.

Considering the generally satisfactory degree of explanation of the observed diffusion patterns with just two independent variables supports the argument to concentrate on them. But, notwithstanding this conclusion, it may be worthwhile to critically assess the exogenous factors. The first two sets of factors (A) and (B) are more interesting to look at[4]. The following paragraphs discuss the possibility to include (some of) them in an adjusted theoretical framework.

Group A - exogenous factors and alternative specifications

In Chapter 10 - while summarising the main empirical findings for the six case studies in Spain - we mentioned that several exogenous factors were found to affect the forms of three indicators in similar ways. These indicators were: drivers to invest, types of developers, and project sizes. Among the factors named in Chapter 10 there were *the first four factors* also listed in group A of Table 14.7 (on upper grey area). These four variables affected the three indicators towards the absence / poor presence of the same forms: small developers, (partly-)self-generation projects and small size projects. The case study on wind diffusion in England and Wales also observed the poor presence of small developers and (partly-)self-generation plants[5] due to the same four factors[6].

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[4] The very last row represents direct action on diffusion patterns, which we theoretically assumed in Section 2.5 not to happen. In empirical research we observed how in Spain the government attempted to compensate by means of special policy support mechanisms for the market entry difficulties for small developers, self-generation plants and small size projects.

[5] Special calls for tenders were organised for the technological band of small size wind projects in order to enable investments in small plants which were not economically feasible under the price convergence policy (see Chapter 13).

[6] See the simultaneous presence of signs X and Z in Table 14.7 for the indicators types of developers, drivers to invest and project sizes. In Spain, and England and Wales the four exogenous factors influenced the three diffusion indicators in the same way.

Table 14.7 *Exogenous factors affecting the forms of diffusion patterns and alternative specifications*

Exogenous factors and alternative specifications	types of developers	financing schemes	drivers invest	project sizes	technology choice	Capacity increase
entrepreneurship small developers: new technology and level of risk acceptability	**XYZ**					**XY**
interest in environmental performance / green image concerns of potential developers	**XYZ**		**XYZ**			**XY**
requirements on project sizes by banks and developers				**XZ**		
banks' preference for loans to large/utility developers	**XZ**					
stage technical development			**X**	**X**	**X**	**X**
technology characteristics: size / complexity / expensiveness	**X**		**X**	**X**		
local social opposition	**X**	**X**	**X**	**X**	**X**	**XYZ**
administrative approval projects: requirements and procedures	**X**		**X**	**X**	**XY**	**XYZ**
competition from other types resources / technologies		**X**				**X**
(perceptions on) [economical] resource potential, by banks and large corporations	**X**	**X**				**X**
regulation on profitability of electricity companies/ utilities	**Y**					**Y**
voluntary agreements developers-government	**Y**		**Y**			**Y**
business culture: impact of opinion-makers on financing agents & large developers		**X**				**X**
perception on the stage of technical development		**Y**				**XY**
market expectations short term						**Y**
institutional framework for stock investments by individuals	**Z**					
subsidy interpretation by banks: equity or loan contribution	**XY**					
ownership connection manufacturers-developers		**X**			**X**	
business culture of large corporations (joints ventures with small developers)	**Z**					
business interests of regional authorities as (co-)owners	**X**	**X**				
business interests of banks as (co-)owners	**X**					
interest of banks in green investments		**Y**				
impact design support system	**Z**					
Governmental R&D support for national manufacturers					**X Y**	
Governmental intervention in diffusion patterns	**X**	**XY**	**X**	**XZ**	**X**	

However, in the case study of wind diffusion in the Netherlands we observed that the indicators drivers to invest and types of developers were affected by the same four factors but in a completely different way. In the Netherlands, the high level of entrepreneurship among many types of economic actors, but especially among small developers, combined with the interest in environmentally friendly and green image investments led to unexpected high market presence of small developers and commercial projects[7]. This was helped by the fact that banks did not have requirements to approve loans on large size projects. On the contrary, very small projects and single turbine projects could be financed easily based on project financing schemes (after the Green Funds scheme became available). Besides, banks are open and flexible in negotiating loans with small developers and individuals in the Netherlands, while in Spain and the United Kingdom banks prefer to give loans for projects developed by large/utility developers[8]. Consequently, as regards the first four factors mentioned in Table 14.7, we would not argue in favour of their uptake as independent variables in the theoretical framework and hypotheses, because our research obtained mixed results regarding their impact.

Further, as regards the factor of ‘stage of technical development’, this appeared to influence the drivers to invest, project sizes and technological choice in some case studies. We observed this influence to be additional to that exerted by the risk-profitability levels in the support system. Its influence seems however to be methodological and related to the operationalisation of the last two indicators. In Section 2.6.2 (see Figure 2.8) we focused the theoretical framework on the technologies attempting the market progress from the stage of first commercial availability to that of technical and commercial maturity. In some of the selected empirical case studies, however, the support system was already available (and its impacts studied) when the technology or designs of it were still (also) in the demonstration stage. Besides, we considered in Section 2.6.2 that as the innovation processes continues, new technological designs are passed from the demonstration stage to initial commercial availability while other designs of the same technology already enjoy a large extend of market adoption. In testing the theoretical expectations for wind technology and biomass technologies, we observed the impact of the innovation process and of the transition between market stages, on the forms of diffusion patterns. In addition, we mentioned in Chapters 4 and 5 that the operationalisation of the indicator ‘project sizes’ - and consequently of installed capacity increase - needs to be seen flexibly due to changes in the stages of technical development.

Finally, we also mentioned in the group of core explanatory factors that of ‘technology characteristics: size/complexity/expensiveness’. This emerged to have a *potential* impact on diffusion patterns only in the case of biomass technology (hence not systematically present across case studies), next to the influence of independent variables. However, we mentioned it

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[7] To remind: in this case study investments in self-generation projects by small and medium size production companies did not appear due to the exogenous factor ‘voluntary agreements developers-government’. The rest of the types of economic actors included in the small developers group appear interested only in commercial projects.

[8] As it can be seen in Table 14.7, there is no sign Y for the third and fourth rows of exogenous factors. Therefore, these two factors actually helped investments by small developers, in small size plants, and for more commercial projects than normally expected under minimal investment contexts (Area 4). For the first two factors mentioned in the table, the sign Y was placed below the indicator ‘installed capacity’ because the two factors contributed also to a large interest to invest than expected as short-medium term effectiveness of the support system. But in the case of biomass in Spain since 1995, when small developers were expected to be seen it was observed a decreasing presence of them as compared to the previous period when a minimal investment context existed. For this reason we also played the sign X below the indicator ‘installed capacity’.

in the core-group because its role is important in our theory. Renewable energy technologies are not a homogenous group of technologies. If their technical particularities have impacts with regard to who may be able to adopt, finance and operate them, and for what project sizes, then it is important to know per type of technology to what extent this may happen. This is because technology particularities may lead to a situation where whatever the risk-profitability profile of the support system, diffusion patterns would be highly similar.

So far, our empirical research regarding biomass technology diffusion has actually a good extent of confirmation for the two case studies (see the forms of diffusion indicators in Tables 14.5 and 14.6). But there are reasons to believe - technical literature and empirical observations - that for some renewable technologies, including biomass, diffusion patterns may not be as differentiated as theoretically predicted in the four risk-profitability investment contexts. New forms of renewable resources are being explored and demonstrated, some of which are likely to pose serious challenges for diffusion patterns *diversity* as biomass electricity technologies. Examples of such technologies, so far, are ocean wave and tidal power technologies[9]. Consequently, we assume that this exogenous factor may be the most serious challenge for the validity of theory, in the sense that for some types of technologies - with low potential for modularity (or divisibility) and high technical complexity - it may not apply.

Group B - exogenous factors and alternative specifications

We placed in group B all those factors in Table 14.7 which influence both diffusion patterns and the rate of installed capacity increase, in addition to the influence observed to be played by the risk-profitability profile of the support system. Of these factors, the most pervasive influence appeared to be exerted by local social opposition and the administrative criteria and procedures for the approval of projects. In Section 2.5, we made the assumption that no obstacles such as local-social or administrative approval would impede investors' decisions to implement investment plans[10]. This was motivated by the fact that these factors may have taken too different forms in different national contexts, being also strongly technology specific. Our empirical case studies confirmed this argument, which strengthens the idea that the incorporation of these two exogenous factors in a theory regarding the diffusion impacts of economic-policy support systems makes little sense.

As regards the role of the other factors we have the following comments. When they are present they may indeed lead to 'deviations' from some of the predicted diffusion patterns; in some cases they may also substantially affect the rate of installed capacity increase, as we observed in three case studies (see Table 14.8). However, the *forms* of some of these factors cannot be the same easily specified and modelled in theoretical predictions, as the nature of these factors may be spelled out. Here we have in mind all factors not mentioned so far in group B: perception on the stage of technical development; (perceptions on) [economical] resource potential by banks and large corporations; competition from other types resources/technologies; regulation on profitability of electricity companies/utilities; business

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[10] The later factor may influence diffusion both positively and negatively. The positive influence may be for example by means of increasing the diversity in types of developers, the availability of financial resources underlying diffusion, the adoption of diffusion-optimal technology designs, and higher rates of installed capacity increase. This was observed in the case of wind diffusion in Spain since 1995. But it can also influence diffusion negatively by - perhaps unawearingly placing obstacles for the use of project financing schemes and diversity in the types of developers preserving interest to invest as the times goes by, as we observed in the case study of small hydropower diffusion in Spain since 1995.

culture: impact of opinion-makers on financing agents and large developers; voluntary agreements between potential developers and the government.

Consequently, since we doubt the potential for theoretical specification of the forms of these factors, we also doubt the feasibility of their incorporation in a theory regarding support systems' impacts on diffusion. Besides, such an attempt would come at the costs of parsimony. We developed a theory with four scenarios for diffusion patterns, and six scenarios of prospects for diffusion sustainability. The introduction of six or more factors, each of which may take numerous forms, may lead to countless scenarios.

Final remarks on the explanatory power for diffusion patterns

The conclusion on the validity of theory 1 answering research questions 5 and 6 (see Figure 2.6, Chapter 2) is the following. Overall, in spite of the influence of exogenous factors, empirical findings support the theoretical argument that the risk-profitability characteristics of economic-policy support systems influence the patterns by which a technology diffuses. Theoretical analyses suggested there are *significant differences* in diffusion patterns among the four investment contexts analytically differentiated. The empirically observed patterns *match to a satisfactory extent* those theoretically predicted, showing that there are indeed significant differences among the diffusion patterns in different risk-profitability contexts. Table 14.4 summarises the extent of confirmation per risk-profitability investment context. But the argument of satisfactory explanatory power can also be supported by looking at the extent of confirmation of expectations per type of indicator. We conducted eight empirical case studies, observing that (see Tables 14.5 and 14.6):

- for the indicator types of developers, theoretical expectations were three times 'confirmed', and five times 'confirmed to large extent';
- for the indicator drivers to invest, theoretical expectations were two times 'confirmed', and three times 'confirmed to large extent';
- for the indicator project sizes, theoretical expectations were five times 'confirmed', from a set of only six case studies where this could be tested;
- for the indicator types of financing schemes, theoretical expectations were five times 'confirmed', from a set of seven case studies where this could be tested;
- for the indicator technological design, the theoretical expectations were six times 'confirmed'.

From the situations[11] of 'non-confirmation' and 'partly confirmation' we distinguish:

- situations where exogenous factors played a role (see discussions above), and
- situations that learnt us something that may be feasible to incorporate in theory specification.

In the second category, the following comments need to be made. Firstly, regarding the types of financing schemes and technological designs in optimal investment contexts: when support systems enable only 'high' profitability, while key economic actors and financing agents have 'very high' profitability requirements, the forms of these two indicators may change towards the dominance of internal financing schemes and lack of interest in diffusion-optimal technological designs. These may have negative impacts on the prospects for long term continuity of diffusion processes, when the technically available resources cannot be fully

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[11] By 'situation' me mean testing the expectation for one indicator in one case study (or one cell in Tables 14.5 or 14.6).

exploited due to shortage of financial resources. Consequently, when the profitability characteristic is operationalised as we did - we cannot *always* say that optimal investment contexts have good prospects for sustainability of diffusion processes.

Secondly - referring in general to all situations of 'non-confirmation' and 'partly confirmation', *as well as* those with 'confirmation to large extent' - the following observation is important from theory specification standpoint. Beside the action of the factors mentioned in Table 14.7, the poor presence of small developers and (partly-)self-generation projects may be also explained by *the novelty of this investment option for non-utility economic actors*. National electricity industries have been for many decades under the monopoly of one or several energy utilities. Electricity supply was a service - not a commercial activity opened for any economic actors. A significant market entry of (smaller) independent power producers and self-generators may take a long time. The electricity generation business is a technically complex and cash-intensive economic activity, even for modular technologies such as wind systems. So far empirical evidence suggests that when new companies enter the business sector, the commercial generation of electricity is preferred to that of (partly-)self-generation activity. In our case studies it appeared that whenever (the prospect for) profitability increases, many non-energy-core developers switch to/enter the market with solely-profit motivated projects.

The market presence of small developers and (partly-)self-generation plants may be time-variables, related to the relative novelty of investment opportunities in power plants. Our empirical research focused on the 1990s, which was the decade of start-up with electricity industry liberalisation. But empirical research for the decade starting with 2000 may show increasing presence of small developers and plants serving self-generation purposes. A series of barriers are still active that discourage the market presence of smaller developers, such as those categorised in group C of factors (lower grey area in Table 14.7). But these may be overcome by special policy intervention to stimulate such investments[12] and, perhaps, also endogenous increase in the investment interest. More emperical research would be necessary with regard to the attitude of this potential group of economic actors vis-à-vis renewable energy investments when liberalisation has consolidated in a couple of years.

14.2.2.2 Diffusion results

Empirical research suggests an *overall satisfactory explanatory power* for the influence of independent variables - risks and profitability from support systems - on the rate of installed capacity increase in short-medium term, and for the development of national industrial basis and dynamics. However, the extent of socio-economic benefits from diffusion did not appear to be in the hypothesised relationship with the type of risk-profitability investment contexts. Table 14.8 presents the results for the extent of confirmation of theoretical expectations regarding diffusion results.

We conducted eight empirical case studies, observing that:

- for the indicator installed capacity increase (also measured as proposed capacity), the theoretical expectations were five times 'confirmed';

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[12] The case study for wind technology in Spain suggested that when (since 1998) special policy support mechanisms stimulate small developers and self-generation plants, these brought results and interest to invest has increased.

- for the indicator industrial basis and dynamics, theoretical expectations were also five times ‘confirmed’ (of which four times in the same case studies as capacity increase) and one time ‘confirmed to large extent’;
- for the indicator socio-economic benefits, theoretical expectations were two times ‘confirmed’, and one time ‘confirmed to large extent’.

Table 14.8 *The extent of confirmation of theoretical expectations regarding diffusion results*

Case study / Hypothesis	Installed capacity	Socio-economic benefits	Industrial basis
Hypothesis 1 wind in Spain, since 1995	confirmed	confirmed	confirmed
Hypothesis 1 SHP in Spain, since 1995	confirmed	not confirmed	confirmed
Hypothesis 1 wind in the UK, 1990-2000	confirmed	not confirmed	confirmed
Hypothesis 2 wind in Spain, up to 1994	not confirmed	not confirmed	confirmed
Hypothesis 2 SHP in Spain, up to 1994	confirmed	not confirmed	partly confirmed
Hypothesis 4, biomass in Spain up to 1994	confirmed	confirmed	confirmed
Hypothesis 3/4 wind in Netherlands, 1990-1897	not confirmed	confirmed to large extent	not confirmed
Hypotheses 3/1 biomass in Spain, 1996-2001	partly confirmed	partly confirmed	confirmed to large extent

Empirical findings lead to several main observations from the standpoint of theory formulation. Firstly, there were five situations of non-confirmation for the indicator socio-economic benefits. In the two cases regarding small hydropower, we already observed in Chapter 9 that the small-sizeness of investments does not facilitate indirect local social benefits from this technology. In the same time, in the case-study of biomass in Spain, 1996-2001, we observed how commercial investments in biomass tend to generate very fast significant local economic benefits[13]. In the two case studies regarding wind energy (in the UK and in Spain) the ranges of profitability was ‘high’/‘very high’, while in both cases the expectations regarding the extent of indirect local economic benefits were not confirmed[14]. Based on these observations, two conclusions can be drawn:

- indirect local economic benefits are to a large extent technology-specific emerging from the technical characteristics of the technology or its resource features; hence for some types of technologies such kind of benefits may be realised - for others not;
- for technologies that may in principle enable indirect local economic benefits (such as wind and biomass-based) we cannot always say that high/very high profitability for projects would lead to this kind of benefits to be indeed realised.

In addition to these, we also observed that diffusion may not lead to institutional investments, that is stock investments by individuals/households and other economic actors, unless special

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[13] Biomass attracts high local indirect benefits in relation to resource (cultivation) collection and/or preparation. As a rule of thumb empirical literature often mention a range of 40 km of resource collection space for a profitable biomass power plant.

[14] We observed how in the UK a policy towards such benefits was only started by large developers after one decade of diffusion.

fiscal measures are applied to stimulate this. When they were present, however, in the case study on wind diffusion in the Netherlands, no political influence was observed from this group of investors. Very dispersed small stakeholders without a certain representation agent may have very limited influence on policy making and price support.

Consequently, we see sufficient reason to eliminate the indicator(s) of socio-economic benefits from diffusion results, since the risk-profitability context has a poor explanatory power for this. The stakeholder group of industry and owners appeared in our empirical research to have a good potential to exert political lobby when support systems result in optimal investment contexts. We noticed this in the case studies of wind in Spain and in the United Kingdom. *Therefore, we see it appropriate to restrict the theoretical discussion about political lobby potential to the industry size and dynamics indicators*.

Secondly, looking at empirical findings per investment context, it can be observed that a poor explanatory power appeared in entrepreneurial investment context (Hypothesis 2). In the case study of wind technology in Spain up to 1994 this was a consequence of the 'partly satisfactory' confirmation of expectations on diffusion patterns. However, looking at Table 14.4 the expectations regarding diffusion patterns of small hydropower in Spain up to 1994 were assessed to have an overall 'good' confirmation[15]. We explain the contrast with the 'partly confirmation' of expectations on industrial basis and dynamics from the perspective of local social and administrative approval obstacles. The rate of annual capacity growth was too slow, which did not help the expansion of the industrial basis for technology manufacturing and support services.

The same situation - of 'good' confirmation of diffusion patterns - was observed for the case study of biomass in Spain since 1995. But in this case study, the limited governmental price support combined with institutional obstacles for the creation of a market for biomass energy resources were the key factors leading to a low rate of market growth and an overall lower investment interest (see Chapter 8 for other exogenous factors). These case studies suggest that inducing certain diffusion patterns does not always lead to the obtainment of the operationalised effectiveness of support systems, when:

- exogenous factors affect investment interest to be implemented, and when
- the resource potential economically feasible with the respective price support is small.

In Chapter 2 we explained that the national potential of any renewable resource can be roughly divided into:

1) not technically feasible;
2) technically feasible but not economically feasible given the applicable support system;
3) both technically and economically feasible - given the support system; and
4) cost-competitive without any form of support instruments.

When the governmental price support allows only a small share of the available potential to be shifted from group (2) to group (3), even if the profitability range expands towards the 'high' range, the economically feasible resource potential may only lead to a small capacity increase in terms of MW installed. Therefore, an important lesson from the case study on biomass in Spain since 1995 is that *the operationalisation of the dependent variable of support system effectiveness cannot be generalised. The operationalisation of support system effectiveness in*

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[15] The non-confirmation of the expectation for drivers to invest was due to the very large presence of commercial projects, which should have contributed to improvements in socio-economic benefits and industrial basis.

the form of - small, modest, large - capacity increase needs to be seen as relative to (or implicit for the) national economically feasible resource potential (group 3). Alternatively, this can also be referred to as *the rate of exploitation of economically feasible resources under the respective support system*.

This lesson is strengthened by the empirical case studies on wind energy in the Netherlands and in Spain (also valid for UK). While in Netherlands the maximum on-land installed capacity was assessed as somewhere in the range 1500-2250 MW due to siting constraints, in Spain this was assessed as around 15100 MW (with 1998 technology). Therefore, when making international comparisons of support system effectiveness it is important to take into account the national economically feasible resource potential, defined by the extent of price support.

The following conclusions may be formulated from the standpoint of validity of theory answering research question seven.

I. The risk-profitability characteristics of the support system appear to have an *overall satisfactory explanatory power* with regard to the effectiveness of support systems in short medium term. The high effectiveness of optimal investment contexts was confirmed in three case studies, while the ineffectiveness of minimal investment contexts was confirmed in one case study. More research may be necessary however with regard to entrepreneurial and political investment contexts. Hypothesis 2 was confirmed in one case study. But in a second case-study this was not confirmed. The strongest exogenous factor was the perceived stage of technical development by potential developers and financing agents. Hence, more case studies would be desirable for technologies already perceived as commercially sound. Also, more case studies would be necessary to get a better understanding on the effectiveness of support systems resulting in political investment contexts.
II. The operationalisation of the dependent variable of support system effectiveness cannot be generalised.
III. The analysis of the prospects for the sustainability of market diffusion processes from the perspective of national technological embeddness (see Figure 2.10, Chapter 2) may be theoretically restricted to the analysis of the size of industrial basis and dynamics. The risk-profitability investment contexts did not appear to have a satisfactory explanatory power regarding the extent of socio-economic benefits from diffusion.
IV. As regards the size of national industrial basis and dynamics, the independent variables appeared to have an *overall satisfactory explanatory power* for the observed empirical results.

The following section summarises the main findings with regard to the empirically observed evolution of cost and technical performances - for the three technologies in three national contexts - and makes some final considerations on research questions 2 and 3.

14.2.3 Research questions 3 and 4 - cost and technical performances

We formulated research questions three and four as follows:

3. To what extent can support systems influence the cost-performances of renewable electricity technologies?
4. What aspects of technical performances could improve the prospects for long-term sustainability of diffusion processes?

In Chapter 2 we explained that production costs of renewable electricity, expressed as costs/kWh, are influenced by many factors that can be grouped into four categories. It was discussed that the likely way these factors would change as diffusion progresses in time is: decrease in technology specific costs and in the quality and availability of resources; increase in technology complementary costs, and likely sinuous evolution in the context induced costs (see Table 2.8 in Chapter 2). We argued that regarding production costs per kWh the only theoretical statement that can be made is that they will change from (very) high levels to *a range of costs* that can be very wide, and perhaps not always reaching cost competitiveness with its lower end. We argued in Chapter 2 that the relationship between cost performances, resource availability and technical performances with regard to diffusion expansion potential is very tight, resource-specific and country-specific. For different types of resources, different types of technical performances might be needed to enable the expansion of installed capacity.

The evolution in cost performances was analysed empirically, in relation to the country specific (remaining) available resource potential, and the technical performances of technologies. In this section we summarise and discuss empirical findings regarding changes in the four categories of factors affecting production costs and the resulting range of production costs after short medium term of diffusion. These are summarised in Tables 14.9 and 14.10. In Chapter 4 we answered research question four, for the three renewable technologies for which we conducted empirical research. Drawing on technical literature we explained which aspects of technical performances may help expand the market share in the long term of the renewable resource used by the respective technology. In this section, we also review the main empirical findings regarding technical performances. These were assessed in terms of industry level impact of one indicator of diffusion patterns - market choice of technological designs.

14.2.3.1 Cost performances

Empirical research confirms the theoretical trend we formulated in Chapter 2 with regard to the evolution of cost performances. To large extent, the trends for the evolution of cost components in the four categories of cost factors were also confirmed.

The evolution of cost performances for wind technology in Spain, the United Kingdom and the Netherlands during the 1990s shows that (as anticipated):

- by 2000, production costs spread over wide ranges in each country;
- the production cost range was wide in all countries; however, the lower end of cost’ range reached competitiveness with conventional technologies only in Spain and the United Kingdom; in the Netherlands wind resources are lower while the support system did not stimulate competition in manufacturing and in the support service industrial sector;

Table 14.9 *The cost performances of wind technology in the UK, Netherlands and Spain*

Cost factors 1990-2000	wind technology in Spain, 1990 - 2000	wind technology in the UK, 1990 - 2000	wind in Netherlands 1990 - 2000
technology specific costs (factory costs per kW)	33 % reduction (in 1990: ~ 950 €/kW; in 2000: 630 €/kW)	24 % reduction (in 1990: ~ 1000 - 950 €/kW; in 2000: 650 €/kW)	33 %reduction; (in 1990: ~ 1100 €/kW; in 2000: 730 €/kW)
technology-complementary costs	increasing slowly	not clear	decrease
context induced costs	fast increase since 1995	high sinuous evolution	decrease
quality resource feasible with 2000 price support	wind speeds > 6 m/s mostly 4,2 - 6,6 €c/kWh	wind speeds > 6,5 m/s, mostly 3,8 - 7,2 €c/kWh (NFFO-3,4,5)	wind speeds > 7 m/s, mostly 5 - 8,5 €c/kWh, up to 9,7 €c/kWh
lowest production costs/kWh in 2000	3,6-4,2 €c/kWh at wind speeds 9-10 m/s	3,8 - 4,3 €c/kWh, at wind speeds 9-10 m/s	5 €c/kWh at wind speeds > 9 m/s
coal-based electricity	~ 4 €c/kWh	4 - 5,2 €c/kWh	~ 4 €c/kWh

As regard the small hydropower and biomass technologies data on cost ranges were not available. However for small hydropower it was assessed that the remaining potential for cost reduction was low, while cost-competitiveness was still not reached. For biomass the cost range is very large, since biomass resources come at largely different and sometimes also very high costs (see Chapter 8).

Table 14.10 *Cost performances of biomass and small hydropower technologies in Spain*

Evolution cost sources	SHP in Spain, 1980s-2000	biomass in Spain 1980s-2001
technology specific	small decrease	small decrease
technology-complementary	(very high levels) small decrease	on the increase since 1999
context induced	increasing	little change
quality / price resource exploited	decreasing	resource costs increase
lowest (per kWh) production costs	not available (~ 5 €c/kWh)	3-4 €c/kWh biogas 5,2 €c/kWh for conventional technology

As regards t*echnology specific* factors, the empirical findings summarised in Tables 14.8 and 14.9 show a decrease of factory costs per kilowatt during the 1990s. The sharpest decrease was registered for wind technology. In Spain and the United Kingdom where optimal investment contexts were implemented, they reached lower levels than in the Netherlands. This can be explained by the fact that the high interest to invest created by the support systems in Spain and the UK led to intensive competition among manufacturers[16]. In the case of small hydropower, technology specific costs lowered only to a small extent because there was little potential for improvement left. In the case of biomass electricity, the support systems put in place in Spain were not attractive for developers. Therefore, in the empirical cases studied in this thesis, reductions in technology specific costs and improvements in technical parameters led to a decrease in production costs. But this happened at different rates depending on the attractiveness of the support system used, and the particularities of the supported technology.

In the category of *technology complementary factors*, costs increased for wind technology in Spain. They started to slowly increase also in the case of biomass electricity plants in Spain, especially since 1998/1999, as clean biomass resources have begun to be employed. For small hydropower plants, technology complementary costs decreased slightly because new opportunities emerged to improve plant design and use lighter and cheaper construction materials[17]. For the case of wind investments in the United Kingdom we could not find empirical information, while for the Dutch case a small decrease was actually signalled.

Context induced costs had, as expected, a mixed evolution in the three countries and for the three technologies studied. In the first two segments differentiated in this category - the monetary consequences of financing and trade arrangements, and the increasing competition in the industrial basis for projects' life cycle services, contributed to the decrease of the weight of this category in the production costs for wind technology in Spain and the United Kingdom, and for small hydropower in Spain. However in the United Kingdom bank fees and legal costs remained high due to the tough competition for contracts' allocation. For biomass electricity

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[16] In Spain, the entrance of foreign manufacturers in the second part of the 1990s increased competition to supply low cost technology. In the UK the price convergence policy and the business requirement of large developers to maintain high equity returns led to the hunt for the cheapest technology from abroad.

[17] The expensiveness of small hydropower technology comes mainly from technology complementary factors, where the remaining cost reduction potential is also small.

plants in Spain no cost decrease was observed in these two cost segments by 2000, since banks approving project finance still saw such investments risky and the industrial basis was not sufficiently developed.

As regards the third segment of context induced costs - comprising factors related to administrative and local social consent - a fast and substantial increase in costs was observed for wind and small hydropower technologies in Spain and wind in the United Kingdom. Combined with the continuation of high legal and bank costs for project preparation, the overall context induced costs were high (see also Table 14.12) and had a sinuous evolution during the 1990s for wind technology in the United Kingdom. In the case studies of wind technology in the Netherlands and biomass plants in Spain no significant changes were observed in the context-induced costs categories. This can be explained by the small installed capacity increase realised in both cases by 2000. Finally in the case of small hydropower in Spain, costs increases were observed in this segment due to the very long delays in administrative approval and due to the fact that local consent required numerous and expensive feasibility studies, especially for environmental impacts.

Finally, as regards *resource quality and availability*, developments by 2000 already signalled the need for price support increase in order to expand the installed capacity of resources studied. As regards wind technology in our empirical case studies, three situations of cost performances could be described in 2000. Firstly, there was a limited potential of wind energy that could be exploited without any form of financial support. Table 14.8 shows that in Spain and in the UK the lower end of the range of wind electricity production costs reached the level of 4 €c/kWh. This is the average market price for electricity in the two countries and also the cost of coal based electricity. But such low production costs require wind speeds above 9-10 m/s. Wind speeds could also be lower, for example 7,5-8 m/s but in this case one has to minimise costs in all remaining three categories of factors. High wind speed sites are to a larger extent available in the United Kingdom but only to a small extent available in Spain.

The second situation on cost performances distinguished was the possibility to exploit *some part of the resource potential* based on the price support available in 2000. The Spanish support system enabled the exploitation of sites with wind speeds above 6 m/s. In the Netherlands projects were economically feasible mainly for more than 7 m/s wind speed sites, while in the UK the price convergence policy crowded most projects in sites with more than 8 m/s (under the NFFO contracts). It was however possible with NFFO 3 contracts to invest also at sites with 7 m/s. But this does not mean that all available sites with such wind speeds are automatically also economically feasible. Various factors in the technology-complementary and context- induced categories might bring too high costs even in these sites.

The third situation on cost performances was when the extent of financial support did not make sites economically feasible. In the United Kingdom and Spain, the sites where wind electricity generation costs are above 6,5-7 €c/kWh could not be economically exploited in 2000 with the available price support. In the Netherlands this border was around 8,5 €c/kWh. But wind speeds and annual availability is lower in the Netherlands than in Spain, which is in turn lower than in the UK.

In terms of the relationship wind plants *capacity increase - production costs* the situation on costs performances in 2000/2 suggests that sustained governmental price support will be needed in the long term for a meaningful diffusion. The Dutch government aims to raise the on-land installed capacity from 450 MW in 2000, to 1500 MW in 2010. However, the available potential considered feasible from location standpoint is between 2100-2250 MW. To realise at least the target, diffusion will have to take place also inside the territory where wind speeds are below 7 m/s, and more often only between 5-6 m/s. If technology specific costs do not continue to decrease substantially, price support will have to increase the more wind speeds and annual availability lower. Similarly in Spain price increases are likely to be needed. Based on available data, we estimated that (counting from 1999) up to around 12.000 MW could be installed if a price support of 9 €c/kWh was available, and using current technologies. The new governmental target by 2011 is 13.000 MW, which is not likely to be realised without a price increase for the new plants. These increases need not be general, but site-specific, as already practised in Germany and France, in order to ensure that developers of difficult sites get sufficiently attractive profits, while developers of more attractive sites to not get windfall profits.

In the United Kingdom it was assessed that the on-shore wind resource potential is so large and of such good quality that basically all electricity consumption could be covered by wind electricity at prices below 16 €c/kWh. Studies suggest, however, that location restrictions limit the exploitable potential at around 17-20%. This is also the potential that, according to the government, could be absorbed in grid without major reinforcement works. There are estimations that 20% of the British land has wind speeds above 7 m/s. With the cost performances of 2000 these sites would need a sustained price support below 5,5 €c/kWh, only 1,5 €c/kWh above the average market price.

As concerns small hydropower technology, competitiveness of production costs was not reached. In future small cost reduction could still be registered, especially if context induced costs are deflated. But the lower end of the range of production costs is not likely to reach market price levels, because of the high role played by technology complementary costs (more than 50% in investment costs) and limited potential for reductions in the other cost components.

As regards biomass electricity generation in Spain, only organic waste resources and a limited amount of clean biomass resources could be economically feasibly exploited by 2001. The remaining potential was estimated at around 465 MW for organic wastes. For clean biomass no estimation was available but market experts consider that increases in price support of at least 2 €c/kWh are needed in order to make more plants profitable. This would allow the industry to grow sufficiently to induce reductions in technology specific costs and the other spin-offs expected.

In conclusion, empirical research suggests that technology specific costs may decrease more when support systems enable high levels of projects profitability, that is in optimal and entrepreneurial investment contexts. In lower profitability investment contexts the industrial basis is not sufficiently competitive to lead to substantial reduction in technology costs required by manufacturers. Besides, empirical research also confirmed that the rough directions of costs' evolution in the technology complementary and the context induced categories mentioned in Table 2.8 of Chapter 2 can be also observed in practice. Several empirical findings are different from the theoretically discussed directions because of reasons such as:

- small installed capacity increase and still small industrial basis, leading to lower (or lower rate of increase in) context induced costs;
- country specific conditions (small size country and good coverage of electricity grids); leading to lower (or lower rate of increase in) technology complementary costs;
- technology characteristics (long established but new opportunities for improvement) enabling reductions in technology complementary costs.

In addition it was also observed, as discussed in Chapter 2, that production costs span over a wide range that is influenced by an intertwine of natural resource potential and location, institutional factors affecting investment decisions and their implementation, and the characteristics of the economic policy support system. In the empirical cases studied, the remaining resource potential is very large for wind in the United Kingdom and in Spain, and for biomass in Spain. For wind on-shore in the Netherlands and for small hydropower in Spain it appears to be modest, by comparison. However, the analyses of cost performances in these case studies suggest that substantial diffusion requires sustained increase in governmental price support.

The issue of costs performance achievements is in the first instance an issue of technical improvements, economies of scale and learning, and spin-offs from market diffusion. But ultimately it is an issue of political decision on the extent to which the capacity increase and contribution of the respective resource in the national electricity supply is considered necessary or desirable. This may come to limited extent at the market price, or it may come to larger extent at a politically set and sustained price support.

14.2.3.2 Technical performances

Apart from the issue of the extent of price support, the sustainability of market diffusion processes depends in long term also on the technical performances of the technology in relation to the resource potential. The national potential of any renewable resource can be roughly divided into:

1) not technically feasible;
2) technically feasible but not economically feasible given the applicable support system;
3) both technically and economically feasible - given the support system; and
4) cost-competitive without any form of support instruments.

When the market-adopted technology designs result - at industry level - in the possibility to expand the technically feasible resource potential, we may say that a step has been made forward, towards the improvement of the prospects for sustainable diffusion. Diffusion-optimal designs take the technology from the category of ‘non-technically feasible’ (from the above classification) to the following categories. But also when technology designs manage to exploit the technically feasible resources at substantially higher efficiency, the prospects of sustainable diffusion improve - such as in the case of biomass gasification, since this may enable the increase in the potential market share of the respective renewable resource.

In Table 14.11 we summarize the answer to research question four that we gave in Chapter 4. There we discussed the issue of technical performances and selected a set of performances required for technology designs to be considered as diffusion-optimal. In empirical research, we analyzed the choice of technology design as one of the indicators for diffusion patterns. Aggregated at industry level, design choices define the technical performances of the respective technology.

In empirical research we observed that when support systems resulted in minimal and political investment contexts there was no concern for technologies with diffusion optimal features, as expected. In the two case studies for entrepreneurial investment contexts, the expectation to see a small extent of interest in diffusion optimal designs was not confirmed in one case, but confirmed in another case. The case of non-confirmation was strongly influenced by the early demonstration - commercial availability period in which wind technology was at that time.

When the support system covered the optimal investment context, some mixed results were obtained. Theoretically we expected in this situation that the adoption of new and/or existing technological designs with potential for substantial contribution to diffusion expansion is likely to be more frequent. This was observed in the case studies of biomass (since 1999), wind and small hydropower (since 1995) technology diffusion in Spain, but not in the case study of wind diffusion in the United Kingdom (see Table 14.12).

Table 14.11 *Renewable technologies and technical performances of 'diffusion-optimal' designs*

Renewable technology	Technical performances required for 'diffusion-optimal' designs[18]
Technologies for the use of wind energy	- grid-friendly and stand-alone-compatible application, - substantially high efficiency rates in transforming wind in electricity; - function in low wind speeds, below average annual levels of 5 m/s which are the dominant ranges across the globe.
Technologies for the use of small hydropower	- the ability to improve cost performances as compared to conventional technologies, especially the ability to bring improvements in the economic feasibility of exploiting sites with low water head; - the ability to bring substantial reductions in the environmental impacts, especially with regard to impacts created by civil works.
Technologies for the use of biomass energy resources in gasification processes	- enlarge the types of biomass resources that can be fed in at higher efficiency and lower costs for gas cleaning; - increase efficiency (potential still remaining), especially by means of increasing gas heating values; - improve the quality of gas (as resulting feedstock) and to reduce the atmospheric emission of these biomass plants; - reduction of investment and operation costs, especially small plants - improvements in integrating the gasifier in the power conversion system.
Biomass pyrolysis technologies	substantial improvements are needed to in the areas of bio-oil upgrading and reduction of production cost

In Spain, we observed the adoption in more than half of the wind installed capacity of a new technological design bringing substantial performance improvements from the grid friendliness perspective. Besides, we also observed that several companies were concerned with developing turbine designs able to operate efficiently in moderate wind speed regimes. Table 14.12 summarizes the conclusions for the three case-studies for wind energy regarding the country-specificity of diffusion-optimal designs (see Section 4.2). In Spain, the short-medium term priority - from the technical feasibility perspective - needs to go towards higher-efficiency and low-wind-speed technologies. The concern for these designs emerged among manufacturers and developers only recently (but not a priority on governmental agenda) with the exponential growth in wind energy capacity since 1998.

Table 14.12 *The relation resource potential - technology design priority - market adoption*

Wind energy	Resource potential	Technology design priority	Market adoption (in)	
Wind in the United Kingdom	net technically exploitable wind energy potential higher than the technically feasible grid-integration ceiling	need for priority for grid-friendly and higher-efficiency; possibly later need for low-wind-speed technologies	optimal investment context:	*no*
Wind in Spain	the technically feasible grid-integration ceiling higher than net technically (inland) exploitable wind potential	need for priority for higher-efficiency and low-wind-speed technologies		*R&D & demo recently*
Wind in Netherlands			minimal-political investment context: *no*	
Biomass in Spain	(no grid-integration constraints; for technical performances see Table 14.11)		minimal context: *no*	
			optimal context: *R&D demonstration recently*	
Small hydropower in Spain	(resource potential not very large; for technical performances see Table 14.11)		entrepreneurial and optimal contexts: *yes*	

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[18] In all cases technologies were also viewed as diffusion optimal when technical progress managed to make them cost-competitive with conventional electricity technologies.

Likewise, performance improvements were brought to the small hydropower and biomass technology designs adopted by investors in Spain when optimal investment contexts were present. These case studies confirm our underlying idea that when the perception exists that market diffusion potential is large, and when the profitability of projects is also sufficiently high, manufacturers and/or developers are more likely to invest in technological designs that reduce the obstacles of the respective technology, improving its prospects for market share expansion.

In the United Kingdom[19] financial support was not very generous for last three calls for tenders. Developers seem to have chosen for the lowest cost technologies in order to ensure they can maintain high profitability of projects, in the 8-12% range. Such levels are more in line with the business requirements of large companies.

Consequently, it may be argued that empirical evidence suggests that under entrepreneurial investment contexts when the support system enabled very high profitability levels more regularly, market concern for diffusion optimal technological designs emerges. This concerns increases under optimal investment contexts. Such designs are more able to expand the diffusion potential of the respective renewable resource from the perspective of technical performances.

14.2.4 Research question 2 - the sustainability of market diffusion processes

The second research question of the project was formulated as follows:

2. What are the preconditions for sustainable diffusion processes of renewable electricity technologies?

This question was theoretically addressed in Section 2.7. The view on the preconditions for and the perspectives of discussing the prospects for sustainability of market diffusion processes was summarised in Figure 2.10.

The availability of financing resources was seen as the motor putting into motion the dynamics of diffusion patterns and the national technology embeddness. If external financing schemes do not become available, diffusion may continue as long as the involved types of developers could internally finance capacity expansion. For this however, the accessibility to internal financing resources should match the available resource potential for diffusion to be sustained. Further, we argued that in order to understand if a process of market diffusion may be characterised by potential continuity, it is necessary to look at diffusion from the following three perspectives:

- cost performances in relation to available resource potential,
- technical performances in relation to available resource potential, and
- technology embeddness in the national socio-economic and industrial structure.

Theoretical expectations were only formulated with regard to socio-economic-industrial contexts and the availability of financing resources under different risk-profitability investment contexts. Regarding the availability of finance, the role of several intermediary factors was spelled out in hypotheses' formulation in the case when support systems result in

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[19] As explained in Chapter 13, the British government allowed for very high profitability of projects in the first two calls for tenders (1990 and 1991) in order to attract electricity companies in the renewables business. But beginning with 1994 the strong price convergence policy was introduced, putting pressure on projects' profitability.

entrepreneurial and political investment contexts. Cost and technical performances were only discussed empirically.

A large diversity in the types of developers and the large-scale availability of external financing schemes were considered as core preconditions for a sustainable diffusion. They were expected to lead to more pervasive socio-economic benefits and to a larger, more competitive and more politically influential industrial basis for the renewable technology supported. But, in addition, the likelihood of investment in larger size projects and the domination of commercial projects were also seen as contributing to the strengthening of the industrial basis and potential for political lobbying. Finally, the large scale adoption of diffusion-optimal technologies, also contributes to the sustainability of diffusion by means of increasing the level of technologically exploitable resource potential and its/or its integration in current electricity systems. We expected to observe these diffusion patterns under optimal investment contexts. The most favourable socio-economic-industrial context was hence considered to emerge from optimal investment contexts (Area 1).

When support systems result in entrepreneurial (Area 2) or political (Area 3), we hypothesised that socio-economic benefits would only be partial (see Table 14.3) compared to what could be possible under optimal contexts. Likewise, the industrial basis and dynamics would be more reduced as a support system changes its risk-profitability characteristics from Area 1 towards Area 4. These expectations were derived again by looking at the likely diffusion patterns. We took into consideration the influence of three intermediary factors on the long-term diffusion potential:

- the business culture of traditional financing community: with regard to risk-flexibility in the case of entrepreneurial investment contexts, and with regard to attitude towards small developers and flexibility in requirements for profitability of investments, in the case of political investment contexts;
- the level of entrepreneurship of small developers (political investment contexts), and
- the average levels of welfare among small developers (political investment contexts).

We considered that only when specific preconditions are met (see Chapter 3) could external financing schemes become available in long term. This could possibly also attract a larger diversity in types of developers interested to invest, and a change of the other diffusion patterns towards the forms expected under optimal investment contexts.

In Sections 14.2.2 and 14.2.3 we made an overview of the extent of confirmation of expectations on the types of financing schemes and on the features of the socio-economic-industrial contexts of diffusion, and we discussed the main empirical findings with regard to cost and technical performances. In Table 14.13 we bring together the empirically observed diffusion results whose analysis was considered appropriate in order to derive the prospects for the continuity of market diffusion processes. We marked with grey area the cases when the prospects were assessed as favourable or partly favourable to diffusion continuity from the analysed perspective.

The conclusion that can be drawn from our empirical research is that under support systems resulting in optimal investment contexts, the prospects for diffusion continuity are more favourable than under the other types of contexts. In the case of minimal investment contexts, prospects were gloomy from all four perspectives considered. As regards the entrepreneurial and political investment contexts, the results again are mixed. For some technologies prospects seem favourable from certain perspectives, while for others there are other diffusion perspectives that appear more favourable to diffusion continuity. Overall, the results in these two contexts indicate that it may be possible to achieve:

- sufficient availability of financial resources to sustain diffusion (3 case studies),

- modest industrial size and dynamics (2 case studies),
- modest socio-economic benefits from diffusion (2 case studies),, and
- large decrease in technology-specific costs (2 case studies).

Table 14.13 *Prospects of the sustainability of diffusion under different investment contexts*

Support system	Case study	Finance availability	Cost performances		Technical perform-ance	Industrial basis & dynamics	Social-economic benefits
			costs / kWh	factory costs			
Area 1	wind SP	favourable	partly favourable	large decrease	partly favourable	favourable	favourable
	wind UK	partly favourable	partly favourable	large decrease	not favourable	favourable	not favourable
	SHP, SP	favourable	partly favourable	small decrease	favourable	favourable	not favourable
Area 2	wind SP	not favourable	not favourable	large decrease	not favourable	partly favourable	not favourable
	SHP, SP	favourable	partly favourable	small decrease	partly favourable	not favourable	not favourable
Area 1/3	biomass	partly favourable	not favourable	small decrease	not favourable	partly favourable	partly favourable
Area 3/4	wind NL	favourable	not favourable	large decrease	not favourable	not favourable	favourable
Area 4	biomass	not favourable	not favourable	small decrease	not favourable	not favourable	not favourable

The next section formulates some policy lessons and recommendations emerging from the theoretical analyses and empirical findings in this study.

14.3 Policy lessons and recommendations

Based on the research carried out in this study we may argue that renewables policies that fail to recognise the importance of the profitability in support system design and the risks attached to it are by essence problematic. Profitability is a crucial driver for stimulating large developers to join the renewables market and lend their financial weight and influential presence to break through the economic and financing obstacles to diffusion.

The level of risks associated with the policy instruments and legal framework should also become a constant concern for policy design agenda. Providing for public financial support while introducing investment risks is a self-defeating approach. For governments to be more successful in designing support frameworks that are sustainable, policy makers need to pay more attention to the business requirements and business culture of domestic industry players, investors and financing agents - not only to the governmental economic advisers.

In this section, we specify first the policy lessons with regard to the reduction of economic and financing obstacles under different support systems. Further we formulate several suggestions with regard to the strategies for support system choice and change for market introduction and sustained diffusion. We conclude by making policy recommendations regarding the characteristics of support instruments.

14.3.1 Financing and economic obstacles: what may be expected from support systems?

The aim of any governmental policy for renewable energy should be to implement support system(s) that may enable at a certain moment sustained investments outside a trade-price protected niche. This assumes the long-lasting overcoming of economic and financing obstacles. The financing obstacle is generally considered as removed when non-recourse loans (project finance) become largely available - especially when they are accessible for a wide range of developers. The economic obstacle has to do with the production costs of renewable electricity. Its removal/presence is a more debated issue, because of the disagreement on whether the reference should be considered the average market/pool price, the conventional fuel electricity price, or the electricity price that internalises the environmental impacts of fossil fuels burning.

Based on the analytical approach taken in this study it may be argued regarding the prospects for overcoming the financing obstacle that:

- when a support system creates an optimal risk-profitability investment context, the financing obstacle is more likely to be over-passed (see Sections 9.3.1.3 and 13.6.4);
- in entrepreneurial investment contexts the large scale availability of project finance depends on the risk-flexibility of domestic financing agents; in countries where financing agents are not able to over-pass support system risks even when sufficient evidence from a good track record of diffusion becomes available, the financing obstacle may not be removed and the financial pool underpinning diffusion may remain limited to that of interested project developers;
- in political investment contexts, the financing obstacle may be overcome in later stages of diffusion but only when domestic financing agents generally operate with criteria that allows for lower profitability floors and are open towards doing business with small developers;
- in minimal investment contexts the financing obstacle will not be overcome at all.

The potential of support systems to overcome the ‘economic obstacle’ is less clear because this depends on the price reference taken. In our view, this is to some extent a political obstacle in nature, with economic effects (see Section 2.2). When overcoming the ‘economic obstacle’ means the achievement of production costs that are ‘competitive’ with conventional technologies subsidised for decades and not paying for their environmental impacts, it appears that no support system is able to do wonders. Our theoretical analysis in Section 2.8 and the empirical research summarised in Section 14.2.3.1 suggest that while under optimal investment contexts renewable technologies reach the required competitiveness, production costs still span over a wide range that expands far above the average market price. Large reductions in technology-specific (factory) costs of renewable technologies were already achieved and they were observed also in other types of investment contexts (see Table 14.13).

In Section 2.8 we argued that technology-specific costs should be taken as reference in analysing the progress in cost performances by renewable technologies, and not the production costs since they are influenced by many factors outside the scope of the renewable industry to optimise. Consequently, we cannot formulate an answer with regard to the question of ‘which support system is more effective in overcoming the economic obstacle?’. Ultimately, our belief is that only a politically sustained support system may enable renewables to increase their market share in electricity supply to significant levels, as long as the political nature of the economic obstacle of renewables is not addressed. A support system that incorporates a financial benefit from the carbon offset advantages of renewable resources may be part of the answer to the ‘economic obstacle’ provided that the carbon offset value is fairly financially priced. But the political echelon needs to be prepared: the sustainability of renewables diffusion may be to large extent dependent on the sustainability of political price support. When the question becomes ‘which support system may achieve faster improvements in cost performances?’, optimal investment contexts have higher chances for more speedy cost reductions. The comments made in Section 2.8 that in the long run costs may increase again with diffusion expansion remain applicable.

14.3.2 Strategies for support systems' choice and change

Departing from the idea that any support system may be represented in terms of investment risks and profitability, the policy questions may emerge as to 'which strategies should be followed for market introduction and for later stage diffusion?, and 'which are the consequences of using different types of support systems?'.

Our empirical research concluded that under support systems resulting in optimal investment contexts, the prospects for diffusion continuity are more favourable than under the other types of contexts. As regards the entrepreneurial and political investment contexts, diffusion results depend on the presence of certain circumstances in the national context (see sections 3.6.2 and 3.6.3). Using the same type of support system - that falls in one of these two types of investment contexts - good diffusion results and sustainable diffusion processes may be achieved in some countries and poor results may be yielded in other countries. But the results highly depend on the level of market diffusion already achieved by the type of support system introduction or change.

In the first stages of the market introduction, it is necessary to attract as many and as diverse as possible large developers and financing agents. This will put competitive pressure among manufacturers and industrial service suppliers, enabling the national industrial basis to grow faster and achieve cost and technical improvements. Competition in the industrial manufacturing and service support basis is much more important for renewable electricity than competition in the segment of renewable plant owners, because of the high initial investment costs of renewable technology. At later stages of diffusion, the role of small developers in diffusion needs also to be stimulated.

Nevertheless, to achieve socio-economic embeddnesss of renewable technologies, special policy support mechanisms may be needed to encourage small developers and self-generation and to make use of local business opportunities. It appears that when investment contexts are too attractive - optimal investment contexts - a series of factors emerge and converge towards keeping a (handful of) large project developers on the market. When the only policy goal is just installed capacity increase - that would be achieved. But when more is aimed at, such as wider social and economic benefits leaving only few large developers to invest may not reach that.

When the policy main aim is the market introduction of renewable technologies, support systems resulting in entrepreneurial investment contexts may take longer time to achieve their aim. They are more likely to be successful when in the respective national context, there is some flexibility in risk acceptability on the part of financing agents and large developers. However, financing agents appear often to be unwilling to simultaneously accept high risks from the support system and perceived high technology risks. The restricted availability of financial resources may result in a lower rhythm of installed capacity increase, with consequences for the opportunity of a domestic manufacturing and service industry to grow endogenously.

The implementation of a support system with a political investment context may also not lead to a rate of installed capacity growth that would enable fast technology cost reduction and the development of a reliable national industrial basis. Large developers would have a limited investment appetite. Small developers may be interested to invest but this depends on their financial strength and level of entrepreneurship with regard to new technologies and environmental friendly investments. When both are low, the rate of installed capacity may be insufficient for the spin-off required for sustainable diffusion.

Market introduction of renewable technologies should be best attempted by means of optimal support systems. The chances to raise wide investment interest are higher when technology introduction takes place by means of high profitability/low risks contexts. At later time a shift towards entrepreneurial or political contexts may be operated. Such a shift may take some project developers out of the market. But others may be willing to stay after making long term investment strategies in renewable energy. *A shifted route in support system may bring more types of economic and financing agents in the business of renewable energy, and more installed capacity, than a start up with a political or an entrepreneurial investment context.*

In principle, *we argue against the use of (very) high risk support systems at any time.* On the one hand, placing owners of renewable power plants in risky environments makes little sense because the variable costs of renewable electricity production are very low compared to the investment costs. *Risky investment contexts will do more damage than good to cost performances.* Perhaps incremental production cost reductions may be achieved by means of reductions in variable costs. But driving out the market entire groups of potential project owners may result in a less competitive manufacturing industry serving the domestic market, unable to achieve meaningful reductions in investment costs.

On the other hand, financing costs will considerably increase due to political and market risk premiums - when project financing is possible. Some project owners may also require higher equity returns for the additional investment risks taken. This results in higher social costs for the diffusion of one unit of renewable capacity, as compared to optimal investment contexts. These extra financial costs will have to be recovered from increased price support per kWh from consumers' bills (because profitability has to be maintained high/very high - or otherwise the system may degenerate in a minimal investment context). Besides, in conditions of high investment risks, investors prefer to contain risks by developing smaller size projects. These are notoriously more expensive both as investment costs per kW and production costs per kWh than large size projects. Therefore, high investment risks can only bring financial leakages. They place extra costs on consumers without benefiting to diffusion. In addition, more potential developers will remain outside the market leading to a lower rate of installed capacity increase. Therefore, *with the same amount of public financial support, more capacity increase may be achieved in optimal investment contexts than in entrepreneurial investment contexts. In the same time, the prospects of fast cost and technical performance improvements are higher.*

In conclusion, to achieve both socio-economic and industrial integration of renewable technologies, support systems should ideally start-up by attracting large developers and financing agents and be followed-up by the stimulation of small and local economic actors. This may imply a transition from an optimal investment context to a political investment context. A modest profitability/low-modest risk investment context is more desirable than a change towards an entrepreneurial investment context, from the perspective of social costs of diffusion. Besides, when the support system moves towards the entrepreneurial context, special policy support mechanisms need to be designed to enable market entry of a larger diversity of economic actors and investments in (partly-)self-generation plants towards a wider - and quite likely more long term oriented - integration of renewable technologies in the national context.

The inappropriateness of using high-risk investment contexts for the 'later diffusion' phase was illustrated in the case study regarding the market revival of small hydropower technology in Spain in the period 1980-1994. Our empirical analysis showed that in case market diffusion processes of a technology are unsustainable, i.e. no new investments are done for a longer period of time, the revival of market diffusion processes becomes almost as difficult as the market introduction of a new technology. *In the process of market revival the need to offer an economic-policy system with low risks and attractive levels of project profitability is the same important as in the process of the first market introduction of a completely new technology. Besides, obstacles to invest may re-emerge after a long period of diffusion stand-still.*

14.3.3 Policy recommendations regarding the characteristics of support instruments

Further policy lessons may be drawn both in relation to the theoretical framework and in relation to the exogenous factors. The following *core* policy lessons appear from our empirically-backed theoretical considerations. Awareness on the ranges of profitability that support system enable is necessary both in the phase of policy design and at the time of its fine tuning in later stages of diffusion. Policy makers should look at the business requirements of domestic economic actors - both financing agents and potential project developers - in terms of minimum project profitability or minimum equity returns expected. This needs to be compared to the financial impact of the policy instruments used. A realistic comparison requires updated knowledge on the production costs and how different factors that play a role in production costs evolved lately (see Section 2.8).

Further, a more careful consideration of the risks associated with policy design - sometimes unintentionally - is necessary. While a totally risk free policy may not be feasible, it is important that support systems enables investors to predict within reasonably narrow ranges the payment on a long-term basis. The weaker the predictability of payment streams is, the higher the financial leakages, and the more ineffectively the public financial support will be spent. For example, in terms of risk lessons, our research showed that the legal guarantee of renewable electricity purchase is not sufficient to create an attractive investment context, even when the profitability enabled is (very) high. As orientation for investors, it is necessary to also mention the guaranteed contract length. But the shorter the contract guarantee is, the higher the investment risks remain. Further, the fine-tuning of support - especially with regard to price - needs to be made at higher levels of decision making. Decisions at ministerial level appear to be associated with increasing investment risks than governmental decisions, which are in their turn seen as more risky than parliamentary decisions.

Moreover, in order to create an attractive investment context, complex and versatile payment streams need to be avoided. The operation of one or few clear support schemes increases the range of developers likely to understand and able to assess their financial impact. Transparency and stability in support system may increase the diversity of diffusion patterns towards a faster progress in reducing the financing obstacle. This may bring substantial contribution to the socio-economic-industrial embeddness of technology. But in order to achieve transparency and stability in support systems, governments need to define what they want to achieve and why, as clearly as possible. When support systems are highly versatile with frequent change in policy instruments types (see wind in the Netherlands, Chapter 11) or annual price revisions based on unilaterally decided un-transparent price methodologies (see Chapter 6) - even when they still enable overall very high profitability - they will have damaging impacts on diffusion[20].

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[20] As a market expert observed, “renewable energy policy making is unfortunately nowhere near as mature as the technology is.” (WPM, June 1999: 30, “Competition and the renewables”).

Policy makers should not stop their responsibility for renewables diffusion with the implementation of support systems. Diffusion patterns need to be continuously monitored in order to timely observe which are the prospects for support system effectiveness and the continuity of diffusion processes. The failure of policy instruments to achieve results may be viewed as a failure of renewable technologies to win investor interest or confidence. This may have long term damaging consequences for the perceptions of economic actors who chose to observe the technology and market experience before entering the new sector - with impact on the rate of market growth.

The analysis of the factors leading to the restricted involvement of small developers in the renewable power generation industry suggests that, on the one hand, special support mechanisms need to be targeted at the stimulation of their investment interest. For example, diffusion may not lead to institutional investments, that is stock investments by individuals/ household and other economic actors, unless special fiscal measures are applied to stimulate this. But on the other hand, pervasive intervention may also be needed to adapt the financing market and the institutional/legal context for a new business approach towards small developers.

Further, the analysis of technology designs of project developers suggested that developers become more seriously concerned with diffusion-optimal designs, only when very high profitability is possible on a more regular basis. When the implemented support system does not offer such profitability terms, government may want to directly influence market choice by various stimulation mechanisms or even technical requirement criteria for project approval. While public money is anyhow being spent on technology diffusion, there is no reason why technology choice should not be directed towards improving the long term expansion potential of the renewable resources in the electricity system. In our empirical research for wind technology in three countries, we did not observe a concern on the governmental research agenda for what we considered as diffusion optimal technology designs. This concern was growing however among manufacturers of wind technology in Spain, and the only manufacturing company in the Netherlands. This suggests one more time that governments are often ‘out of touch’ with market developments and long term trends. Of direct relevance from the perspective of policy making are also our empirical findings regarding possible impacts of exogenous factors on diffusion patterns and the rate of renewable capacity increase. In the design of support systems, one may account for the presence of various factors mentioned in Table 14.7 and the forms they may take in the respective national context.

With regard to few factors, direct governmental intervention may help, such as in the case of administrative approval procedures and criteria or the institutional framework for stock investments by individuals. With regard to other factors, however, compensatory action may be needed to steer diffusion patterns. For example, when domestic financing agents have a clear preference towards approving loans towards large developers, special financing lines or financing mechanisms may be created to enable smaller and local developers to invest. Similarly, when financing agents are very interested to invest creating obstacles for market entry of certain groups of potential developers.

Some of the influencing factors may emerge/become visible after the support system has been in operation for some time. This makes the check-up of the evolution of diffusion patterns again important, for timely intervention with policy instruments when changes in diffusion patterns threaten to hamper the achievement of policy goals.

Local social opposition and the administrative approval of renewable power plants - and in the case of biomass in Spain still other institutional obstacles - have impacts not only in the (obvious) terms of rate of installed capacity increase, but they have also pervasive impacts on diffusion patterns. They may have serious negative consequences for the national industrial basis of the supported RET, as we observed in the case study for wind diffusion in the UK. But they may also frustrate the achievement of local socio-economic benefits from diffusion as we observed in the same case study.

When support systems are designed, it is important not only to minimise the influence of factors that may impede diffusion but also to make as much use as possible of the presence of exogenous factors that may help diffusion. Examples of positive factors are when financing agents agree to consider investment subsidies as part of the equity contribution to financing. This increases the chances of loan accessibility of small developers when such support instruments are used, improving the chances for local economic embeddness of technologies. Similarly, when banks are open towards environmentally friendly investments it may be possible to implement for example a higher risk support system - assuming that there is a goal implying it, such as when competition among generators is also viewed as a priority.

A final core policy lesson regards the obstacles to diffusion. Beside the issue of financing and economic obstacles, in Chapter 2 we also planned to look empirically at the spin-offs induced by diffusion in terms of the reduction of other types of obstacles (theoretically ignored) - the way non-technical obstacles changed in time and which are the obstacles impeding the working of the support systems. In a nutshell, the lesson from empirical research is that the obstacles that affected diffusion the most did not change in magnitude during the diffusion period studied. The obstacles that impeded the working of support systems the most were local social approval and/or the administrative approval in the case of wind and small hydropower technology. In the case of biomass electricity, institutional obstacles played an important role in slow rhythm of diffusion. There was no governmental policy implemented to reduce the obstacles observed, and the economic actors interested to invest did not manage - on their own - to dampen their impact.

In conclusion, empirical research suggests the crucial importance of governmental action to overcome such obstacles when support systems are implemented. *Diffusion itself - to the extent that this is possible to take place - is highly unlikely to have spins-off in the direction of the endogenous removal of administrative, social and institutional obstacles.*

14.4 Concluding remarks

The use of renewable energy resources in the 21st century and thereafter is of crucial importance to subdue the climate impacts of centuries of combustion of fossil fuels. The question is however how to achieve a substantial resource shift in electricity supply, and how to sustain the use of renewable resources. In the framework of this study, we aimed to bring our contribution to this question. We concentrated on the potential of support systems to relieve and overcome the economic and financing obstacles for the sustained diffusion of renewable electricity technologies in industrialised countries.

The chances, rhythm and long-term prospects of diffusion are undoubtedly influenced by many factors, including many types of policy and targets of governmental intervention. In dealing with the complexities of policy support systems, our analytical choice was to restrict the analysis to only two independent variables: the investment risks emerging from support systems and profitability enabled by them. The aim was to theoretically underpin the diffusion mechanisms parsimoniously and systematically, so as to increase the insight into why and how certain diffusion results may be obtained, what can be done to sustain them. From theoretical standpoint, the virtue of having an as lean as possible theoretical explanation is as such very important. Considering the generally satisfactory degree of explanation of the observed diffusion patterns with just two independent variables supports the argument to concentrate on them in policy making addressing the economic and financing obstacles. Our findings confirm the significance of policy support for the resource shift in electricity supply but, more importantly, they show the necessity of its continued short-term fine-tuning in order to be successful in the longer-term.

Furthermore, we also aimed to contribute to the current state of knowledge by means of detailed empirical analyses unravelling the diffusion mechanisms and results obtained under several support systems used so far in three industrialised countries. Both theoretical and empirical insight into the diffusion potential of governmental support systems are important building blocks towards an improved understanding on how the needed shift towards renewable energy use may be achieved and sustained on the background of fossil fuels' backlash.

Samenvatting

Duurzame energiebronnen voor de productie van elektriciteit staan volop in de politieke belangstelling. Dit is onder meer een gevolg van de toenemende zorg om de verandering van klimatologische omstandigheden (klimaatverandering), de eindigheid van fossiele brandstoffen en mogelijke gezondheidseffecten van de toepassing van fossiele en nucleaire energiebronnen. Nationaal en internationaal wordt er daarom gestreefd naar een vergroting van het aandeel duurzame energiebronnen in de productie van elektriciteit en ondersteunen overheden van geindustrialiseerde landen de ontwikkeling en diffusie van technologie gebaseerd op deze bronnen. Ons onderzoek is gericht op de vraag naar de effectiviteit van deze vormen van overheidssteun. Echter, in tegenstelling tot de gangbare onderzoekstraditie naar de effecten van beleidsondersteuning van duurzame elektriciteitproductietechnologie, is ons onderzoek niet op de korte, maar op de langere termijn effecten van deze beleidsondersteuning gericht. Deze lange termijn effecten zijn in tegenstelling tot de korte termijn effecten nog relatief weinig onderzocht. Met ons onderzoek beogen we juist een bijdrage te leveren aan het inzicht in de lange termijn effecten van beleidsondersteuning van elektriciteitproductietechnologie gebaseerd op duurzame energiebronnen.

De centrale vraag die in het onderzoek is beantwoord luidt:

> *Wat zijn de consequenties van specifieke vormen van overheidsbeleid gericht op het verminderen of wegnemen van economische en financiele belemmeringen voor de korte termijn marktintroductie en lange termijn diffusie van duurzame elektriciteitproductietechnologie?*

In het eerste deel van het proefschrift is een theorie ontwikkeld over de lange termijn effecten van beleidsondersteuning van duurzame elektriciteitsproductietechnologie. Deze theorie is in het tweede deel van het proefschrift empirisch getoetst. In het derde en laatste deel van het proefschrift zijn de empirische bevindingen systematisch vergeleken met de theoretische verwachtingen en is de balans opgemaakt over de houdbaarheid van de theorie. Figuur 1 geeft het analytische kader van het onderzoek schematisch weer.

Figuur 1 *Het analytische kader van het onderzoek*

Het in dit onderzoek toegepaste kader veronderstelt dat het effect van beleidsondersteuning op de diffusie van duurzame elektriciteitsproductietechnologie op geaggregeerd niveau zichtbaar is in de economische en politieke risico's en de winstgevendheid van investeringen in duurzame elektriciteitsproductietechnologie. Afhankelijk van de risico's en de winstgevendheid van investeringsprojecten, zo stelt onze theorie, zullen bepaalde diffusiepatronen ontwikkelen die de mate van continuiteit van het diffusieproces bepalen en daarmee de effectiviteit van de beleidsondersteuning. Diffussiepatronen en lange termijn continuiteit van het diffusieproces zijn de twee afhankelijke variabelen in onze theorie, waarbij diffusiepatronen het lange termijn effect van de beleidsondersteuning dragen.

In het eerste deel van het proefschrift (hoofdstukken 2 tot en met 4) is de centrale vraag van het onderzoek theoretisch uitgewerkt met behulp van zeven deelvragen. De eerste drie deelvragen zijn geformuleerd om de bouwstenen van het theoretische model uit te werken. Deze drie deelvragen, beantwoord in hoofdstuk 2, luiden:

1. Hoe kunnen beleidsinstrumenten gericht op het verminderen of wegnemen van financiele en economisch belemmeringen in de diffusie van duurzame elektriciteitstechnologie systematisch worden beschreven en vergeleken vanuit het perspectief van investeerders in duurzame elektriciteitstechnologie?
2. Onder welke voorwaarden zal de diffusie van duurzame elektriciteitstechnologie op de lange termijn continueren?
3. In welke mate beïnvloedt beleidsondersteuning de financiële prestaties (kosten) van duurzame elektriciteitstechnologie?

Onze analyse van beleidsinstrumenten gericht op de ondersteuning van duurzame elektriciteitstechnologie leidde tot de conclusie dat het huidige wetenschappelijke onderzoek twee tekortkomingen kent. In de eerste plaats negeert het onderzoek het effect van de specifieke financiele ondersteuning die beleidsinstrumenten bieden. In de tweede plaats houdt het bestaande onderzoek te weinig rekening met de effecten van de beleidsondersteuning op de investeringsbereidheid van actoren en de risico's die deze actoren daarbij bereid zijn te accepteren. Om die reden hebben we een theoretisch kader uitgewerkt waarmee de grote hoeveelheid beleidsinstrumenten gericht op het stimuleren van duurzame elektriciteit technologie kan worden beschreven, geclassificeerd en vergeleken op basis van twee kenmerken:

- het geaggregeerde economische en financiele risico van de toegepaste instrumenten van investeringen in duurzame elektriciteitsprojecten;
- de mate van winstgevendheid van investeringsprojecten voor de investeerder.

In hoofdstuk 2 van het proefschrift is het effect van ondersteunend beleid aan de hand van deze beide kenmerken alsmede specifieke waarden die deze kunnen aannemen, uitgewerkt in vier verschillende investeringscontexten:

- De optimale investeringscontext
- De ondernemende investeringscontext
- De politieke investeringscontext
- De minimale investeringscontext

Ter beantwoording van de tweede onderzoeksvraag zijn vervolgens in elk van deze vier investerings contexten theoretisch de condities gespecificeerd waaronder het diffusieproces zal continueren. Deze condities zijn:

- De beschikbaarheid van financiële middelen om het diffusieproces te kunnen continueren;
- De technische prestaties van de technologie in verhouding tot het nationaal beschikbare potentieel aan duurzame energiebronnen;
- De financiële prestaties van de technologie (kosten) in verhouding tot het nationaal beschikbare potentieel aan duurzame energiebronnen;
- De verankering van de technologie in de nationale socio-economische en industriële structuur.

De eerste conditie, de beschikbaarheid van financiële middelen, is in het onderzoek als motor (drijvende kracht) van het diffusieproces beschouwd. De beschikbaarheid van financiële middelen is theoretisch uitgewerkt en gespecificeerd naar elk van de vier hierboven onderscheiden investeringscontexten. Ook de drie andere condities zijn op deze wijze theoretisch uitgewerkt, waarbij de beschikbaarheid van financiële middelen en de verankering in de nationale socio-economische en industriële structuur theoretisch werden gespecificeerd in een aantal hypothesen. Onze theorie beschouwt de diffusie van een duurzame elektriciteittechnologie op de lange termijn effectief als de betreffende technologie verankert in de socio-economische en industriële structuur en de financiële prestaties van de technologie geen verdere beleidsondersteuning vergen. Ook als er duidelijk sprake is van verankering in de nationale structuur maar de financiële prestaties van de technologie nog niet het volledige nationale potentieel aan duurzame energiebronnen kunnen exploiteren (en dus continuering van de beleidsondersteuning gerechtvaardigd zou zijn), spreekt de theorie over een effectief diffusieproces.

In het laatste deel van hoofdstuk 2 zijn ter beantwoording van de derde onderzoeksvraag de financiële prestaties (kosten) van een duurzame elektriciteittechnologie theoretisch uitgewerkt. Daartoe werden factoren geanalyseerd die de kosten per kWh beïnvloeden en hoe deze onder invloed van het diffusieproces veranderen. Onze analyse leidde tot de conclusie dat slechts twee van de vier factoren die de kosten van een technologie bepalen, direct of indirect met overheidsbeleid kunnen worden beïnvloed. Dit zijn contextbepaalde factorkosten en technologiespecifieke factorkosten. In het diffusieproces kunnen de initieel hoge productiekosten een heel scala van waarden aannemen, variërend van ‘competitief met gangbare technologie’ tot ‘zeer hoog’. In onze analyse van de samenhang tussen factorkosten en diffusieproces hebben we laten zien dat bij een uitbreiding van de op duurzame bronnen gebaseerde productiecapaciteit de productiekosten in toenemende mate enkel door de geografische omstandigheden worden bepaald en daardoor sterk kunnen stijgen. Bij een bepaalde capaciteitsomvang zal daarom de capaciteitsuitbreiding in toenemende mate worden bepaald door de bereidheid tot en beschikbaarheid van prijsondersteuning.

In hoofdstuk 3 zijn de vijfde, zesde en zevende onderzoeksvraag beantwoord. Deze luiden:

5 Hoe handelen investeerders (potentiële projecteigenaren en financiële instellingen) onder verschillende vormen van beleidsondersteuning?
6 Wat zijn de consequenties van investeringsgedrag onder verschillende vormen van beleidsondersteuning voor diffusie van duurzame elektriciteittechnologie?
7 Wat zijn de consequenties van de diffusiepatronen voor de korte, middellange en lange termijn diffusie van duurzame elektriciteittechnologie?

In hoofdstuk 3 is het lange termijn effect van beleidsondersteuning verder uitgewerkt aan de hand van een specificatie van diffusiepatronen zoals die verwacht mogen worden in de vier eerder onderscheiden investeringscontexten. In onze theorie wordt dit lange termijn diffusiepotentieel gedragen door de specifieke waarden die onderstaande factoren in de vier investeringscontexten aannemen:

- Het type projectontwikkelaars dat bereid is te investeren;
- De wijze waarop de investering wordt gefinancierd;
- De aard van de investeringsbeslissing, in het bijzonder het investeringsmotief, de omvang van het investeringsproject in termen van productiecapaciteit en de keuze van het technologische ontwerp.

In hoofdstuk 3 zijn allereerst de waarden van elk van deze factoren verder uitgewerkt en gespecificeerd. Op basis van de specifieke waarden die deze drie factoren - per investeringscontext - kunnen aannemen, zijn vervolgens theoretisch de omstandigheden (diffusiepatronen) gespecificeerd die het diffusieproces op termijn continueren. Op deze wijze hebben we onze theoretische verwachtingen over het lange termijn effect van beleidsondersteunende maatregelen op de diffusie van duurzame elektriciteitsproductie technologie in de volgende vier hypothesen samengevat:

Hypothese 1:
Beleidsondersteuning die leidt tot een investeringscontext met een laag tot gemiddeld financieel risico en een (zeer) hoge winstgevendheid, zal leiden tot een diffusiepatroon met:
- alle typen projectontwikkelaars;
- overwegend commerciële investeringsmotieven;
- overwegend extern gefinancierde investeringen;
- voornamelijk middelgrote en grote investeringsprojecten;
- alle typen technologische ontwerpen, maar met een lichte voorkeur voor nieuwe en bestaande diffusieoptimale technologische ontwerpen.

Zo’n diffusiepatroon zal leiden tot:
- een omvangrijke toename van de productiecapaciteit op de korte en middellange termijn; en
- goede vooruitzichten voor de continuïteit van het diffusieproces op de lange termijn.

Hypothese 2:
Beleidsondersteuning die leidt tot een investeringscontext met (zeer) hoge financiële risico’s en een (zeer) hoge winstgevendheid, zal leiden tot een diffusiepatroon met:
- overwegend grote en slechts weinig kleine projectontwikkelaars;
- met strategische, commerciële en zelfvoorziening investeringsmotieven;
- overwegend intern gefinancierde investeringen;
- voornamelijk middelgrote en kleine investeringsprojecten;
- alle typen technologische ontwerpen, maar nieuwe en bestaande diffusieoptimale technologische ontwerpen maar in geringe mate.

Zo’n diffusiepatroon zal leiden tot:
- een bescheiden toename van de productiecapaciteit op de korte en middellange termijn; en
- mogelijke continuïteit van het diffusieproces op de lange termijn.

Het diffusieproces zal zich op de lange termijn continueren als de bestaande financiële gemeenschap voldoende flexibel is om financiële middelen beschikbaar te stellen en risico’s te accepteren.

Hypothese 3:
Beleidsondersteuning die leidt tot een investeringscontext met lage financiële risico’s en lage winstgevendheid, zal leiden tot een diffusiepatroon met:
- overwegend kleine projectontwikkelaars maar ook wel energiebedrijven en grote industriële ondernemingen;
- met strategische, commerciële en zelfvoorziening investeringsmotieven;
- overwegend intern gefinancierde investeringen;
- voornamelijk kleine investeringsprojecten;
- voornamelijk niet-diffusie optimale conventionele technologische ontwerpen.

Zo’n diffusiepatroon zal leiden tot:
- een bescheiden toename van de productiecapaciteit op de korte en middellange termijn; en
- mogelijke continuïteit van het diffusieproces op de lange termijn als tegelijkertijd aan de volgende drie condities wordt voldaan:
    - er een nationale traditie is van entrepreneurschap onder kleine projectontwikkelaars;

- het welvaartsniveau voldoende hoog is om investeerders gelegenheid te geven om te investeren in de betreffende technologieën; en
- financiële instellingen voldoende vertrouwen hebben en geven aan kleine projectontwikkelaars en geen al te stringente eisen stellen aan de minimale winstgevendheid van de projecten die zij financieel ondersteunen.

Hypothese 4:
Beleidsondersteuning die leidt tot een investeringscontext met (zeer) hoge financiële risico's en lage winstgevendheid, zal leiden tot een diffusiepatroon met:

- overwegend private projectontwikkelaars die investeren ten behoeve zelfvoorziening;
- overwegend kleine investeringsprojecten;
- overwegend conventionele commercieel rijpe technologische ontwerpen;
- overwegend kleine projectontwikkelaars en industriële productiebedrijven die investeren op basis van strategishe redenen;
- overwegend intern gefinancierde investeringen;

Zo'n diffusiepatroon zal leiden tot:

- een geringe toename van de productiecapaciteit op de korte en middellange termijn; en
- discontinue diffusieprocessen op de lange termijn.

In het vierde hoofdstuk is de samenhang tussen technische eigenschappen en de lange termijn continuïteit van diffusie van duurzame elektriciteittechnologieën geanalyseerd aan de hand van de vraag welke aspecten van hun technische prestaties de vooruitzichten voor de lange termijn continuïteit van hun diffusie kunnen verbeteren. Op basis van technisch literatuur werden voor windtechnologie, biomassa en waterkracht deze diffusiebevorderende aspecten in kaart gebracht, geanalyseerd en ten behoeve van het empirische deel van het onderzoek geoperationaliseerd.

Deel twee en drie van het proefschrift bevat het verslag van ons empirische onderzoek. De theorie werd in totaal in acht gevalsstudies getoetst door middel van empirisch onderzoek van de diffusie van wind technologie in Spanje, Nederland en het Verenigd Koninkrijk en de diffusie van (kleine) waterkrachtturbines en biomassacentrales in Spanje. In het empirische onderzoek bleek het door ons theoretisch uitgewerkte idee van beleidsondersteuning als winst-risico investeringscontext in de praktijk goed te werken. Hoewel het verzamelen van het empirische materiaal niet altijd gemakkelijk bleek, kon met behulp van de investeringscontexten wel een betrouwbare internationale vergelijking van nationale beleidsondersteuning van duurzame elektriciteitproductietechnologie worden gemaakt. In hoofdstuk 14 van het proefschrift zijn we uitgebreid ingegaan op de problemen die we daarbij hebben ondervonden en hoe we deze problemen in ons empirisch onderzoek hebben opgelost.

Onze theoretische verwachtingen *over de lange termijn continuïteit van het diffusieproces* in de vier investeringscontexten werden in het empirische onderzoek in grote lijnen bevestigd. In de optimale investeringscontext bleek de beschikbaarheid van financiële middelen in verhouding tot de drie andere contexten zeer goed. In de politieke en de ondernemende context bleken de financiële condities mede te worden beïnvloed door factoren die we in onze theorie als intermediaire factoren hebben uitgewerkt: de bedrijfscultuur van financiële instellingen, het welvaartsniveau van potentieele investeerders; en de bereidheid van investeerders om in technologie intensieve projecten te investeren (entrepreneurshap van investeerders). Daarnaast bleken een aantal andere factoren de wijze waarop investeringen worden gefinancierd, te beïnvloeden (zie tabel 14.7).

Verbeteringen in de financiële prestaties (productiekosten per kWh) bleken, zoals theoretisch voorspeld, geen verband te houden met de aard van de beleidsondersteunende maatregelen. Uit ons empirisch onderzoek kwam naar voren dat na een periode van diffusie de productiekosten nogal kunnen variëren en mede worden bepaald door de gezamenlijke werking van de aanwezigheid en locatie van de natuurlijke energiebronnen, institutionele factoren die investeringsbeslissingen beïnvloeden en de specifieke vorm en inhoud van beleidsondersteunende maatregelen. Ook werd in het empirische onderzoek de door ons theoretisch voorspelde evolutionaire ontwikkeling van de factorkosten bevestigd.

Voor wat betreft de keuze van het technologisch ontwerp leidde het empirisch onderzoek tot de conclusie dat een minimale en een politieke investeringscontext, zoals voorspelt, nauwelijks aanzetten tot investeringen in diffusiebevorderende technologische ontwerpen. In een ondernemende en een optimale investeringscontext, waarin de vooruitzichten van de winstgevendheid van investeringen in het algemeen goed zijn, bleken investeerders juist wel voor diffusiebevorderende technologische ontwerpen te kiezen.

Ondanks de werking van externe factoren, werden onze theoretische verwachtingen ten aanzien van investeringsgedrag en de consequenties daarvan voor de lange termijn diffusie van duurzame elektriciteittechnologie in het algemeen bevestigd. In het empirische onderzoek bleken de winst en risico eigenschappen van beleidsondersteunende maatregelen inderdaad van invloed op het diffusiepatroon van duurzame elektriciteittechnologie. In de door ons empirisch onderzochte diffusieprocessen bleek de verspreiding van duurzame elektriciteittechnologie in grote lijnen de patronen te volgen zoals theoretisch voorspeld en uitgewerkt in de vier investeringscontexten en voor elk van de indicatoren van diffusie. Onze theoretische verwachtingen ten aanzien van het diffusiepatroon werden zowel voor de korte en middellange als voor de lange termijn in grote lijnen bevestigd.

Op basis van ons onderzoek kan worden geconcludeerd dat elke beleidsondersteuning van duurzame elektriciteitstechnologie die geen of onvoldoende rekening houdt met de daaraan verbonden risico's en winstgevendheid voor investeerders, minder effectief zal zijn. Winstgevendheid is essentieel om met name grote investeerders tot investeringen in duurzame elektriciteittechnologie te bewegen omdat vooral grote investeerders over het vermogen en de middelen beschikken om de financiële obstakels te doorbreken die de diffusie van duurzame elektriciteittechnologie belemmeren. Daarnaast is het essentieel dat beleidsondersteunende maatregelen ook meer rekening houden met de risico's voor investeerders. Publieke financiële ondersteuning in combinatie met een hoog investeringsrisico is een zelfvernietigende beleidsstrategie. Beleidsondersteunende maatregelen kunnen pas werkelijk effectief zijn als ze meer aansluiten bij de behoeften van de betrokkenen bij investeringen in duurzame elektriciteittechnologie, zoals de industrie, investeerders en financiële instellingen in plaats van enkel rekening te houden met de behoeften van beleidsadviseurs.

In de 21e eeuw, maar ook daarna, is het gebruik van hernieuwbare energiebronnen van cruciaal belang om het klimaateffect ten gevolge van het gebruik van fossiele brandstoffen gedurende de afgelopen eeuwen, te beheersen. De vraag is echter hoe zo'n verandering in de energiebasis van elektriciteitsproductie ten gunste van duurzame bronnen kan worden bewerkstelligd en op termijn kan doorzetten. Aan de beantwoording van deze vraag hebben wij met dit proefschrift een bijdragen willen leveren door de omstandigheden te onderzoeken waarin beleidsondersteunende maatregelen de financiële en economische belemmeringen in de lange termijn diffusie van duurzame elektriciteittechnologie kunnen verminderen en wegnemen.

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March, 1997 :20", Record low prices for British contracts
April 1997: 39, "Contracts spread across many players"
February 1999: 48, "Taylor Woodrow out of wind"
February 1999: 36, "Push towards small scale development"
April 1998: 31, "Good bye to British wind technology"
June 1998: 30, "Keen response to share issue"
September 2000: 39, "Commercial reality kept at bay in most Europe"
November 2001: 31, "Corporates raising to dominate market"

List of interviews

Spain

Interviewees – April / May 2001	Organisation / company
Alcor, Enrique	ATERSA company
Alberto Ucha, Carmen – Chief Wind Turbines Sale	Grupo Industrial IZAR (Bonus Bazan wind technology manufacturing company)
Anegon, Rafael Naranjo – Delegate adviser	Grupo SUFI company
Arrieta, Jose – Director	Energia Hidraulica Navarra subsidiary of the second largest electricity company
Arlaban Gabeiras, J. – Financing Director	Energias Hidraulica Navarra in February 2002
Avellaner Lacal, Juan – Chief Department of Public Programs Management	Institute of Energy Saving and Diversification (IDAE)
Basarioti, Rafael	Gamasa Energia (subsidiary of wind manufacturing company)
Baztarrica, Marimar – Public relations	Energia Hidraulica Navarra (ECN), subsidiary of the second largest electricity company
Bettschider, Roland – Manger	Ibero Energias Renovables company
Blanco Alvarez, Isabel – International Relations Department	Institute of Energy Saving and Diversification (IDAE)
Bustos Mancera, Manuel – Public Relations, Communications Department	Association of Renewable Energy Producers (APPA)
Carrasco, Juan – Biomass Department	Center for Energy, Technology and Environmental Research (CIEMAT) April 2002
Castillo, Joaquin	Union Fenosa Energias Especiales (UFEE – subsidiary of the third largest electricity company) in April and September 2001
Castro, Jose Angel	CEASA company (Obtober 2001)
Claver Cabrero, Ana – Commercial relations	Center for Energy, Technology and Environmental Research (CIEMAT)
Colinet Carmona, Maria Jose – Department of Energy Saving & Planning	Energy Agency of Andalucia (SODEAN) in April 2001 and April 2002
Cruz, Ignacio Cruz	Center for Energy, Technology and Environmental Research (CIEMAT), in August 2001
Donder, Ole	Neg-Micon Iberica (subsidiary of wind technology manufacturer)
Dorado, Vicente Marcos	ACYSA company
Escobar, Guillermo Jose – Manager Energy and Environment	BESEL company
Galvan Gonzalez, Francisco – Manager Technical Bureau	Dessarollos Eolicos (DESA – wind technology manufacturer)
Fages Torras, Joan – Delegated Adviser	Hidrowatt company, April 2002
Fernandez Lopez, Carlos Alberto – Department biomass (termoelectric plants)	Institute of Energy Saving and Diversification (IDAE) in April 2002
Fernandez Borbons, Marta – Director Renewable Energy	SINAE company (renewable subsidiary of the fourth largest electricity company in Spain
Fernandez Jesus – Scientific President	The Spanish Biomes Association (ADABE); April 2002
Galvan, Guillermo	Institute for the Research of Renewable Energy Technology (ITER) in August 2001

Gonzalez Fernandez, Teresa – Laywer	Energiekontor Iberia company
Gonzalez Velez, Jose Maria – President Hydropower Section and Director company	Association of Renewable Energy Producers (APPA); Hidronorte company; February 2002
Gonzalez, Ermina	UNELCO – electricity company (September 2001)
Guillen, Felix	Canary Technology Institute, in August 2001
Hurtado Sanchez, Francisco – Director Financing Department	Dessarollos Eolicos (DESA – wind technology manufacturer)
Lose Luis, Himenez – Technical Director	Taim-Neg Mocon Eolica in August 2001
Lara Cruz, Antonio de – General Director	MADE Tecnologias Grupo Endesa (wind technology manufacture company long time subsidiary of the largest electricity company)
Lopez, Cristobal Lopez – wind power engineer	Iberdrola Inginieria y Consultoria (subsidiary of the second largest electricity company) in April 2001, September 2001, April 2002
Marrero Huoebye, Julia – Commercial Department	Aerogeneradores Canarios (ACSA wind technology manufacturer under Vestas license) in September 2001
Martin, Francisco	Sevillana de Electricidad (grid company)
Mendilluce, Maria	IbeRenova (subsidiary of the second largest electricity company)
Morena Valenzuela, Ignacio de la – Industrial engineer	DISOL company
Nunies, Carlos – Financing Director	MADE Tecnologias Grupo Endesa (wind technology manufacture company)
Ocharan de la Camara, Enrique – Technical adviser of the General Sub-direction of Energy Planning	Ministry of Economy (former employee of the Ministry of Industry and Energy MINER) in April and August 2001
Pena, Juan	Eolica Cabanillas company in August 2001
Prats, Pep – Technology Development Manager	Ecotecnia (wind technology manufacturer
del Pozo, Jose Antonio Franco – Market Direction	Endesa Cogeneracion y Renovables (subsidiary of the largest electricity company in Spain)
Rodriguez Matin, Jose Manuel – Industrial engineer	Becosa Energias Renovables company
Rojas Barcona, Alberto de – Industrial Engineer Energy and Environment	Elecnor Technology and Products company
Sanchez Montero, Jose Antonio	National Energy Commission
Salat i Mardaras, Salvador – Chief Renewable Energy	Energy Institute of Catalonia
Santo, Margarita	CESA company in August 2001
Tores Ramos, Jose Manuel – Department of Energy Saving & Planning	Energy agency of Andalucia (SODEAN)
Utrillas Saez, Antonio – Technical Director	DeWind Iberia company
Vela Vico, Antonio – General Director	Soluciones Energeticas company

United Kingdom

Interviewees	Organization	Date
Catherine Mitchell	Centre for Management under Regulation, Warwick Business School	June 2000
Steve Sorrell	Science and Policy Research Unit, University of Sussex	June 2000
Steve Thomas		June 2000
Walt Patterson	Royal Institute for International Affairs	June 2000
Karren Marshall	Office of Electricity Regulation	
Amanda McIntyre	Office of Gas and Electricity Markets	October 2002 e-mail communication
Gaynor Hartnell	British Wind Energy Association	June 2000
Jan Fletcher	Former employee ETSU	October 2002 e-mail communication
Martin Adler	British Wind Energy Association	July 2002
Nicola Steen	Association Electricity Producers	June 2000
David Porter President AEP		June 2000
Chris Naish, Programe Area Manager - ETSU	Energy Technology and Support Unit [ETSU] subordinated to the Department of Trade & Industry	June 2000
Dan Staniaszek	Energy Saving Trust ('Future Energy')	July 2000
Chris Shears	Renewable Energy Systems (wind technology- technical aspects)	Phone interview
Chris Barrett	Product Manager Green Electron - SWEB (electricity company)	Phone interview

The Netherlands

Interviewees	Organization	Date
Akerboom, H.N.M.	EDON Sustainable - Product and Innovation Department	December 1999
Beets, Dick	Zaanse Energie Koöperatie	August 2002
Bemmelen, van J.A.H.	EnergieNed - Economic and Market Research Department	December 1999
Benner, J.	CEA (Consultancy for Energy and Environment), Rotterdam	January 2001
Bosma, J. and Laureissen, F.	PNEM&MEGA, Energy Systems BV	December 1999
Dingemans, Jorrit	Marketmanager Windenergie, ENECO Energy Systems & Development	August 2002
Fabius, Jan Willem	consultant European Energy Consult	November 1999
Groot, J.W de	Delta Energy Distribution Company	December 1999
Kersten, Wim	VCBW Noord-Brabant cooperative	August 2002
Jeroense, B.	Project Agency for Sustainable Energy	December 1999
Kap, G. and Wiegersma-Colmer, G.	Noordenwind	October 2002
Kees, Veerman	CVWd	September 2002
Kwant, K.W.	Novem - Biomass Energy Department	December 1999
Marbus, S.	EnergieNed	May 2001
Niermeijer, Peter	EnergieNed	January 2001
Ruijgrok, Walter	KEMA Sustainable	January 2001 and May 2001
Scheuerman, Willem	Zeeuwind Cooperative	August 2002
Vasen, Norbert	CEA (Consultancy for Energy and Environment), Rotterdam	January 2001
Vliet, Fred van	Cooperative	September 2002

Curriculum Vitae

Valentina Dinica (1971) works since 1998 as a research associate at the Center for Clean Technology and Environmental Policy, University of Twente, The Netherlands. Her undergraduate studies were carried out in Romania, in the field of textile engineering, at the Technical University of Iasi (1989-1994). Following that she specialised in public administration and environmental policy, attending post-graduate programs at the National School of Political Studies and Public Administration (*Cum Laude.* Bucharest, Romania 1994-1996), Environmental Science and Policy Department at the Central European University (MSc. Budapest, Hungary 1996-1997) and the European Postgraduate Course in Environmental Management (MEM. University of Amsterdam, The Netherlands 1997-1998).

In September 1998 she started working for her doctoral thesis on the impact of various policy approaches on the diffusion of renewable electricity technologies. During this time she also wrote articles and book chapters on renewable energy policies and climate change policies. On these topics she also teaches in international post-graduate programs. For more information on other publications, developing research interests, and contact details please visit the website of the Center for Clean Technology and Environmental Policy at the University of Twente at http://www.utwente.nl/cstm.