Rural Electrification

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Preface and Acknowledgements

While there have been many publications on electricity supply to rural areas, the implications of recent power sector developments and trends for utility organisation and management seem to have received less attention. Most of the past research addressed issues such as the technical and financial performance of both grid connected and decentralised power systems and the socio-economic impact of electrification.
For some years the power sector in developed and developing countries alike, has faced a range of changes, problems and challenges that will probably have an effect on rural electrification strategy. An exploratory survey of the many developments and trends in the sector has revealed that research into the implications for utilities and other organisations engaged in electricity supply to rural and remote areas was justified.

The objective of this research, which is performed from an utility perspective, is to identify and assess relevant trends, to look ahead to opportunities for electricity supply to rural and remote areas, and to translate the results into recommendations for decision makers. The resulting publication seeks to complement existing literature and to act as a vehicle to transfer specific managerial know how and, in particular, know why.
This work does not give universal recommendations and does not pretend to shape the future of rural electricity supply technology and management. It is emphasised that the situations and backgrounds differ from country to country and that, as an obvious consequence, the decision makers will have to adopt those solutions which are appropriate to their local circumstances.
The research fits into the programme and activities of the Technology and Development Group of the University of Twente (Faculty of Technology and Management) , The Netherlands. The research of the Group concentrates on the planning and management of small scale energy systems in developing countries, industrial development and the role of industrial companies, institutional development and the role of non-governmental organisations and technology and sustainable development.

I am aware that the theoretical framework of this study is not very special and that radical new insights are also limited. However, I believe that this work will not only contribute to the scientific insight into the effects of current developments and trends on the electricity supply to rural and remote areas but that, in particular, it will help decision makers in the electricity supply sector in developing countries and in support agencies to take appropriate decisions. Thus it can contribute to the betterment of the situation of rural communities and of the performance of the organisations serving their areas.

In effect this work consists of three components: an analytical, a theoretical and a practical component, divided between a number of chapters.
Chapter 1 sets the scene, arguing that energy is needed to achieve an acceptable quality of life, and that the urgency of the electrification of rural and remote areas must be seen within the context of human need priorities. This chapter also explains the whys and wherefores of the research and it also covers such issues as the research method and the problem description.
Chapter 2 emphasises that developed and less developed countries do have a number of problems in common and also that “living apart together” needs to become more meaningful.
This chapter provides background information on issues which are relevant for the electrification of rural areas such as poverty, rural development, environmental degradation concerns and energy needs in general. The objectives and socio-economic aspects of rural electrification are addressed as well.
The analysis of the historical aspects of rural electrification is the most important part of this research and therefore a number of cases have been described and analysed comprehensively in chapter 3. This chapter together with chapter 4 in which the nature and scope of the developments and trends are identified and discussed, constitutes the analytical component.
Chapter 5 outlines the implications of the findings for electricity supply organisations, and therefore constitutes the practical, or application oriented, component of this work. In this chapter the question included in the title of the work, is also answered.
The final chapter gives a reflective consideration of the likely future developments in the field of electricity supply to the rural and remote areas of our world.

I extend thanks to NUON, The Netherlands, in which my former employer the Energy Board of Friesland (PEB) was merged, for providing support during this research.
I am also grateful to all the colleagues of utilities, donor agencies, support, financing, and other organisations in the Netherlands and abroad who have offered advice, comments and research material. Thanks are due to The World Bank, ESMAP and ASTAE in Washington, ESCAP of the United Nations in Bangkok, ESB International of Ireland, GTZ and EVS of Germany, and NRECA of the United States who have provided me with valuable documentation.
A special word of gratitude is owed to the Netherlands Development Co-operation (DGIS) part of the Dutch Ministry of Foreign Affairs in The Hague. This organisation entrusted me over a succession of years with activities in the field of energy supply and related environmental issues as part of their operations for developing countries. These activities, including the resulting contacts with colleagues in other countries, gave me the opportunities to exchange views on rural electrification problems and challenges. The results prompted me to start an in-depth study of rural electrification issues and to link

the results with my experience gained in the electricity supply industry and during my activities in CIGRÉ, the International Council on large Electric Systems.
I also wish to thank the staff of DGIS/DML-KM and my colleagues of the Dutch Government Support Group for Energy and Environment (SEM) for their discussions and Giles Stacey, a consultant in Hengelo, The Netherlands, for linguistic support.

The research was guided at the Technology and Development Group of the University of Twente by Prof.dr.ir. W. Hulscher during the initial stage and later by Prof.dr. E.W. Hommes, Drs. J.H.M. Opdam and Dr. J. Clancy. All four had a profound interest in the subject and I owe much gratitude for their guidance which was perceived not only as being in-depth but also as stimulating and amicable.
Finally I thank my wife Martha for her patience and understanding during the years of work on this publication.

I am aware that publicising research achievements generally provokes criticism and in this respect the study at hand is believed to be particularly vulnerable because of its multidisciplinary nature. Both the preparation and the review of a publication virtually always induce a reconsideration of certain aspects and other views (Raan, 1996) and these benefits are needed to achieve a proper final result.
On the other hand, Aulus Persius Flaccus (34-62) stated: “your knowledge counts for little unless other people know what you know”. To some extent, I consider this statement to be valid and it enhanced my motivation to commit my research findings to paper. The outcome of my exertions is before you and I trust that it will help you to assess the current situation and to anticipate future developments.

Adriaan N. Zomers,
The Netherlands, December 2000

Chapter 1

Introduction

1.1. Background and rationale of the research

1.1.1. A matter of priorities?

The year 1961 contained the first manned space flight: a striking example of mankind's capabilities enabled by applied scientific research. Some 25 years later such flights have become common and now launchings on a profit basis are even being performed to bring stationary satellites to orbit.

Mankind is capable of having a number of people remaining extraterrestrial for many months. Further removed from us than the furthermost rural dweller on this planet, the astronauts have an extremely reliable electricity supply at their disposal for food preparation, air-conditioning, heating, telecommunication, video equipment and scientific experiments.

The International Space Station Alpha for instance, will be provided with a 94 kW peak power generation system consisting of solar arrays and a nickel-hydrogen battery based energy storage system. In the future the system will be complemented with solar dynamic (gas turbine) generators. It should be noted that in orbit electricity generation by solar arrays is considerably advantaged by the local solar constant flux of 1371 W/m² as compared with a mean annual of 100 to 300 W/m² on earth.

The continuous power of this station amounts to 76 kW which includes an average of 20 kW for the execution of payload experiments. In their remote accommodation up to six astronauts will have an electricity supply of some 56 kW available for the space station infrastructure including preventive, diagnostic and therapeutic medical equipment and housekeeping operations (ESA, 1996).

The power available on board the Space Station Alpha for housekeeping and medical care, could fulfil the basic electricity needs of some 600 rural households in developing countries by using modern energy-efficient appliances are used.

Although electrification commenced some one hundred years ago, currently still about 40% of the world's population have neither access to electricity, nor to sufficient other non-traditional energy forms.

Some 2 billion people depend almost exclusively on biomass for their energy supplies and the United Nations Food and Agriculture Organisation estimates that the number of people suffering from wood fuel shortages will grow to 350 million by the year 2000 (Lenssen, 1993).

It is fairly certain that the world population will grow from the present five billion to eight billion within the next 20 years or so and as a consequence the number of citizens without an adequate energy supply will further increase if "business as usual" is supposed.

Most of the two billion people without access to electricity live in thinly populated areas in developing countries and the extension of the grid to these areas is for economical reasons not feasible (Haufstein, 1996). Thus other solutions are needed for these areas.

The question arises why we have managed to satisfy extraterrestrial energy requirements but not those on earth. Undoubtedly many reasons can be found to explain this inconsistency but most of them will be beyond the scope of this research.
As demonstrated by space research, mankind is technically and organisationally capable of realising complex and impressive projects. There is no reason to believe that extraterrestrial power supply is economically more feasible, technically less complicated, or socially more obvious than the energy supply to the underdeveloped rural and remote areas on earth.
The opinion of Vermeersch (1993) is that the present global situation, in both positive and negative senses, is the result of the intrinsic dynamism and effectiveness of a system consisting of three components: science, technology and capital. He also argues that this system has developed into a more or less autonomous system in the sense that the human objectives to be realised, are not determined in advance. But could the answer to the preceding question not more simply be found in political unwillingness or incompetence to alleviate poverty, and the order of priorities in the world's efforts?
Additionally, it remains to be seen whether another order of priorities would have led to an appropriate worldwide energy supply. It is however frustrating to observe that at this very moment a large part of the global village lives in poverty and suffers a lack of water, proper health care and energy.

1.1.2. Energy for development

There is no doubt that energy is needed to achieve an acceptable quality of life for the global village as a whole. Over the next few decades a wide range of energy forms will be required to satisfy the increasing global demand.
Moreover, our global energy system is such that developed and developing countries are interdependent in their efforts to provide sufficient and affordable energy, and to maintain an ecologically sound planet. Emphasis should thus be on the development of a global energy and environmental policy, and planning to achieve a sustainable energy supply for the world's population and the mitigation of the impact of energy-related activities on the environment. The difficulties encountered during the Sixth Conference of the Parties to the Framework Convention on Climate Change (COP-6) held in The Hague, from 13-25 November 2000 demonstrate the complexity of this issue. Climate change is considered one of the most serious global problems and the build-up of greenhouse gases, such as carbon dioxide, is held largely responsible for this threat to the sustainability of the world's environment. In spite of this observation and the urgency of mitigation measures, the conference failed to reach consensus on a number of key political issues. The World Energy Council (WEC 1995) is right in concluding that the energy and ecological issues of both developed and developing countries, and the transition to a sustainable path of

development, will require a stronger determination by governments, energy enterprises and international organisations.
The majority of the world's population, primarily living in rural areas, lack a number of facilities as a result of poverty and insufficient access to energy. The conditions necessary to satisfy basic needs and to promote economic and social development cannot be fulfilled.
The majority of the additional 2.8 billion people predicted by the year 2020 are not even expected to have any access to commercial forms of energy at all, supposing "business as usual".
Khatib (1993) argues that the lack of access to a reliable energy source is a major impediment to sustainable development in developing countries and to the harmonious progress of the global society. He also believes that the idea that all nations on earth have a right – and should have the means – to pursue these benefits will become increasingly important in a world where opportunity is disproportionately divided between the industrialised countries of the northern hemisphere and the poorer nations farther south. Wider access to electricity in developing countries will be a key requirement for narrowing the north-south gap (see Figure 1.1). He also states that if electricity is to truly promote human progress in developing countries, then the problem of rural electricity supply must be addressed.

Figure 1.1. *Electricity: the difference between haves and have-nots.*
(photo left Ciske A. Anema; photo right G. Martha Zomers)

The subject of energy supply to rural and remote places appears on many agendas including that of the World Energy Council. During the 16th Congress held in Tokyo in 1995 the World Energy Council concluded: “the first challenge is to respond now, with urgency and determination, to the plight of over 2 billion people in lower-income developing countries, both the urban and the rural poor, who neither have electricity nor adequate access to other commercial energy. In consequence, they have no realistic prospects of breaking out of the vicious circle of poverty and taking the first steps towards development, higher living standards, and the reversal of serious local environmental degradation. The second challenge is that of achieving a path to sustainable development in the longer term. The next two or three decades represent the key period of opportunity for transition to a more sustainable path of development for the longer term. The direction is towards greater energy efficiency, greater conservation and recycling wherever appropriate, cleaner fossil fuel conversion and use, bringing forward more quickly of economic non-fossil energy ....” (WEC 1995).

It is quite clear that further investments in energy supply and use will be necessary to support both industrialised and, in particular, developing countries in making progress (see Tables 1.1 and 1.2).

Table 1.1. *Population with access to electricity (1990). (source: Khatib 1993)*

	Population with electricity (%)	Rural population (%)	Rural population with electricity (%)
Industrialised countries	100	27	100
Developing countries:			
China	75	66	63
India	25	73	10
Sub-Saharan Africa	19	69	5
Least developed	13	80	5
Other	78	45	63
Total developing countries	52	63	40
Total world	63	55	54

Table 1.2. *Rural electrification and population data. (source: IENPD 1995)*

Population	1970	1980	1990
World (millions)	3,635	4,428	5,267
Developing countries (DC)	2,543	3,185	3,919
Developing countries, rural	1,929	2,287	2,482
Percent. of rural population in DC with electricity	18	25	33
Number of rural population with electricity	347	572	819
Number of rural population without electricity	1,582	1,715	1,663

This study addresses electricity supply for rural and remote areas. Although electricity is a desirable commodity in the majority of the areas, it should be noted that electricity is only one of the options to satisfy the energy needs of the rural population and cannot be detached from other rural needs. Bringing electricity to the people is, in itself, not a contribution to reducing poverty nor does it automatically lead to rural development. However, the availability of electricity can support advanced development methods such as tele-education and it could provide access to distant information and support for farmers and other entrepreneurs. These important issues will be addressed in more detail in Chapter 2 “General considerations”.

1.1.3. Rationale of the research

Since electrification commenced, the electricity supply industry has brought many benefits to society. Today, electricity plays a vital role in our society, socially, environmentally and economically.
Until recently, a monopoly position, favourable financial strength, a reliable electricity supply, and a limited numbers of players, have in general characterised the industry.
Over the last few years, the sector has faced rather dramatic changes, the most salient being of an institutional nature. Today deregulation, power share, market forces, unbundling, non-utility generation and third party access to the grids are the new key words in the sector.
In a number of countries, the electricity supply sector has become the playing field of traders, economists and brokers, with standards, values, performance and procedures adapted to the new players and circumstances.
In some countries industrial, commercial and residential consumers are already able to shop for electricity and therefore the electric utility operators will primarily be directed towards effective competition. Obviously, the new circumstances will force utilities to reduce costs and to reconsider their strategies and

organisations. The possible social and environmental effects of this development will be addressed in Sections 4.6 and 4.7.
In industrialised countries, richer families are tending to leave the cities and move to the rural areas, even in a relatively rural province such as Friesland in The Netherlands (Bosma 1996). Also in the United States of America, pensioners are moving to rural areas and expecting to have the same benefits of electricity as in urban areas.
Utilities in the poorer nations of the world are however still struggling to maintain existing supply, and make electricity more widely available particularly in rural and remote areas. They face problems such as institutional weakness, lack of capital, uneconomic tariffs and, in some respects, substandard technical and managerial performance. These countries also have reasons to reassess their operations and in this respect they are encouraged, and occasionally "obliged", by lending institutions.
Apart from the institutional changes, utilities in both developed and developing countries have to meet increasingly stringent requirements to protect the environment and to conserve energy. Section 4.2 of this study elaborates on this issue.

It is noted that rural and remote areas often have substantial renewable energy potential. The IEA Renewable Energy Working Group Party (IEA 1999) argues that renewables are localised energy sources and that their deployment benefits rural and remote communities in terms of employment and income generation.
New technologies effect at both the supply side and the demand side and there is reason to believe that current developments and trends in the power sector will have an effect on the way rural electricity supply is approached. It is also likely that the developments will not only influence new systems but also existing rural electricity supply schemes.
A "wait and see" attitude is not the appropriate approach. Some two billion people and huge amounts of money are involved. Based on figures given by Schramm (1991), Foley (1995) and in MPS (1996), the average costs per connection can be roughly estimated at US$ 1200[1].
With an average of five persons per connection, an amount of some 500 billion dollars would be needed just to establish connection of the two billion people to the grid. If the costs for the generation and transmission facilities were included, the total amount would be in the order of 800 billion dollars[2]. The IEA Renewable Energy Working Party even estimated that in the next four decades over five trillion dollar would be needed for additional generating capacity only.

1 See also Section 2.7.1

2 For comparison: total annual development assistance budget of the Netherlands is 2.5 billion US$, and total costs of the International Space Station (ISS) project are estimated at 100 billion US$.

A literature survey revealed that rural electrification has been the subject of many studies and publications and the question had to be answered whether it would be socially and/or scientifically justified to add further to this research.
The answer to this question appeared to be positive. Existing literature, with a focus on developing countries, albeit comprehensive, has mainly addressed the technical, financial and socio-economical aspects in isolation. Moreover, the approach was almost exclusively from the side of specialists and seldom from a utility management perspective.
It was clear that a comprehensive historical analysis of a broad field of rural electrification cases can reveal lessons learned. To that end this issue got a prominent place in this study. An integrated analysis of the impact of recent technological and institutional developments, and other trends, on the electricity supply to rural and remote areas can contribute to the assessment of future technical and institutional arrangements.

1.2. Problem description and research questions

An exploratory survey, including a retrospective assessment of the author's personal experiences, led to the following observations.
Generally speaking, the electrification of rural areas is expensive. Capital cost are relatively high and revenues are frequently poor. Rural electrification is therefore often regarded as a utility's chafe.
However, rural electricity supply may have new dimensions because of recent technological advances, a better insight into the whys and wherefores, and the ongoing power sector reform.
In the last few years significant developments and a number of trends have appeared as has been indicated briefly in the previous section and which will be discussed in more depth in Chapter 4.

The developments and trends can be grouped into five dimensions: the environmental aspects of power supply and the sustainability of power resources, the technological advances, the organisation and performance of the power sector, the societal trends and the institutional aspects.
It is apparent that both energy sustainability and environmental constraints will increasingly force appropriate measures onto the global power sector. The progress in the field of energy technology, including renewables, has been significant and new opportunities present themselves through both demand side and supply side developments.
Renewables, for instance, can contribute to the mitigation of environmental problems. Conventional electricity generation will still be required but, for reasons of energy efficiency, the combination with heat production needs to be pursued. This requires a closer co-operation between the utility and industrial and commercial consumers in both rural and urbanised areas.

There is some doubt whether the ongoing power sector reform will have a positive or negative impact on the design and implementation of the inevitable programmes for energy conservation, environmental protection and the deployment of renewable technologies.
In many less developed countries the performance of electric power utilities supplying remote and rural areas has decreased gradually in spite of the provision of external financial support (EPUES 1991, SEED 1991). Moreover the benefits and progress of a considerable number of rural electrification projects has fallen short of expectations, financially and managerially.
The disappointing performance of utilities and relevant projects in some developing countries has already resulted in a distant attitude of lending agencies and a search for other institutional solutions to rural electricity supply than those using traditional utilities.
There is a worldwide trend towards power sector reform including the introduction of competition. This development together with the opportunities offered by renewables, could have a major effect on the way rural electrification is approached, not only in electrified countries but also in developing countries.
With the emergence of a more competitive and deregulated environment, utilities are being forced to reassess the benefits and costs of many of their internal business practices and to increase their efficiency. This development is at odds with electricity supply to rural and remote areas because of their generally unfavourable contribution to the financial performance of the utilities.
It is therefore possible that a drastic economic rationalism may result in a fall of interest in the electrification of rural areas. Will the rural population become the victim of this tension between economic and social objectives?

> *The central hypothesis is that current developments and trends force a more advanced approach to electricity supply to rural and remote areas, which should be reflected in the operations of utilities.*

From the previous sections the conclusion can be drawn that it is more or less a matter of both an established and a future problem. This study therefore analyses rural electrification issues in the light of past experiences and current developments in the electricity supply sector and aims to provide an insight into the way rural electrification should be approached.
The most important question is whether the appropriate institutional circumstances exist or can be created to take full advantage of the developments while taking into consideration current concerns and the "lessons learned".
Therefore the general research question may be formulated as follows:

> *"What is the impact of past experiences and current developments and trends in the electricity sector on the electricity supply to rural and remote areas, and which approach could lead to improvements?"*

The answer to this general question can be derived from the answers to a number of more specific underlying questions. These guiding questions can be formulated as follows:

1. *What are the features of rural electricity supply?*
   The reality of rural electricity supply is complicated and there are many relevant aspects. This subject is addressed in Chapter 2.
2. *How has rural electrification been effected over the years and why? What are the lessons learned?*
   To answer this important question, Chapter 3 addresses the historical aspects of rural electrification by describing and analysing a number of cases.
3. *What are the relevant developments and trends in the sector?*
   This question will be dealt with in Chapter 4 in which the nature and scope of the developments and trends are identified and assessed. This chapter also addresses the technologies currently available on both the demand side and the supply side.
4. *What are the implications for the electricity supply to rural and remote areas?*
   The implications of the findings for electricity supply organisations are outlined in Chapter 5 and in this chapter the general research question and the question that forms the title of the work, are answered.

1.3. Research justification

1.3.1. Research objectives

Originally, the research was initiated out of surprise that so many rural electrification projects in developing countries were considered to be below standard and also from curiosity into the possible effects of current sectoral developments and trends on rural electricity supply.

The idea that, where relevant, future electricity supply to rural and remote areas should be done following a fresh approach, played a role in the decision to actually perform the research. In the next sections this idea is explained from the societal and scientific perspective.

The research aims to prove the central hypothesis but it also seeks, in particular, to contribute to the question as to how utilities could take full advantage of new technologies and better insights to meet their objectives.

In fact the research has a dual objective. In one respect it aims to make a theoretical contribution to the scientific knowledge about rural electricity supply and in the other to generate and disseminate knowledge which could support decision makers of utilities and donor agencies when deciding on policy.

With regard to the latter point, the research concerns the field of strategic planning, including the implications for utility operations. To this end the research identifies and assesses relevant trends, looks ahead to opportunities for electricity supply to rural and remote areas and translates the results into operational recommendations. In this respect the present publication seeks to complement existing literature and to act as a vehicle to transfer specific managerial know how and -in particular- know why.

It is emphasised that this work is not intended to be a “how-to” manual for organisation structures and management methods. The implementation of the suggestions described, will need individual tailoring to specific circumstances and this can only be done on the basis of a thorough knowledge of the situation.
The results of this research are expected to contribute to the implementation, in rural and remote areas, of utility facilities that are energy-efficient and organisationally, environmentally and financially optimal and sustainable.

1.3.2. Target audience

Before starting this research, I addressed the question as to what message was to be disseminated and to whom. The answer is important because it reveals the antecedents of the target group and it allows one to “strike the right note”.
It is expected that this study will be read by decision makers of utilities and donor agencies on the one hand, and by specialists in some of the relevant disciplines on the other. I have focussed on the former and therefore the link with practice has been emphasised.
However, I am convinced that the implementation of any recommendation will still require the necessary support of specialists.

1.3.3. Societal relevance

The societal relevance of the research is based on the following observations.
The large number of “global villagers” in rural areas that are still deprived of electric power but undoubtedly want to use it in the very near future. A continuation of “business as usual” would imply an increasing number of people deprived of electricity.
The assessment of rural electrification projects revealed that many of the existing rural electrification systems in developing countries fell short of expectations and did not meet the objectives. The costs associated with disappointing projects can be very high, apart from the stakeholder’s frustrations.
The importance of an efficient, effective and affordable electricity supply to rural and remote areas.
The need to implement ecological and energy sustainable solutions in the world’s power supply. Rural areas in particular appear to offer opportunities for

the deployment of renewables and the obvious question is to what extent the possibilities can be geared to the demands of the market.
The tendency of reforming the power sector and introducing competition could have adverse consequences but also opportunities for rural areas. A well performing organisation is extremely important particularly when the developments become more radical and significant.
Given these observations, it appears sensible to investigate whether presently available technologies and insights enable and/or require a specific organisation of the electricity supply to rural and remote areas. The results could contribute to the betterment of the situation of rural communities and in the performance of the organisations serving their areas.

1.3.4. Scientific relevance

In literature, there have been many publications on electricity supply to rural areas. Many of them have been consulted for this research and some of the authors and organisations are mentioned below by way of illustration.
Foley (1990, 1991, 1995) addressed in his publications nearly all the many aspects of rural electrification. The United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) organised some years ago a number of meetings on the socio-economic impact of rural electrification and energy conservation. The proceedings of the meetings presented comprehensive and very useful information on these topics (UN 1990).
Other recent socio-economic studies that should be mentioned are: Barnes (1988), Mason (1990), Samanta and Sundaram (1983), Samanta and Varma (1980), Saunders et al (1978), USAID (1978), Fluitman (1983), Cecelski and Glatt (1982), Brodman (1982), Velez et al (1983), Ventekasan et al (1983), Wasserman (1983) and Shamannay (1996).
Barnes (1988) focussed in his study on the socio-economic impact of electrification. He also addressed cost-benefit ratios of electrification in both financial and social terms and the various rural electrification policies.
EPUES (1991) investigated the performance of decentralised diesel-based power stations and identified the main causes of substandard operation.
The Stockholm Environmental Institute has published many papers on rural energy issues including electrification and the deployment of renewable energy sources.
The National Rural Electric Co-operative Association in Washington has also been very active in the field of rural electrification. A recent publication (Inversin 1995) addressed private sector experiences in Nepal with creative ideas for cost-effective rural distribution systems.
Mbewe et al (1990) studied rural electrification in a number of African countries. This study focussed on the impact of electrification on regional development and on financial and economic aspects of electrification projects.

Although her study was not specifically oriented towards electricity supply to rural and remote areas, the work of Kristof (1992) should also be mentioned. Prompted partly by the limited fossil fuel energy resources and the environmental impact of their use, she researched into centralised versus decentralised energy economy including the deployment of renewable energy sources.

Most of the research has addressed issues such as the technical and financial performance of both grid connected and decentralised power systems and the socio-economic impact of electrification.
The implications of recent developments and trends[3] for power utility operations seem to have received less attention. No research is known of in which the effects of current developments and trends have been systematically and integratedly investigated. The present research undertakes such an task.
This study links existing theoretical knowledge, practical experience and empirical findings with the aim of increasing the specific expertise needed for organising utility operations. In this respect the publication also aims of bridging the gap between more theoretically focussed researchers and managers/decision makers with a more practical approach.
The research fits into the programme and activities of the Technology and Development Group of the University of Twente (Faculty of Technology and Management), The Netherlands. The research of the Group concentrates on rural electrification, and on the planning and management of small scale energy systems in developing countries, industrial development and the role of industrial companies, institutional development and the role of non-governmental organisations, and technology and sustainable development. The fact that the present research is partially approached from a management perspective, attaches an additional dimension to the activities of the Technology and Development Group.

1.4. Research boundaries

1.4.1. Research domain

This study is confined to the electricity supply to rural and remote areas. The effects of the developments and trends in large scale electricity supply systems and relevant organisations are not considered in detail. It is noted that the problems applicable to large scale systems differ from those of the electricity supply to rural and remote areas and are mainly of an administrative and technical nature.

3 The power sector currently faces unrivalled institutional and technical developments, see Chapter 4.

The importance of historical research is highly valued because it creates the possibility of identifying analogies and analysing the experiences gained with alternative arrangements. That is the reason why in Chapter 3 rural electrification cases in both industrialised and developing countries are described and analysed in some detail. These cases have been selected on the basis of the extent and quality of the available information, the diversity, and the involvement of the author. This historical analysis is a key part of the research.
Given the scope of this study, past research and the experiences in both developing and developed countries, it is argued that there is no need for an in-depth analysis of all the aspects of rural electrification. For instance such issues as tariff policy, the specific features which make electrification projects feasible, the incremental revenues and internal rates of return are not addressed in detail.
The reality of electricity supply to developing rural areas is very complicated and there are many relevant aspects. Therefore the features of the rural market have been listed insofar they are needed to draw conclusions regarding the appropriate approaches.

As discussed in Chapter 5 the conclusions can be grouped into three specific areas: the rural market, the available technology and institutional issues. Any further confinement would have the drawback of an increased probability that only part of the problems and possible solutions would surface.
The features of the rural market, and advanced technical opportunities for rural electrification, are discussed but the study focuses on the impact of the developments and trends on the institutional aspects of utilities. The emphasis is on an integral approach and on the success factors for rural electricity supply. Technical developments have been analysed to identify their possible opportunities and implications on both the supply and the demand sides.

In Chapter 2 “General considerations”, the socio-economic aspects of electricity supply to rural and remote areas are addressed but this is confined to a discussion of existing knowledge as opposed to own research or fieldwork. This limitation is justified given the scope of this study, and the fact that these aspects have received substantial attention in past research.
An in-depth discussion of the theories of organisation structures and management models is not necessary to answer the research questions. But appropriate solutions for organisational and managerial questions can only be identified and successfully implemented with a proper understanding of the nature of the problems and preconditions and of the environment in which they occur. This is the reason why considerable attention has been paid to the various aspects of the environment of contemporary utilities. The theory of organisations, the system theory, and social science are in this study used solely as tools. Consequently they are only open for discussion with regard to their selection and the way in which they have been applied.

1.4.2. Perspective

Contrary to most other academic research, this study was initiated from practice. The problem under consideration can be approached from various perspectives such as that of the global villager, the specialist and the utility manager. The study is marked by its width and thus requires interdisciplinary knowledge of utility operations, the technical installations and the demand side needs. In view of this requirement, the objective of the work, and the author's background, the research has been performed from the perspective of a utility manager. This implies certain limitations and specialists will probably find it regrettable that a more profound discussion of their disciplines get only limited space. The author would not claim to be an expert in all of the relevant disciplines. He has used specific publications of others to gain sufficient in-depth knowledge for the scope of this research.

Naturally, the statements contained in the study have been given a scientific basis. Because of the nature of the research, combining theoretical and practical experience, an occasional personal view or preference can hardly be avoided. The personal experience of the author is used however solely as a complementary and exemplifying role.

1.5. Method and structure of the research

1.5.1. Fundamental and application-oriented research

The viewpoint has been put forward that science should serve only for the solution of societal problems and that "science as such" should be avoided. We will avoid this debate, but it is observed that there is a difference between the notions of fundamental research and application-oriented research.

Many researchers have addressed this difference (Kramer 1978). An important difference is that fundamental research can be considered as independent of time, place, subject/client and observer while application-oriented research is subject/client dependent. In the of former case there is no direct beneficiary while in the latter case a concrete person or organisation can always be recognised (Groen, Emshoff cited in Kramer 1978).

Another important difference is that fundamental research basically aims at maximum truth and application-oriented research at maximum usefulness (Van de Poel 1977 cited in Kramer 1978).

It is however questionable whether a strictly qualitative distinction is meaningful: fundamental and application-oriented are interrelated and moreover the choice is often arbitrary.

Vogelezang (1994) for instance argues that, in technology the applications are in fact the horizon of all research, fundamental research included. Andriesse

(1994) states that energy research is for the greater part, or even totally, application-oriented.
Radelaar (1996) observes that, frequently, the notions of fundamental and applied research do not cover certain activities and he concludes that the distinction is in fact meaningless because neither can exist without the other. Also Beuker (cited in Vogelezang 1994) is of the opinion that avoiding a distinction between fundamental and applied research is perhaps the best solution.
Not a theoretical, but a pragmatic approach is needed. Long term fundamental research remains necessary to further explore basic existence and there is also a need for application-oriented research to help solve society-driven problems.
Obviously, research must satisfy certain rules but these are not necessarily different for various kinds of research (van Strien cited in Kramer 1978). The assessment criteria however should be adapted to the particular features of the specific type of research.

The present research was carried out starting from the perceived need of the "market", albeit that my curiosity into the whys and wherefores of rural electricity supply had also been a motive behind the activity.
I tried to approach the research in such a way that a synthesis of academic research and power utility practices could be achieved without jeopardising the academic standards demanded by the university. In doing so, I had to balance the degree of attention paid to the various subjects. This involved the risk of a "conflict of interests", but in this respect the decisive factor was that the research should properly be adapted to the needs of the electricity sector.

1.5.2. Multidisciplinary approach

In the past rural electrification projects were frequently treated as solely technical activities and separated from other rural aspects. The statement "the client disposes of electricity and will therefore be happy" is sometimes heard, but frequently appears to be incorrect.
Evidence suggests that rural energy supply must be treated within the context of rural development at large. Dividing the development problem into more or less "autonomous" areas that are considered somewhat interrelated but not interdependent appears to be neither efficient nor effective. It is extremely important that all consequences and all aspects of policies and actions are not overlooked. To this end, thinking in processes rather than in disciplines is needed.
In 't Veld (1995) concludes within the framework of a future policy, that regarding business administration research, most emerging problems have a multidisciplinary nature. He also argues that, at present, proposals for multidisciplinary research are not to be expected from university scientists.

In effect this research aims at giving an organisation advice, in such a form, that those involved can make relevant decisions applicable for their particular situation.
To transfer expertise to the industrial sector, a thematic and – even more importantly – an integrated approach is necessary (Vogelezang 1994). Moreover, one should focus on the recognition of both problems and the directions of solutions.
That is why a multidisciplinary approach has been adopted with priority given to a wide scope. However, a number of specific areas were studied in more depth and that caused the multidisciplinary approach to be a challenge, in addition to a requirement.
The energy supply to developing rural areas is an area *par excellence* where technology, organisational, social and economical sciences should work together. The present research does not unveil a new area but adopts an integrated approach to identify the implications of various developments for the organisation of power supply utilities in rural and remote areas.

1.5.3. Research method

The objective of this research is to identify and assess relevant trends, to look ahead to opportunities for electricity supply to rural and remote areas, and to translate the results into recommendations that can be used by decision makers. This study therefore analyses rural electrification issues in the light of past experiences and current developments in the electricity supply sector and discusses theoretical aspects related to the environment of electricity supply utilities.
Actually this research field lacks a sound theory albeit various theoretical propositions exist in sub-areas. A method based on the formulation of hypotheses followed by validation based on empirical facts therefore seems appropriate. However, in view of the nature of the subject and the scope of the present research however, an assessment based on operational evidence is barely possible.
In effect this work consists of three components: an analytical, a theoretical and a practical component divided between a number of chapters. The analysis of the developments and trends leads to three research themes: the rural market, the available technologies, and institutional aspects. The dimensions of the latter theme, and more particularly the environment of utilities, are elaborated upon as part of the theoretical component. The implications of the findings for electricity supply organisations are outlined in the practical, or application oriented component, of this work.
As a first step existing knowledge and personal experience were combined and hypotheses formulated. Likert and Minzberg (cited in In ’t Veld 1995) showed that such an approach can produce excellent results. These two scientists

performed hardly any of their own research but based their work on the results of other researchers. The results of their work have had a strong influence on the development of organisational knowledge.
Following the first step, the central research question and a number of guiding questions were formulated. The latter are related to different themes and serve as guidelines for the study.
Next the specific features of the developments and trends were identified with particular reference to the analysis of their possible impact on organisations.
The activities revealed three specific areas of influence: the rural market, the technology, and institutional aspects.
To answer a number of questions a thorough insight into how and why the electrification of rural and remote areas was established in the past is needed. This led to comprehensive historical research. A number of cases have been described and analysed, and conclusions drawn on the basis of three aspects: the institutional circumstances, the available technical solutions, and the features of the market.
The information needed for the research has been obtained from:

- study of literature;
- survey of policy documents, project assessments and progress reports;
- supervision/monitoring of field studies performed by others;
- participation in ongoing international studies;
- case studies including conducting field interviews.

Furthermore the author's personal experience in the electricity supply sector has been included.
A number of case studies are used throughout the research but they mainly provide qualitative information. The lack of statistical data and other quantitative information could be considered as a weakness of the research.

1.5.4. Desk and field research

The desk study included:

- a literature study on such issues as rural development, utility operations and performance;
- analysis of reports on technical facilities for rural energy supply;
- a review of publications on the institutional developments and arrangements in the power sector of different countries;
- comprehensive historical research into the rural electrification in various countries since 1890;
- a study of other publications on selected topics.

This research is partly based on the author's own observations and experiences in the electricity supply sector. To justify the latter, reference is made to the late

professor Feldmann of Delft University (cited in Hesselmans 1995) who put experience ("be able to") first and foremost. He attributed scientific value to experience but he also argued that for an engineer to be effective, he had to be familiar with fundamental science as well.
As part of the research, experiences with a number of rural electrification projects in developing countries have been investigated.
Interviews have been held with owners and managers of decentralised power stations and with staff of organisations involved in rural energy systems. These interviews were open and no formal questions were formulated because of the differences between the organisations.

Field research was performed as part of the problem identification phase but, in addition, attempts were made to relate some of the case studies with a theoretical model of the environmental conditions with the purpose of illustrating the consequences for the organisation.
The case studies have deliberately avoided too many details with the aim of focussing on the main subject, to wit the institutional and organisational aspects.
Reports on the interviews were made for verification purposes. However it is noted that the validity of the cases based on interviews is not of prime importance for two reasons: the cases in themselves are not the subject of statements, and no general conclusions are drawn. The significance of these cases is mainly in terms of illustration.

1.5.5. Systems and models

Difficulties in solving problems are often the consequence of a lack of sufficient insight into the relationship between relevant phenomena (Kramer 1978). Every manager uses consciously or unconsciously analytical tools and theoretical models during the design and management of organisations (Staehle 1973).
However a precise mathematical description of most problems is impossible without drastic simplifications. The nature of the problem considered here suggests that an approach is needed which is based on experience rather than on a derivation from a theoretical framework.
Thinking in terms of systems should be seen as a means to support analysis and synthesis. System thinking enables us to achieve a structured view of more or less separate developments and trends. This could lead to a more effective search for opportunities to improve situations and to take better advantage of situations. It goes without saying that a system in itself does not solve problems. To achieve this all existing disciplines have to play a part.
The question arises whether it is meaningful to adopt the concepts and methods of system theory. Within the scope of this research, I believe it would distract to

discuss the ins and outs of system theory and I have therefore summarised the interpretations of Kramer (1978) and Udink ten Cate (1992)[4].
In systems theory, the notions of hard and soft systems, and systems analysis are distinguished. The latter is used as a means of making policy decisions. Soft systems are mainly found in problem areas covered by social, economic and organisational sciences and are very difficult to describe. An important feature of a hard system is that the observer is situated outside the system. In soft systems, the observer is part of the system. Checkland (cited in Udink ten Cate 1992) introduced a methodology for soft systems, named “action research”.

To assess the degree of influence on the utility of the external developments and trends, an insight into the relationship between the utility and its environment is required. This subject however does not lend itself to numerical modelling and only quantitative research can reveal appropriate solutions in terms of results and specific circumstances. In this research, the model of Staehle (1973) has been adopted as a basis. This model assumes four more or less independent variables each having implications for the structure of the organisation and the management system (the dependent variable).
To identify organisational opportunities, a vision of the structure and management of organisations is needed. In this research, a vision is adopted which is based on the contingency approach which is discussed in more detail in Chapter 5. This approach departs from a pluralistic view of organisations and aims at specifying *how* problems concerning the structure and management can be tackled. A salient feature of this approach is that both the structure and the way an organisation functions are supposed to be strongly influenced by the specific situation.

1.5.6. Structure of the study

In effect this study consists of three components: an analytical, a theoretical, and a practical component divided between a number of chapters.
Chapter 1 has set the scene arguing that energy is needed to achieve an acceptable quality of life and that the urgency to electrify rural and remote areas must be seen within the context of human need priorities. This chapter also explains the whys and wherefores of the research and it also covers such issues as the research method and the problem description.
Chapter 2 emphasises that developed and less developed countries do have a number of problems in common and that “living apart together” needs to become more meaningful. This chapter provides background information on

4 For a practical approach of systems thinking and system development see also Schlange (1996)

issues which are relevant for the electrification of rural areas such as poverty, rural development, environmental degradation concerns, and energy needs in general. The objectives and socio-economic aspects of rural electrification are also addressed.

As suggested in Sections 1.1.3 and 1.4.1, the analysis of historical aspects of rural electrification is a very important part of this research and therefore a number of cases have been described and analysed comprehensively in Chapter 3. This together with Chapter 4, in which the nature and scope of the developments and trends are identified and discussed, constitutes the analytical component.

Chapter 5 outlines the implications of the findings for electricity supply organisations and therefore constitutes the practical, or application oriented, component of this work. In this chapter the question included in the title of this study, is also answered.

The final chapter reflects on the likely future developments in the field of electricity supply to the rural and remote areas of this world.

Chapter 2

General Considerations

The electrification of rural areas in developing countries is complicated and requires a multitude of skills and techniques. The objectives, planning, realisation and operation of rural electrification projects cannot be detached from such problems as poverty, environmental degradation concerns, rural development and energy needs in general. Other important issues include the global unification process, the costs and benefits, and the socio-economic impacts of electrification. This chapter aims to provide relevant background information on these issues.

2.1. The unification process

The world is on the threshold of a worldwide information era and the opportunities offered will increasingly lead to a "smaller" world. Vermeersch (1993) argues that the fast dissemination of knowledge and material goods, together with the ever improving communication, increasingly leads to global unification and that this development will gradually result in a common world view and material needs for the global population as a whole. The extensive and fast dissemination and processing of information is also expected to lead to more uniform government policies and probably to a more even behaviour of humans worldwide.

Although our world increasingly shows evidence of a "global village", a corresponding community spirit lags behind. Social and cultural diversity is, however, clearly visible (Band 1995).

Although a redistribution of assets is increasingly needed for social reasons, and to promote stability and sustainability, it appears that in our society the social disparity and the number of the poor is growing again (Pronk 1994).

"Living apart together" needs to become more meaningful and it is therefore necessary that citizens identify themselves with each other and have sufficiently strong community ties (Achterberg 1995). Only under these circumstances can joint feelings and commonly accepted standards and values have the chance to become unifying forces.

There is some evidence that the underlaying principle of development co-operation is no longer to assist developing countries in achieving "western levels". The focus is rather on joint efforts towards sustainable solutions for common problems (Hommes 1994).

Developed and less developed countries indeed have not only a single planet in common but also a number of problems. Poverty, shortage of potable water, environmental degradation, future energy supply, and the development of backward areas are, to a certain extent, interrelated and are (and will increasingly be) the sources of common concern. In this respect, all the countries of this world are interdependent and they have a common, albeit differentiated, responsibility which requires joint effort.

There is no doubt that the world has the technology and the financial resources to solve most of the problems noted above. However a lack of adequate institutional, organisational and, in particular, political conditions seems to prohibit their application.
It is obvious that political and other intolerances fit badly with the problems the world is facing. In this connection it is regrettable to record that in 1995 and subsequently many more financial resources than expected were needed for peace-keeping operations all over the world. These resources could otherwise have been spent on poverty alleviation and development activities (NRC 8 May 1996).
If the alleviation of excessive poverty and environmental degradation, and the securement of appropriate resources do not act as unifying forces, the coming decades will show continuing human distress and increasing instability and conflicts instead of urgently needed co-operation.
There is thus more than sufficient reasons to consider problems such as poverty alleviation, environmental degradation and the development of backward areas, as a common responsibility rather than issues with a local or regional character.

2.2. The poverty problem

The most pressing world problem is poverty, followed by environmental degradation (Tinbergen 1994). In this context, the poor are considered to be those people who earn insufficient to provide a minimum quantity of food and accommodation. However, poverty is not limited to a lack of such basic needs but refers also to deprivation and non-material issues such as social contacts (Berg 1995).
It is often underestimated how a hopeless situation can drive people to desperation. Desperate people cannot be prevented from migration leading to urban congestion and dramatic refugee problems. The majority of the 1.3 billion extremely poor people (with incomes < US$ 1/day) are living in rural areas. In many developing countries the urban population is growing three times as fast as the rural population and consequently the number of urban poor increases very rapidly.
The poor are often trapped in their deprivation. As can be seen from Figure 2.1, the so-called clusters of disadvantage: poverty, isolation, powerlessness, vulnerability and physical weakness interlock causing a vicious circle of poverty (Chambers 1993).
But Jazairy (1992) argues that it is a great myth that the poor are destined to remain in their dismal conditions, that poverty is so widespread and deeply ingrained that it has become an inevitable part of the socio-economic landscape. Instead poverty should be seen as the “new frontier” of human advancement and development. The rural poor have to be perceived as actors in development, not as objects of welfare.

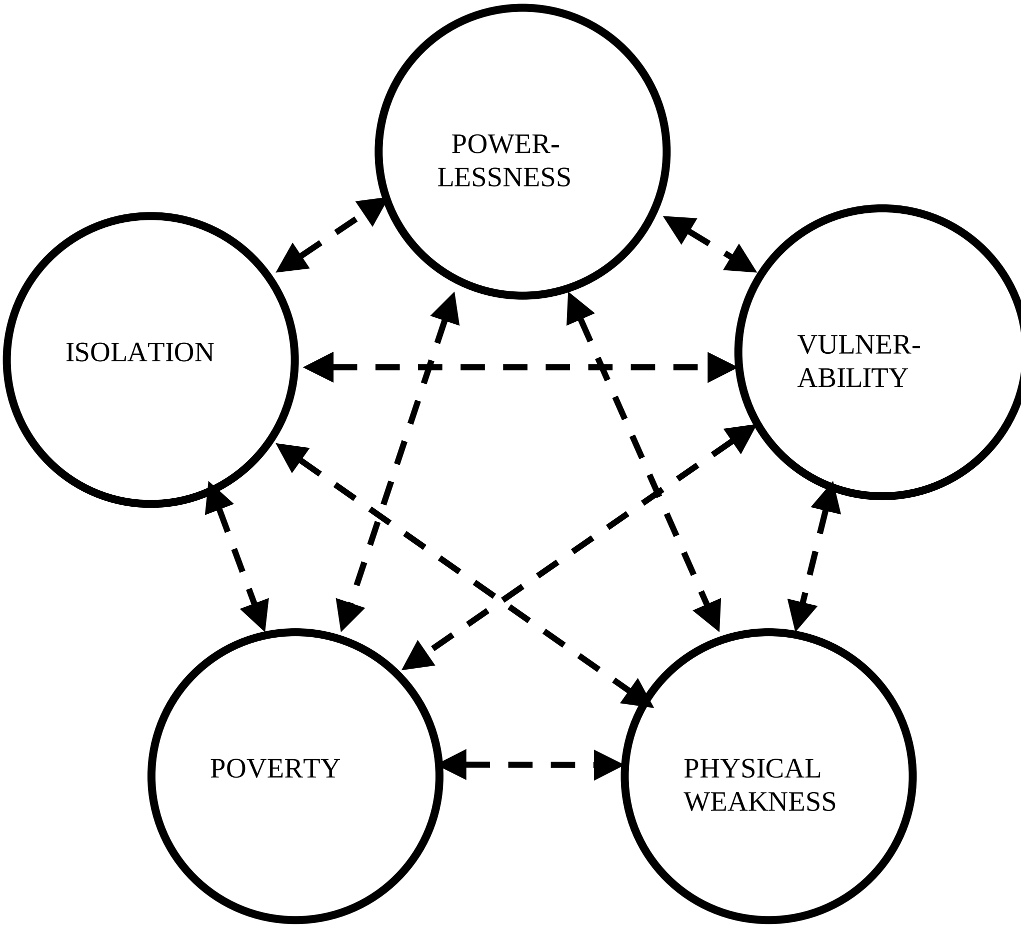

Figure 2.1. *Circle of poverty (Chambers 1993).*

This opinion corresponds to a certain degree with the view of Chambers (1993). In the process to understand rural poverty Chambers also distinguishes two cultures of outside observers: a rather negative academic culture and a more positive culture of practitioners. Each culture has a low view of the other and the gap between them is often wide since both have different explanations for rural poverty. He argues that both cultures are related to urban-based outsiders and therefore in danger of overlooking the bottom-up approach and that a third culture, of the rural people in a particular place, is the true centre of learning for understanding rural poverty and to better judge what to do.

The 1991 White Paper on Dutch Development Co-operation policy (cited in DGIS 1993) identified, in relation to global poverty, the following changes which are expected to affect the prospects and opportunities for developing

countries over the next decade: the changed political and economic relations between east and west, the necessity of sustainable growth patterns and the decreasing power of national policies in a period of globalisation.
Telecommunications and information technology, and tourists from wealthier countries, enable the poor to observe the situation elsewhere, and the impulse to improve their own circumstances will become stronger. The wealthier part of the world cannot deny these endeavours of the poor.

The World Development Report 1990 (World Bank 1990) concludes: “no task should command a higher priority for the world’s policy makers than that of reducing global poverty. The means for reducing poverty are at hand and the principal elements of an effective strategy are well understood and that the external resources needed to support it could be made available at little cost”.
The report suggests that rapid and politically sustainable progress on poverty has been achieved by pursuing a strategy that has two equally important elements. The two elements are mutually reinforcing; one without the other is not sufficient.
The first and most important element is to provide basic social services to the poor. Primary health care, family planning, nutrition, and primary education are especially important.
The second is to promote the productive use of the poor’s most abundant asset – labour. It calls for policies that harness market incentives, social and political institutions, infrastructure and technology to that end.
Within the context of the subject of this study, poverty should not only be seen in terms of a marginal existence, a lack of educational facilities etc., but also as not having access to information and energy supplies including the necessary related services.
With regard to the relationship between poverty and energy, Diallo (1996) argues: “the widespread deficit of energy services in most communities in Africa may not be simply the consequence of poverty as many analysts argue, but its primary cause”.
With the provision of affordable, readily available and environmentally acceptable energy, the living conditions of the poor in rural areas can be improved and the policies to promote productive use supported. Electricity is one of the options.

In 1996, the richer industrialised countries agreed on an ambitious plan to help in halving poverty over the next twenty years, and to support developing countries in protecting the environment (OECD 1996). It should, however, be noted that during the last few years in many countries the emphasis has increasingly been put on achieving economic objectives rather than on social aims such as the mitigation of unemployment and poverty.

2.3. Rural development

Energy is essential and without it societies can neither function socially nor commercially. Without sufficient and adequate energy resources, developing countries will not be able to foster the social and economic developments that are crucial for growth.
Ebohon (1996) concludes, on the basis of recent research in two African countries: “there is a simultaneous causal relationship between energy and economic growth for both countries, the implication being that, unless energy supply constraints are eased, economic growth and development will remain elusive to these countries. Given similar economic characteristics and profiling the same energy scenarios for other developing countries, the findings supports the view that energy plays a key role in economic development”.
On the basis of the complementary relationship, he also states: “modernising economies must take on board the protracted energy problems in the countries. Growth strategies must be validated against the attendant energy requirements. Otherwise, current and future growth prospects would be hampered by energy shortages”.

The population of the world is expected to increase to 8.5 billion by the year 2025 (UN 1995).
In developing countries the majority of the people still live in rural areas but urbanisation is growing (UN 1993). In 1950, about 83%, and in 1975 about 75%, of the population in developing countries lived in rural areas. At the turn of the century some 60% of the population of developing countries is expected to live in the rural areas but nevertheless rural population continues to grow by 1.4% (Asia) and 2% (Africa) per annum.
The pace and scale of urbanisation is a source of anxiety because both the urban and rural sectors are weakened through migration (UN 1993). The decision to migrate from rural areas to urban centres is made by individuals or families and is prompted by external factors such as hopeless poverty and local environmental degradation. According to this report, the only measures which are effective in the long run in releasing the pressure on migration encompass a control on the population growth, the creation of employment and the education of both individuals and families.
Experience has shown that measures aimed at the development of both existing rural areas and new urban centres were most successful in curbing migration. It appeared that co-ordinated international efforts could be very effective in attacking most of the migration problems in the region itself.
However, as was as also the case in industrialised countries in the nineteenth century, many developing countries have paid little attention to rural areas; and investments in social, transport and energy infrastructures have been limited. Stewart (1995) argues that the neglect of rural agriculture in Africa over the past decades was probably the single most important policy mistake. The limited

investment in agriculture and the associated infrastructure led to a substandard performance of this sector, and indirectly to a deterioration of the living conditions and a regression in the economical development.
In “Without Waiting” (1995) by the United Nations Food and Agriculture Organisation, it is also noted that the recent structural adjustments in many developing countries, including the settlement of foreign debts, have contributed to a decline in agricultural investment. Because the emphasis has been on urban and industrial development, insufficient attention has been paid to small scale rural enterprises.

The value of rural areas and particularly their value in terms of agriculture as a means for economical growth, is being rediscovered. The keyword during the 1996 Food Summit in Rome was rural development (Leijendekker 1996). The World Bank report, presented during the summit, emphasised the need to re-address rural growth and poverty alleviation in order to reduce dependence of foreign countries in terms of food on the one hand, and to curb migration to urban centres on the other.
An improvement in the living conditions in rural areas can be effected through satisfying basis needs and by promoting small-scale industrial activities aimed at increasing economic independence.
Research has revealed that in many developing countries most of the industrial employment can be found in small-scale enterprises in rural areas and this is one of the reasons why sufficient attention should be paid to rural development. In this context is should be stated that an adequate provision of services, infra-structure and technology has a decisive influence on the growth of agriculture and associated industries.
Rural areas should not solely act as a supplier of raw materials but should also aim at the manufacture of products with an added value (DGIS 1992). This aspiration can only be realised if modern forms of energy, particularly electricity, are available. After rural Ireland was electrified, it appeared that rural industries were able to manufacture more sophisticated products.[5]

2.3.1. Region oriented approach

Rural development programmes generally aim at an improvement in infra-structure, particularly to stimulate local industrialisation, agricultural production and social services such as health care and education. Rural development plans tend not to include electrification. As a consequence, and in spite of the availability of electrical energy, there are very few development projects that include a clear view of how, where and to what extent electricity can be utilised

5 See Section 3.1.

within the activities of rural development for instance in the agro-industry (Valencia 1990).
Although adequate energy provision is not the only relevant factor in rural development, it is one of the prerequisites for improved agricultural and rural industrial productivity, and the emergence of a middle class. Modern energy, particularly in the form of electricity, in combination with other essential conditions can help raise agricultural output by promoting innovation and improving irrigation. Electricity, in particular, has also a vital role to play in improving living standards through satisfying the basic needs of rural households such as lighting. Improved energy supplies can enhance the success of programmes related to water supply, health care, education etc.

Based on an assessment of the actual benefits and costs of electrification projects, Pearce and Webb (1987) stated the view that it is more useful to integrate rural electrification into a wider rural energy development scheme[6].
Ranagathan (1992) concludes, on the basis of five country studies in Africa[7], that rural electrification in many African countries is not financially viable and, because of the very limited productive use of electricity, will be unlikely to attract funds in view of other pressing needs.
He notes that it would require “a quantum change in thinking, to realise the far-reaching but imperceptible impact of lighting the lives of people and alleviating manual drudgery through mechanisation”. To operationalise such a view, he argues, rural electrification has to be packaged as part of rural development, rather than as a service which delivers the stand-alone benefit of electricity.

Vogel (1993) argues that a broad definition of rural electrification[8] ensures that regional planning objectives can be considered and that electrification can be regarded as a sub-programme and development tool rather than one out of many vaguely defined “projects”. He continues by saying: “within this region-oriented approach the differentiation of settlements structures, economic sectors and development levels and infrastructural facilities has to be considered as an important set of frame conditions affecting the options within a rural electrification programme and the identification of priorities. In a widely tradition-oriented society ... the existing structures of regional and local administration with their specific friction potential constitute another crucial frame condition to be considered”.
However the emphasis should not be too much on modern energy resources. Abdalla (1994) states that rural development plans should include a reliance on traditional energy technologies whenever feasible as such technologies have, in

6 See Section 2.5.
7 See the case description 'Rural electrification in Africa' in Chapter 4.
8 See Section 2.5.

many cases, been developed over a long period of time to meet the specific needs of the rural areas. She also argues that women make many of the decisions regarding household consumption of energy and that this means that their education and involvement is important to the success in achieving sustainable development.

All these considerations underline the need for an integrated and region-wide approach to rural development. Such an integrated approach in rural development schemes would of course demand close co-operation between programme developers, energy engineers, foresters, sociologists, and the participation of the local population. It is noted that there are probably few examples of such an approach, mainly because of the tendency in many developing countries to centralise planning and decision making.

2.4. Definition and features of rural electrification

Basically, the concept of rural electrification refers to the electricity supply to areas outside of cities. But many researchers have given the concept highly divergent interpretations.

Munasinghe (1990) notes that rural electrification schemes are often defined in terms of local administrative units, mainly for convenience in implementation. He also observes (Munasinghe 1988) that most often the term “rural electrification” refers to connections to a central grid. He continues by saying that this is not necessarily the most economical method of electrifying every region in every country.

Vogel (1993) observes: “according to the international discussion and the understanding of agencies such as the World Bank, the concept of rural electrification does not only refer to strictly rural areas as defined in the country statistics but may also include small to medium-sized towns which are service centres for the surrounding rural areas within a given region”.

Barnes (1988) defines rural electrification as “the availability of electricity for use in rural communities, regardless of the form of generation”. Yaron et al (1994) simply state: “rural electrification is the process of bringing electricity to rural communities”.

Maillard et al (1985) state that an exact definition of rural electrification raises the issue of delimiting urban and rural areas. They argue that a differentiation on the basis of statistical data carries with it the danger of inaccuracy because of the differences between countries, and because of the fact that data are often unreliable. It should also be noted that the classification of urban and rural areas based on statistical data, disregards specific features and opportunities of both areas. Maillard et al. proposed the following definition: “rural electrification comprises all activities aimed at enabling users situated outside major cities to have access to electricity. The electrification process can be differentiated from the conventional scheme of extension of a national grid, as it covers everything

up to independent configurations supplying power for a specific, determined need, and the solving of specific technical and economic problems".
Mason (1990) argues that in all relevant sectors including electricity supply, "rural" suffers from the same definitional problems. Although surveys have revealed that most of the rural electrification projects in the past referred to communities of between 500 and 2000 people, both Mason (1990) and Foley (1990) state that the definitions of rural electrification vary considerably between countries. In one country 'rural' also includes provincial towns with a population up to 50,000 and in another it refers to small farming villages and surrounding areas.

One of the consequences of these differences in interpretation is that a comparison between rural electrification projects in different countries is extremely difficult if not impossible.
Mason (1990) correctly states that a uniformity as to the interpretation is not, per se, necessary but that it is important to identify those areas that require special financing, technical and institutional approaches.
This view is confirmed by experiences in Ireland with the rural electrification programme in the 1940s and1950s. Shiel (1984) stated that the meaning of "rural" was defined by the Electricity Supply Board and the government of Ireland because subsidies were given for rural areas only. Towns and villages with populations of over 250 were not considered rural and nor were isolated loads of over 100 kVA maximum demand.
After some time, this definition led to the peculiar situation where the areas surrounding villages were electrified while the villages, with over 250 inhabitants, had no electricity or had to rely on inadequate local generation. A redefinition of the concept of 'rural' was needed.
This experience also shows the importance of a planned approach that takes the whole area into account.

In the context of this study "rural electrification" encompasses the activities designed to provide people with access to electricity in those areas which show specific features. These features do not only include low loads and the need for special approaches as suggested by Mason, but also area specific opportunities.
The method of bringing electricity to these areas can be very different including isolated generators serving a single or several consumers, supply from a regional or national grid, and solar home systems. It is also observed that the methods can vary, depending on local circumstances and the degree of saturation of the electricity supply (see Figure 2.2).

Figure 2.2. *Informal (private) electricity distribution grid (220 Volt AC) with bamboo poles.*

2.4.1. Features of rural electricity supply areas

From the energy point of view, there are important differences between urban and industrialised areas and rural areas. Urban and industrialised areas feature a substantial higher energy density and market opportunities for both heat and power relative to rural and remote areas.
Linked with these differences are the methods and opportunities appropriate to satisfy the energy needs. The features of urban and industrialised areas make it economically more attractive to develop and operate connections to a local, regional or even a national power system, to efficiently deploy combined heat and power units, and to provide adequate services. These circumstances offer opportunities to provide heat and power at reasonable prices.
Rural areas show other features. They can, for instance, be characterised by scattered clusters of premises (as is for instance the case in The Netherlands) or by scattered single farms (as is the case in Ireland, Australia and Canada).
In most developing countries rural electricity systems are characterised by dispersed consumers with often limited consumption, a low load factor and relatively low quality of power supply. Dispersed consumers require long supply lines and/or diesel-based or other generating units.

In spite of the differences between urban and rural areas, Pearce and Webb (1987) hold the view that the electrification of rural areas is not sufficiently special to justify an evaluation procedure that differs from the general appraisal of power sector projects and other rural energy investments.

They identified various reasons that are usually advanced in favour of a special approach to rural electrification: it benefits the poor, it acts as a catalyst to rural development, rural energy problems are particularly complex and rural electrification offers an easily replicated solution, it assists in reducing rural-urban migration and thus in the alleviation of urban congestion and its associated social consequences such as poverty and crime, it helps to promote political stability in rural areas and it has, through the provision of better lighting and refrigeration, social benefits such as an improved health, the enhancement of literacy, general education and the social cohesion and development in rural communities.

Subsequently they conclude, on the basis of an assessment of the actual achievements of various projects and existing literature, that “with the exception of backward and forward linkages into agriculture”, the direct benefits of rural electrification are not sufficiently “special”.

They argue “…. gains in agricultural productivity can be treated in the usual way of estimating producer surplus with and without electrification, while gains to householders can be treated in terms of the usual cost-difference and surplus gain measures, although the quality aspects of household electricity provide the major challenge to the analyst”.

The conclusion that rural electrification is not sufficiently special relative to urban electrification, leads Pearce and Webb to the proposition: “conventional rate of return criteria should play a stronger role in determining rural electrification expenditures and that some of the non-monetary benefits appear neither to be widespread nor as strong as supporters of rural electricity suggest. While rural electrification is nonetheless important in the development process, it is more usefully integrated into wider rural energy development schemes”.

On the basis of this statement Ranganathan (1992) draws the conclusion: “Pearce and Webb reject the social benefit argument asserting that the non-monetory benefits of rural electrification are neither as widespread nor as strong as to warrant a side-stepping of the conventional rate of return criterion”.

In fact Pearce and Webb do not reject the social benefit argument *in itself* but they conclude, on the basis of an assessment of the actual achievements of projects, that there is no or only little evidence that the expectations regarding the benefits often attached to rural electrification, have been substantiated in the past.

It should however be added that, although non-monetary benefits cannot be quantified, it does not necessarily mean that they do not represent a value in social and political terms. As appears from the cases described in Chapter 3, the electricity supply to rural and remote areas have mostly been treated as “special” cases in such terms as rates of return, subsidies and technology.

Mason (1990) also raises the question as to why there should be a distinction between rural and urban areas for the purpose of power distribution programmes. She argues that rural distribution projects generally cost more than urban distribution projects per connected household and that government policies are sometimes directed specifically at the rural areas making it necessary to identify rural areas in electrification programmes. The higher costs of rural electrification will have implications for the financial and economic viability of these projects and this makes it essential that they are separated from general power distribution programmes. However in some countries power distribution installations often cover the electricity supply to urban, peri-urban and rural areas and therefore a precise separation may be difficult.
There are three major reasons suggested for a distinction between rural and urban power supply:

- Rural electrification schemes generally cost more on a per connection basis as a result of dispersed loads, the rather low consumption and the poor load factor.
- Rural electrification should be integrated or co-ordinated with other rural development programmes.
- Urban and industrial power supply, and rural power supply need different marketing and technical approaches.

Table 2.1 summarises, for the purpose of mutual comparison, a number of features specific to urban/industrialised supply areas and rural supply areas. The combined effects of the specific features of rural power systems and their more problematic operation and maintenance, make the marginal costs of electricity supply to rural consumers high relative to that of consumers in urban areas.

2.5. Objectives of rural electrification

In the past, the electrification of rural areas has often been seen as a remedy to a number of problems such as deforestation for fuelwood, poverty, and migration to urban areas (see Table 2.2). However most of the impact studies of the last two decades[9], have revealed that the majority of these problems cannot be solved by electrification alone.

9 Socio-economic studies from the last two decades include Abdalla (1994), Barnes (1988), Brodman (1982), Cecelski and Glatt (1982), Davis (1994), Fluitman (1983), Foley (1990), Maillard (1985), Mason (1990), Munasinghe (1990), Mustanoja et al (1991), Nziramasanga (1995), Pearce and Webb (1987), Samanta and Sundaram (1983), Samanta and Varma (1980), Saunders et al (1978), Schramm (1991), USAID (1978), Shamannay (1996), Valencia (1990), Velez et al (1983), Ventekasan et al (1983), Vogel (1993) and Wasserman (1983).

Table 2.1. *Typical features of industrial/urban and rural supply areas.*

Feature	Industrial/urban supply areas	Rural supply areas
Area load density (kW/km²)	500 to 100,000	2 to 50
Consumer density (conn/km²)	> 500	1 to 75
Number of consumers per km line length(both MV and LV included)	> 75	1 to 75
Consumption density (kWh/km²)	> 2,000,000	5,000 to 200,000
Total costs/kWh (USct)	10 to 15	Grid based: 12 to 50
		Diesel based: 25 to 100 or more
		PV home systems based: 50 to 500
Investment costs per connection (US$), excl. gen & transm.	<500	500 to 7000, average 1200, extremes of over 100,000
Social aspects	limited	specific financial support and solutions needed
Technical/ organisational aspects	large projects; often heavy power technologies on supply and demand side; reasonable load factors as a result of mixed loads	various technologies and small scale applications; low load factor because of dominant domestic and agricultural loads; intensive customer support needed; ratio of labour to capital high.
Socio-cultural aspects	seldom of importance	important
Economical aspects	profitable business opportunities	limited profitable business opportunities

Sources: Mason (1990), Hourcade (1990), Munasinghe (1990), Twidell (1988), Dowling (1956), Lakervi (1995)

What have been the objectives behind the electrification of rural areas in both developing and industrialised countries? It seems from Chapter 3, that the objectives of rural electrification programmes in the latter countries have been very mixed. In one country the reduction in the growing disparity between rural and urban areas with its social consequences and resulting urbanisation was the main objective, while in other countries the improvement of social conditions or

the discouragement of the unrestrained expansion of decentralised and non-standardised power systems typically had priority.
Mason (1990) analysed 35 rural electrification projects in developing countries in the 1970s and 1980s and concluded that the following objectives were mentioned (Table 2.2).

Table 2.2. *Objectives of 35 rural electrification projects (source: Mason 1990).*

Objectives	Percentage of projects
Support agricultural, industrial and commercial development, including irrigation	80
Reduction of migration from rural to urban areas	49
Substitution for more costly energy sources	43
Improvement of quality of life and time savings through such means as improved quality of light and use of domestic electrical appliances	40
Enhancement of security, political stability and/or correction of regional disparities	34
Improvement in the standard of living of the rural poor	28
Alleviation of urban/rural disparities	6
Mitigation of deforestation	6

The findings of Mason are more or less confirmed by Maillard and Hourcade (1990). They bracket together the improvement of the economic situation of the population by increasing rural industrialisation and productivity, and the improvement of rural living conditions up to the level enjoyed in urban areas.
There is indeed good reason to consider both objectives simultaneously. To successfully support rural development, the appropriate circumstances in rural areas are necessary and, in this respect, electricity is a very attractive means. There is no doubt that teachers, doctors and the more affluent farmers and businessmen are more willing to accept a job in electrified areas with their more comfortable living conditions.
Pearce and Webb (1987) argue that rural electrification schemes are usually justified by reference to multiple objectives and Maillard (1985) states that the reasons for the implementation of a rural electrification programme may vary from one country to the next.
The objectives can theoretically be grouped into four categories: economic objectives, social objectives, political objectives and environmental objectives. In practice, however, often two or more objectives occur simultaneously and are interrelated.

The results of the majority of the socio-economic studies give rise to the conclusion that the objectives of rural electrification projects should be made very clear for both assessment and evaluation reasons. Electrification aiming at economical development through agricultural production growth for instance, should be assessed and evaluated differently than electrification for purely social reasons. Not only will the assessment aspects and the weights they should receive be different for both cases, but also the preferential implementation areas because of the differences in relevant potentials for success.

2.6. Benefits of rural electrification

The idea that rural electrification in itself substantially contributes to the development of rural and remote areas was questioned in the eighties. On one hand this was prompted by the experience that most of the expectations were structurally not met, and on the other by a growing discomfort about the below standard performance of many rural power systems in developing countries. This resulted in research into the actual impact of electrification and the performance of utilities supplying remote areas[10].

Fluitman (1983) had already concluded that the economic and environmental benefits of rural electrification tend to be overestimated and the costs under-stated. The majority of the rural electrification projects were related to the extension of a central grid and demand forecast was often based on over-optimistic expectations regarding regional development and people’s ability to pay.

One of his conclusions was that the use of electricity for productive purposes has been very limited. He even noted that some reports suggested a loss of production due to an unreliable electricity service.

He based his conclusions on information from the 1970s and generally speaking at the time there existed no acceptable correspondence between costs and benefits. It should however be noted that since an analysis of both the economic and social aspects is necessary that the cost and benefits are very difficult to value. Fluitman argued that most of the existing impact studies were of a descriptive nature and he concluded “costs it appears, becomes trivial compared to the happiness of a villager who can see (an electric) light at the end of the poverty tunnel”.

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10 The results of a comprehensive study into the performance of diesel-based rural power supply systems (EPUES,1991) are summarised in Chapter 4.

Case 2.1: Perception of electrification benefits

Rural electrification is potentially a desirable investment in many countries (Schramm, 1991) but there has been, and still is, considerable discussion about the socio-economic benefits and the costs of the electrification of these areas in developing countries.
For many rural people in the Third World however, electrification of their areas means modernity, progress and, above all, light in the darkness (Foley 1990).
During a recent socio-economic impact evaluation in Bangladesh, a villager even appreciated electricity as "freedom" (Schiller 1996). In the early 1940s a farmer, who had just been connected to the electric grid, gave witness in a rural church in the United States of America: "Brothers and sisters, I want to tell you this. The greatest thing on earth is to have the love of God in your heart, and the next greatest thing is to have electricity in your house" (NRECA, 1985).
Rev. Fr.J.M. Hayes, a priest in the parish of Bansha in rural Ireland, said during a speech on the occasion of the completion of the electrification of the area in the fifties: "it is more that an amenity, it is a revolution which will sweep away inferiority complexes" (Manning 1978).
More recently, the author enjoyed a dinner with friends in Lesotho in their unelectrified home. The food was excellent and, for someone who takes electricity for granted, candlelight can contribute to a cosy atmosphere. However his friends' daily discomfort caused by the lack of electricity, has contributed to the commitment to complete this research.
The impact on people's lives of a rural society without electricity is difficult to imagine. Life without electricity is possible, as has been demonstrated in the past and is still demonstrated every day by many people all over the world. But in qualitative terms, things look completely different. Because electricity is seen as a "light in the darkness" and a symbol of progress, the electrification of rural areas can be socially and politically very important.

2.6.1. Assessment of benefits

Fluitman (1983) suggested conducting additional and well documented impact studies with the purpose of maximising the socio-economic impacts of past and future investments. He emphasised the need to specifically investigate relevant complementary factors that have to be addressed in order to make rural electrification effective. Examples of complementary factors mentioned were: local attitudes and skills, the state of the infrastructure, levels of income, patterns of land use and land ownership, access to credit, and the demand for products.
An impact evaluation needs to address all the attributes of rural development: improvements in infrastructure to support local industrialisation, increase in

agricultural productivity and improvements to public services (Barnes 1988, Valencia 1990).
A quantification of the effects of electrification in terms of these aspects is however difficult and the conclusions rather unreliable: the indicators are often debatable as they depend on many other factors.
To varying extents, all the impact studies have shown a discrepancy between theoretical justifications for projects and the measurable impact once those projects have been carried out (Maillard 1985).

The methodologies used to analyse the costs and benefits of rural electrification have been the subject of many studies and papers. Formerly cost-benefit techniques generally included only the quantifiable benefits but more advanced methodologies have also included impacts which are more difficult to quantify e.g. the benefits accruing to a society or the community.
Basically there are three methods that can be used to assess the economic benefits of electricity used for productive purposes (Shamannay 1996):

- The direct method: the willingness and/or ability of the consumer to pay based on the additional income generated through the use of electricity.
- The indirect method: the additional output of the production process as a result of the use of electricity.
- The intermediate method: the determination of the costs avoided by the introduction of electricity.

Shamannay states that these three methods only measure the static, immediate benefits of electrification but that many more benefits such as the growth of small scale industries and commercial enterprises, and the social development of a community may be identified.
Maillard (1985) argues that it is very difficult to determine the socio-economic impact of rural electrification projects for two essential reasons:

- It is impossible to isolate the specific impact of electrification within a development process and to certify a causal relationship within a process of such complexity.
- Most available assessments were carried out by organisations that were involved in the projects and thus it was important that the conclusions of these assessments were positive.

Abdalla (1994) distinguishes as benefits of rural electrification: consumer benefits, utility benefits and country benefits. In terms of the feasibility of rural electrification, utilities compare *their* costs and benefits and the result is usually negative. There are however other benefits, some of which are very difficult to quantify. Often one distinguishes socio-economic benefits, socio-political benefits and environmental benefits.
Tables 2.3 and 2.4 list typical examples of benefits and uses of rural electrification (Munasinghe 1988, 1999).

Table 2.3. *Quantifiable potential uses and benefits: cost savings and increased productivity.*

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1. Industrial uses of electricity

1.1. Motive power: replacing liquid fuel.
1.2. Lighting: replacing liquid fuel or gas.
1.3. Space heating, cooling and refrigerating: replacing liquid fuel, coal, gas, biomass or animal waste.
1.4. Processing food: replacing liquid fuel, coal, gas, biomass or animal waste.
1.5. Transport: replacing liquid fuel.

2. Commercial uses of electricity

2.1. Lighting.
2.2. Air-conditioning and refrigeration.
2.3. Improved audio and video opportunities.
2.4. More attractive atmosphere.
2.5. Longer opening times.

3. Household uses of electricity

3.1. Lighting-replacing liquid fuel, gas, biomass or animal waste
3.2. Cooking-replacing biomass, animal waste, liquid fuel, coal or gas.
3.3. Space heating, cooling and refrigeration-replacing biomass, animal waste, liquid fuel, coal or gas.
3.4. Home appliances (fan, iron, radio, TV etc)-replacing batteries, biomass or coal.
3.5. Drinking water-replacing liquid fuel (for pumping).

4. Agricultural uses of electricity

4.1. Water pumping-replacing liquid fuel, coal, gas or muscle power.
4.2. Parboiling, heating and drying-replacing biomass, coal or liquid fuel.
4.3. Chaff cutting, threshing etc-replacing liquid fuel, hydro and muscle power, coal or biomass

Table 2.4. *Benefits that are difficult or impossible to quantify.*

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1. Modernisation, dynamic growth and attitude changes-catalytic effects.
2. Improvement of quality of life, community services (including medical) and participation.
3. Income redistribution and improving social equity.
4. Employment creation.
5. Other socio-political effects such as improving political stability, reducing discontent and disparities between urban and rural areas.

2.6.2. Socio-economic benefits

According to a list by NRECA[11] (Fluitman 1983), numerous opportunities exist in rural areas to improve economic productivity by means of electricity and to achieve social benefits.

Mason (1990) analysed some 35 USAID[12] and Worldbank funded electrification projects in 19 developing countries. These projects were selected according to criteria set by governments including political reasons, maintaining or achieving regional balances, and improving the stability of an area. The villages and towns in the region were chosen according to various sets of selection criteria both economic and social. In this context, Mason correctly states that “the problem with using a set of weighted socio-economic factors as a proxy for a socio-economic rate of return is that the weights applied are usually quite subjective since they are not based on any quantitative ex post evaluation of electrification experience”. She also argues that the results of most impact monitoring studies are such that it is difficult to come to firm conclusions regarding the economic benefits.

Nevertheless, she reached a number of tentative conclusions. Rural electrification appeared to have had some impact on agricultural development in a few countries where irrigation is a widespread activity, but very little in others and then only under certain conditions. The impact on industrial and commercial development, in the sense of the growth of the number of new businesses, was in general, been modest.

Schramm (1991) concluded that there is sufficient evidence to argue that electrification by itself has never been a catalyst for economic development. He also concluded that the impact of electrification on agricultural growth is often overestimated and that there is little evidence that electricity by itself results in new agro-industries and commercial or small-scale industrial activities.

In the summary of the conclusions of a study, Foley (1990) states that rural electrification, on its own, does not necessarily cause development of rural areas. He continues by concluding that it can provide a stimulus to economic activity, especially in the service sector and – where the necessary conditions are present – it can have a major impact *on the form that development takes.*

Munasinghe (1990) found that the tendency to overestimate productivity gains in the industrial and commercial sectors during the economic appraisal of electrification schemes, has been systematic. He is of the opinion that rural electrification appears to stimulate agro-industrial and commercial activity, although the direction of causality it not completely clear. He also reports that the electrification of rural areas in developing countries promotes agricultural

11 National Rural Electric Co-operative Association, Arlington, USA.

12 United States Agency for International Development.

development best when certain complementary inputs, such as electric pumps and financial services were included.
It is best to select rural areas that are, more or less, ready for sustained growth for early electrification since these will generally exhibit rapid demand growth.
This was more or less confirmed by Hourcade (1990) et al. They argue “the more developed an area, the greater the impact of electricity on economic growth” and they conclude that rural electrification is a “selective catalyst” in the sense that the regions already well equipped with infrastructure other than energy (transportation, water systems) in fact reap the stimulating effects, while those areas that are less developed cannot benefit from them.

All these evaluations refer to rural electrification projects implemented in the seventies and eighties. Without suggesting that, in general, the situation has dramatically improved since then, a few optimistic notes can be struck. For example, the socio-economic impact evaluation of the rural electric programme in Bangladesh (Shamannay 1996) noted positive results. This comprehensive electrification program is outlined in Chapter 3, Section 5.
Davis et al (1994) examined the impact of the electrification of a small rural community, six years after electrification. Prior to the electrification of the village a baseline study was undertaken and thus their results are based on a comparative analysis. The area featured a large number of government offices, a well-developed commercial sector, some small-scale businesses and a reasonably dense residential area. Even if all the potential domestic consumers would have been connected, their consumptive use of electricity would still have been less than 50% of the total.
A range of interactive interviews and a participatory approach was adopted. Although loan schemes (for up to 60% of the connection charge) existed to facilitate domestic access to electricity, households were still required to make a large upfront payment. As a result only around 4% of the privately owned domestic houses in the area were electrified and only 9% of the small and informal businesses. The majority of the larger businesses and government departments have been connected to the distribution grid.
The “willingness to pay” was determined on the basis of the avoided costs for alternative energy resources. For domestic and small commercial consumers the willingness to pay appeared to be 30% above the actual electricity tariff. For large commercial consumers the willingness to pay was calculated at 10%. Unfortunately, Davies et al. did not give information about the reliability of the service, which is an important factor in the willingness to pay.
Davis et al. concluded that electrification had stimulated local economic development including the establishment of new businesses. The number of additional jobs was assessed, and 10% of the relevant annual salaries were estimated to be a benefit of electrification.
A major conclusion of the impact assessment was that special financing arrangements are necessary to allow low income households to become

connected. Another conclusion was that the project was only marginally economically viable, even with the low social discount rates. Given the fairly favourable conditions of the site investigated, Davis et al. argued that more appropriate economic benefit assessment methods need to be addressed and that in particular attention must be paid to the identification of the most promising rural areas in terms of electrification.

Foley (1997) reports that in Costa Rica after the electrification of rural areas particularly dairy and poultry farms used electricity widely. These farms usually switched from their own diesel generation to grid electricity. The smaller farms did not use electricity for their farm tasks, only for domestic purposes. Thus the idea that rural electrification in general enhances productive farming activities was not confirmed.

Vogel (1993) states: “Both at the macro-economic and the business level, many rural electrification activities appear rather unattractive in the frame of classical evaluation methods for profit oriented projects such as power plant or a factory which are based on the internal rate of return. Thus economic and financial analyses should give priority to a least cost approach rather than to an economic cost-benefit analysis which in rural areas often can rely on doubtful data”.

He continues by saying “in the first instance, rural electrification should be regarded as an infrastructural prerequisite, based on an already achieved economic level, for the further promotion of rural development. It does not belong to the category of profit-oriented projects but rather, like public transport sector activities, to the category of public infrastructure. The justification of rural electrification projects, programmes and plans should therefore not depend on their individual profitability but on their contribution to achieving positive development impacts and to satisfy basic social needs in a wider frame”.

Vogel is right in saying that rural electrification should not be seen in isolation from the overall development level. He is of the opinion that a rural electrification programme should not be derived from the natural, but subjective, wishes of rural people to benefit from the comfort of services requiring electricity supply. It should rather be justified in connection with factors such as:

- An identified potential of economic activities which could not, or not adequately, be realised without the availability of electricity.
- The ability and willingness of the society and their political representatives to redistribute surplus and funds in favour of the development of rural areas.
- The ability of the institutions/establishments implementing the programme and benefiting from it to cope with the organisational and financial requirements.

Considering these aspects, Vogel argues that rural electrification is unlikely to be just a heavy burden on fragile economies without giving significant regional and national development impulses. Rather it could become an instrument to diversify the economy, to create employment, to improve general living

conditions and to reduce rural-urban disparities. In this context, and in combination with other factors, it can contribute to prevent over-centralisation, congestion and growing shanty townships and informal settlements in urban areas.
Barnes (1988) also concluded that rural electrification can significantly contribute to social and economic development but that opportunities depend on complementary programmes or conditions.
A certain degree of economic development seems to be necessary in creating the conditions for successful rural electrification. This implies that electrification should follow, and not attempt to lead, regional economic development.
In any case where rural electrification is considered and planned in combination with other rural development activities, the social and political circumstances need to be conducive. If these other activities are not successful, the positive socio-economic effects of rural electrification will be partly or fully limited.
An often used example of how rural electrification should be organised, is the simultaneous introduction of electricity and agricultural mechanisation to the rural areas of the United States of America.[13]
Mason (1990) found, in her study of the impact of rural electrification projects, that electricity did replace more costly energy sources in some cases. In most of these cases however electricity was heavily subsidised and the alternatives generally were not.
Investigations have shown that electrifying areas in general gives rise to increased energy use because people begin to use all kind of appliances. Barnes (1988) therefore argues that providing electricity to a region may actually increase overall energy use, making assumptions concerning energy cost savings somewhat difficult. He adds that with the electrification of rural areas, (part of) the population makes a major step forward which would otherwise have resulted in an increased energy use at some time in the future.

2.6.3. Socio-political benefits

Naturally the social objectives of rural electrification are directed at an improvement in the living conditions of the rural population including the creation of appropriate circumstances for education and health care.
Electrification of rural and remote areas in developing countries can, in its simplest form, more or less be seen as a social project: the quantity of electricity is sufficient for lighting and a few domestic appliances but insufficient to support productive uses.
Although the objectives of such electrification schemes are often not blemished, electrification should help alleviate the perceived problems and boost the

13 See Chapter 3, Section 3.3.

priorities of the population, and it should be part of a rural development strategy. Projects created only for the sake of politicians to score points or for donors to locate suitable funding opportunities, are not likely to be sustainable.
Mason (1990) and Schramm (1991) argue that in general the electrification of rural areas does not contribute to the alleviation of poverty, nor to stemming migration from rural to urban areas. It mainly benefits the higher income groups, although in some cases lower income groups have benefited as secondary beneficiaries through the simultaneous introduction of irrigation and other income generating measures.

In general, the rural population attaches great importance to the domestic uses of electricity. However without any additional productive use of power, there will be no increased income generation and thus a limit to the ability to pay for the electricity. This could hamper load growth, reduce the beneficial effects, and put sustainability of an electrification scheme at risk. For this reason, some funding organisations attach requirements to the expected ratio of productive and consumptive use of electrification projects.[14]
Despite the fact that the impact of rural electrification on security, political stability and urban/rural bias is difficult to measure (Mason 1990), experience shows that the impact of electric lights on security, civil order and educational facilities is perceived by most rural dwellers as clearly positive. All Mason's studies showed a gain in recreational opportunities such as TV and radio and over time through the use of other electric appliances.
But the impact of the availability of electricity on rural/urban migration, water supply, irrigation and cooking appears to be limited.
Foley (1997) reports that in Costa Rica after the electrification of rural areas, significant social improvements took place: the number of education institutions with lighting and night classes increased considerably, a new hospital was set up and the number of health centres increased.
There are indications that primary schools do not often use electricity but this situation may change quickly with a more widespread use of computers. However electricity does appear to be extremely important for secondary schools, and for health care and information. Research also reveals that children living in houses with electricity take advantage and do their homework mainly in the evening.

14 The German Kreditanstalt fü Wiederaufbau imposed for some grid based electrification projects the requirement that consumptive use of electricity should be less than 40% of total use.

2.6.4. Environmental benefits

Millington (1994) argues that some 68% (and in some cases even 90%) of the population in rural areas use woodfuel and other agricultural biomass residues for cooking. Ebohon (1996) concludes: "given the virtual dependence by rural population on these fuel sources, the combined environmental impact on the one hand, and on the other, supply difficulties are having negative impacts on output and growth. Thus, the need for, and the speed by which solutions must be sought have never been greater".
It is often supposed that the electrification of rural areas will more or less automatically lead to a switch from woodfuel to electricity for cooking. This is not the case, except in special cases such as in Nepal (see Case 2.2).

Research (Mason 1990, Vogel 1993, and others) has revealed that electrification of rural areas generally does not prevent deforestation, certainly not during the early years after electrification. It appears that the expected switch from woodfuel to electricity for cooking purposes only happens on a very limited scale. In general the rural population lacks the financial resources to buy electric appliances. Also the cooking habits and the opportunity of buying small quantities of traditional fuel are cited as reasons.
In rural areas, land clearing for agricultural uses is often the main cause of environmental degradation. The energy demand of the rural population is seldom the cause of deforestation and, moreover, the population has often been successful in managing the local environment.
Woodfuel or charcoal demand by the urban areas, however, can have a substantial impact on deforestation in the surrounding rural areas. In some countries, both urban and rural dwellers have discovered that the forests can be a means to generate income with the effect of over-utilisation of resources (DGIS/SEM 1996). It is therefore of utmost importance that any policy regarding energy supply and the associated environmental impacts should cover both the urban and the rural areas.

Case 2.2. Nepal: substitution of wood for electricity

This project is an example in which electricity replaces woodfuel. In Nepal's rural areas wood is the dominant fuel and a study revealed that the forests would be depleted by 2010. A carpet factory that used a woodfuel boiler, provided one of the most important incentives to substitute for wood as a fuel resource. Currently, this site uses a 65 kW electric boiler. A run-of-river powerstation (max. capacity 2x180kW) has been developed which supplies electricity to industrial consumers and to a number of villages. From the very beginning, at least five connection choices have been offered (reference is made to the table below).

Level	Power (kW)	Fixed costs (US$/ month)	Exempted (kWh)	Further (kWh)	Price per unit (USct/ kW)	Further (kWh)	Price per unit (USct/ kW)
1	0,1	1	all	-	-	-	-
2	0.5	3.7	all	-	-	-	-
3	2,0	3.9	55	55-120	5.8	>120→ ∞	2.1
4	8,0	5.2	65	65-160	6	>160→ ∞	2.1
5/1	>10/0.1*	4.1	50	all	1.9		
5/2	>10/0.5*	6.1	75	all	1.8		
5/3	>10/2.0*	10.6	130	all	1.6		

* first figure refers to off-peak power; second figure refers to peak power.

The Sceco tariff structure has degressive features; prices roughly converted to US$.
With level 1 the load is limited to 100W (lighting only), level 2 (500W) allows for cooking with a special low energy cooking device. Level 1 and 2 have no meter and as a result low connection costs. Level 5 charges are available for the industry but only to 18.00 h. After that time, level 1, 2 or 3 applies for these customers via automatic switching. Load limitation is realised through inexpensive load control switches in the connection boxes. Both the connection and tariff policy were developed starting from the principle that all industrial and residential clients can use electric power. Another important criterion was that the tariffs should cover the operational costs and in the future also depreciation costs.
(Source: Waldschmidt 1992)

2.7. Implementation aspects

2.7.1. Rural electrification costs

Both investment and operation costs of rural electricity supply differ from one country to another but they are always far higher than in urban areas. These higher costs are due to the following factors (Hourcade 1990 and others):

- Dispersed loads requiring long medium voltage lines or decentralised diesel power stations.
- Line losses are often very high and the power system prone to service interruptions.
- Expensive billing procedures and control of illegal connections.
- Low load factor due to dominant domestic consumption (in particular lighting), agricultural demand with seasonal periodicity and the absence of industrial demand.

Table 2.5 gives an overview of the costs per grid connection for various projects. Apart from exceptional cases in Australia and Vietnam, these costs vary between US$ 300 and 6,700. It is evident that the average costs per connection depends heavily on the structure of the medium and low voltage distribution system and particularly on the number of customers served.

Based on this table, Figure 2.3 shows graphically the cost per connection as a function of the number of connections. Although the figures are not very reliable, the graph indicates that the cost per connection increases considerably with below 1000 connections.

The approximate figure of US$ 1,200 for the cost of each connection used in Section 1.1 would seem justified. It is noted that this sum does not include the costs of the transmission system, the generation facilities and the service connection. Transmission system costs and service connection costs are generally similar, at say US$ 100 - 125/connection. An average modern central power station would cost US$ 1,000 per kW. If a modest maximum load per connection of 0,4 kW, a coincidence factor of 0,85 and a reserve margin of 30%[15] is assumed, the total investment cost per grid connection would amount to some US$ 1,900 (see Box 2.1).

Moore et al (1990) calculated, on the basis of expansion plans in 70 developing countries, average investment cost of US$ 1,942 (1989 dollars) for each kW of additional power system capacity added. Additional peak load would even cost US$ 2,513. On average these costs are made up of generation 60%, transmission 11%, distribution 20% and other (administration, offices etc) 9%. Investment

15 Reference is made to STT 1999, Figure 3.5.4. A reserve margin of 30% is in this case very modest and basically only applicable for large systems with a maximum load of over 25,000 MW.

costs varied between US$ 1,390 and US$ 7,786, the higher values often referred to high cost hydro or included a gas pipeline. These calculations show that the total investment costs determined in Box 2.1 are realistic. It is noted that additional peak power is even 30% more expensive.

The cost per connection is commonly used to compare costs of projects but according to Mason (1990) it is not really a good comparator because of the different mix of consumer categories. She argues "the best measure of unit costs to compare projects is the average economic incremental cost (AIC)[16] per kWh of sales. The AIC takes into account the time-value of costs and consumption over the life of the project and accounts for the lumpiness of investment. Variations in load factor are implicitly reflected in this measure of unit cost, since it directly relates cost of capacity to energy consumption".

In the past, the acknowledged cost of many rural electrification projects in developing countries only included the design and implementation of the medium and low voltage extensions to the rural areas. But the real total costs of rural electrification projects are comprised of capital costs, operation and maintenance costs of the medium and low voltage distribution network, plus the long run marginal cost (LRMC) of energy supplied to the distribution grid. The LRMC includes all the costs of the generation of electricity (including fuel if applicable) and of the transmission to the feeder line to the rural electrification scheme. The LRMC often constitutes a substantial share of total costs.

Mason found that the LRMC in 13 countries ranged from 5,5 USct/kWh to 17USct per kWh (the latter included isolated diesel generators; 1996 prices). The average LRMC was about 12 USct/kWh.

Mason (1990) found an average distribution capital cost of 12 USct per kWh with a range from 3.5 USct to 35 USct. Hourcade et al. (1990) found average rural electricity distribution costs per kWh supplied (excluding generation and transmission costs but including operation and maintenance costs) to vary between 5 and 12 USct although they also noted an extreme cost of 45USct. The values quoted by Hourcade et al. are thus lower than those of Mason.

On the basis of the figures in the previous section, Mason also determined, for 13 developing countries, the average total economic costs of rural electricity supply including the capital costs of distribution, the long run marginal costs (LRMC) of energy supplied to the distribution grid, and the operation and maintenance costs. The average was about 26 USct/kWh and the range was from 11 ct to 46 ct/kWh (recalculated for 1996 values). The high values reflect scattered low population centres and high design standards. The actual figures could be even higher, because the cost of the losses and of the energy not supplied during outages, are probably not included in this calculation.

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16 Present value of total capital costs plus operation and maintenance costs divided by the present value of total sales over the life time of the project facilities, using the opportunity cost of capital as the discount rate.

Table 2.5 *Relationship between the number of connections, the line length and costs (rural areas). Connection costs roughly adjusted to 1995 prices.*

Project	Potential consumers	MV lines (km)	LV lines (km)	Average number of conn/km line	Cost/conn. US $
Concept 1	5208	100	60	33	800
Concept 2	795	15	21	22	950
Itapua4	794	18	23	19	1050
Itapua 2	337	16	12	12	1600
Caazapa 1	208	51	16	3	5500
Alt.Para 1	205	46	14	3	5300
Alt.Para 2	378	86	25	3	5400
Neemburu 2	166	50	10	3	6700
Neemburu 4	133	44	8	3	6700
Bangladesh				5/95*	500
Brazil					5500
India				15*	550
Malaysia				110/125*	1600
Marocco				30/50*	2500
Phillippines				50*	800
Syria				75/100*	1300
Thailand				120/>250*	400
Thailand	400,000				1075
Bhutan	3000				3167
Vietnam	2000	10	12	90	100****
Vietnam	200				830
Australia NSW					up to 100,000 **
Botswana					700 - 2300***
Kenia					700
Bolivia					650
El Salvador					550
Nepal					300 - 500
Costa Rica	30,000			5	1126
Nepal	170				180 (special)
South Africa	460				900
Yemen former People's Dem)				105/160*	5500

* Based on number of connections per MV feeder alone; the first figure is related to the initial number of subscribers and the latter after saturation.

** Single homesteads. *** Depending on distance to grid.

**** Figure too low; cost estimate did not include all costs.

(Sources: P.Menanteau, L'électrification rural dans les pays du Tiers monde: les conditions économiques d'un projet politique technique approprié, PhD thesis, University of Paris IX Dauphine, 1987 (cited in Hourcade 1990); Munasinghe 1990; G.Foley 1997; NRECA 1995; Personal communications by the author.)

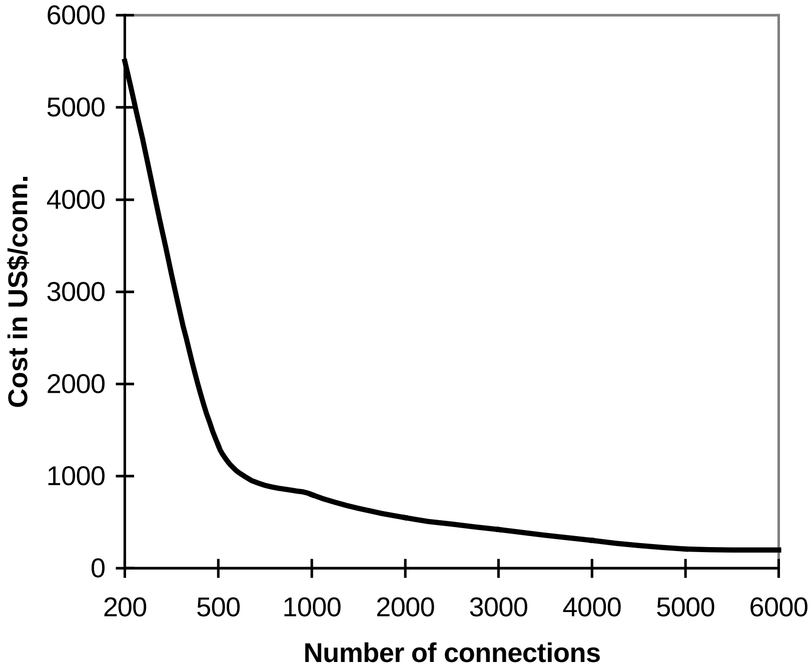

Figure 2.3. *Relation between number of connections and cost per connection (LV and MV system included).*

Schramm (1991) argues that grid based electricity is by far the most costly form of energy supply in low-density rural areas, when compared to the other alternatives. He notes that the real cost of electricity is very high and in most cases is underestimated because of the low load factors, the large distribution losses and the additional burden imposed during peak demand periods.

He states that the main criterion for the desirability of a rural electrification investment is apparently the economic rate of return (ERR) and that "most of the other alleged beneficial

effects must be either disregarded or viewed with great scepticism". His statement is partly based on the results of a review of eleven World Bank and USAID supported projects. This review revealed that only one project had achieved the projected ERR and that all the others had lower rates or even negative ones. There were however doubts whether the figures were correct due to the following reasons:

- Electricity supply costs were generally based on system-wide long-run marginal costs based on system load factors in excess of 60% while the actual figure was generally 15 to 25%.
- System outages resulted in high costs.
- Distribution losses were often in excess of 20%.

- Future demand was often overestimated.
- As a consequence of inappropriate operating and maintenance practices, the condition of the installations ranged from bad to “beyond rescue”.

The economic internal rate of return (EIRR) of rural electrification projects is generally low and usually below 15%. However the accuracy of the EIRR calculation for most projects is often highly questionable because of the difficulties in achieving reliable information. If all the benefits of rural electrification projects are to be included in the economic analysis, then estimates will be required for the following (Mason 1990):

- Revenues and connection charges paid by consumers.
- Any net cost savings realised by consumers due to electricity substituting for other fuels.
- Consumer surplus from consuming more energy than previously i.e. on created demand and increased production realised by agricultural, industrial and commercial consumers.
- Unquantifiable benefits due to improved health services and education, increased satisfaction and stability etc.
- Environmental benefits and hidden costs.

As is shown in Box 2.1, Table 2.6 and Figure 2.4, the average all-in grid-based rural electricity costs could indeed easily be 30 USct per kWh. Nevertheless, grid-based systems are often implicitly assumed to be the least-cost solution when compared with decentralised diesel generation. This view is confirmed by Mason for the cases she considered in her research.

2.7.2. Tariffs and subsidies

One of the most important issues in electricity supply is the setting of the tariff. In view of the problems experienced by utilities in developing countries, Renooij (OGEM 1963) noted, already in the sixties, the finding of a study carried out by Cavers and Nelson for the International Bank for Reconstruction and Development and the United Nations Economic Commission for Latin America: “…. the evidence accumulated by the study points to the need to adjust charges for electricity services, whether public or private, so that costs can be fully met and surpluses accumulated from earnings to finance future expansions”.

Cavers and Nelson also concluded with regard to the consequences: “Shortages in supply and the erratic quality of electric service in many communities have led to the widespread installation of diesel generators for private supply, thereby entailing costs for electricity well above the level which public utilities would have to charge after the needed upward adjustment in their rates”.

Box 2.1: Cost estimation of rural electrification

In this cost estimation the global costs as a function of various annual consumption levels are calculated. The impact of utility profits, losses and costs of outages and brown-outs on total costs has been neglected. For the capital costs, and operation and maintenance costs, thermal power generation has been assumed.

Asssumptions: Capital cost generation: US$ 1000/kW, fuel costs generation: USct 7/kWh, average capital cost of HV transmission: US$ 125/ connection, average capital cost MV/LV distribution (with overhead lines): US$ 1200/connection, average capital cost service connection: US$100/ conection, average household load factor: 0.28, household coincidence factor: 0.85, maximum load/household: 0.4 kW, reserve margin generation: 1.3; depreciation: 25 years, interest: 7%, annual operation and maintenance costs: 4% of capital costs for distribution and transmission grid, 7% for generation installations and 2% for service connections

The average installed generation capacity per connection can be estimated as 0.85 x 0.4 x 1,3 = 0.442 kW and the associated investment costs US$ 442. (For comparison: Kolos (1999) calculated for Europe 1.3 kW/person and for North America 2.4 kW/person).

The total investment cost per connection including generation, transmission, distribution and service connection amounts to US$ 1876. The average connection consumption is 0,28 x 0,4 x 8760 = 981 kWh/year

Table 2.6. *Global cost as a function of various annual consumption levels.*

Annual fixed costs/connection (US$)			annual consumption (kWh)				
			500	981	1500	2000	3000
Generation	US$	64.1					
Distribution	US$	138					
Transmission	US$	14.4					
Service connection	US$	9.5					
Total annual fixed cost	US$	226					
Fixed cost per kWh			45.2	23	15.1	11.3	7.5
Fuel cost/kWh	USct		7	7	7	7	7
Total costs/kWh	USct		52.1	30	22.1	18.3	14.5

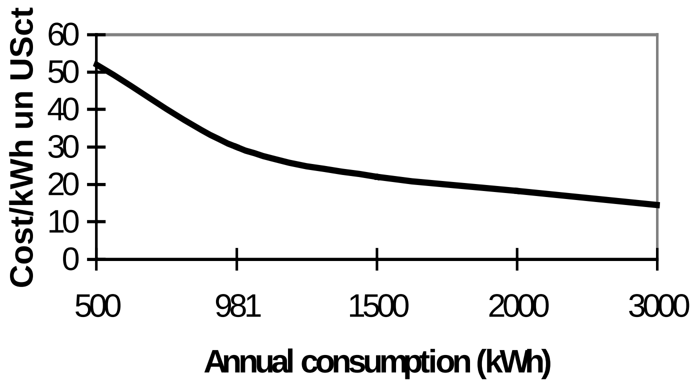

Figure 2.4. *Global cost as a function of various annual consumption levels.*

Basically, the consequences of uneconomically low tariffs are the same for both private and government-owned companies. The opportunities for covering the capital needs of the companies are limited because loans, even with government guarantees, are difficult to obtain on account of the size of the debt-service and the Government's own creditworthiness (A.E.Matter 1960). Matter also argues: "The emphasis in all considerations regarding tariffs and financing of electric power should be on plentiful electric power rather than cheap power. The saying that for any economy the most expensive electric power is the power which it does not have is quite true".

Socio-political and similar considerations often play an important role in the development of a rural electrification policy. Many rural electrification schemes start with a very low demand level and to accelerate cost recovery, electricity consumption has to be built up as soon as possible. The associated policy often aims to reduce the initial connection fee or the electricity tariff or even both. The design of such a policy is also prompted by the desire to allow low income households to enjoy the benefits of electricity, and by the expectation that electrification will enhance development and income generation. The policy sometimes also includes financial support for the purchase of electric appliances.

However, in many developing countries tariffs are permanently very low. Munasinghe (1990) observes that in quite a few developing countries rural electricity tariffs rarely cover more than 15 to 30% of estimated costs of supply.

Mason (1990) notes, on the basis of an assessment of 35 rural electrification programmes, that in nearly all cases the financial costs could not be covered, even though a substantial government subsidy on the initial investment costs had been granted.

The WEC Congress 1995 (WEC 1995) concluded: "today, energy subsidies around the world amount to many billions US dollars annually[17], concentrated mainly in the transitional economies and developing countries. In other words, the price of energy to huge numbers of consumers is less than the cost of providing the energy in question. One result is waste and inefficiency, through over-consumption now. A second is the disincentive to invest now so as to assure sustainable energy supplies for the future. Such subsidies exist for a variety of reasons: historic, political, vested interest or simply because the customer cannot yet afford to pay market prices".
Table 2.7 gives examples from some countries. Is should however be noted that the figures are from 1993 and that circumstances in these countries might have changed since then under the influence of the power sector reform process.

Table 2.7. *Costs and tariffs for electricity in rural areas of certain countries (source: World Bank 1994).*

Country	Fuel cost	Generation and transm. capacity costs	Distribution capacity costs	Total cost	Actual average agricultural tariff
Bangladesh	4.6	9.2	10.6	24.4	16.0
India	2.1	5.8	8.7	16.4	0.5
Indonesia	3.8	4.1	9.8	17.6	5.8
Malaysia	2.3	8.8	4.4	15.5	7.2
Philippines	5.0	2.8	7.5	15.3	9.2
Thailand	5.0	3.8	8.3	17.1	7.0

Figures in USct per kWh and related to the long-run marginal cost. Tariff for use in agriculture at low voltage.
Year:1993.

Subsidisation often leads to a more rapid demand growth than would occur without subsidies, making rural electrification projects appear rather successful. However subsidised electricity prices conceal the real costs, puts the electricity supply entity at risk, and also gives the wrong signals to consumers.
Today it is widely accepted that electricity should be provided economically and efficiently at a price which, on average, reflects its full cost including the actual costs of the resources employed and of the environmental detriments. Such

17 De Moor and Calamai estimated for the mid-1990s an amount of US$ 250 - 300 billion per year for conventional energy (1997 cited in UNDP 1997).

prices give the customers the right signals to use electricity efficiently, and enable the power company to generate the financial resources needed for investments, operation and maintenance.

Apart from the “price” of the environmental impacts, marginal cost-based tariffs satisfy these criteria. But since tariff setting must also satisfy several other criteria such as the provision of a certain level of service to low income and low consumption consumers, the marginal cost principle cannot be applied rigidly.

Given the high capital costs and operation and maintenance costs of grid-based rural supply systems, and the present ability to pay by the majority of the rural dwellers in developing countries, it is unlikely that all costs can be covered in the near future. As has been the case in most industrialised countries[18], some form of subsidy towards the capital costs of rural electrification programmes is necessary.

However, tariffs should at least generate income to cover the operation and maintenance costs and part of the capital costs to allow the utility to perform normal operations. However, tariffs are also limited by a maximum in order to avoid industrial consumers deciding to embark on their own power generation and other consumers ceasing to use electricity.

Apart from indirect subsidies, such as through fiscal measures, three different subsidies can be distinguished:

- Subsidy on the investment cost.
- Subsidy to relieve the poor.
- Cross-subsidy to achieve nation-wide or region-wide tariffs.

Subsidy on the investment cost

As will become clear from Chapter 3, the investment costs of rural electrification programmes in industrialised countries have in most cases been subsidised. In Ireland for instance, the government paid up to 50% of the investment costs of rural grid extensions.

The success of the rural electrification programme in Thailand was the result of a combination of factors: a commitment by the government to rural development and to improve living standards in rural areas, a careful grid expansion plan with appropriate selection criteria, cost orientation, an advanced revenue collection programme, a pragmatic institutional approach and a system of cross-subsidies (ESMAP 1997b).

This 20 years programme was supported by donors but grants were only available for feasibility studies. Capital costs were covered by low-cost and long-term concessional loans and, on a voluntary basis, by affluent villages paying for part of the construction costs. The latter solution was in fact incentive-based because these villages were then electrified on a priority basis. 24% of the villages did pay 30% of the construction costs but only 1% of the

18 See Chapter 3.

villages paid 100% of these costs. The financial contributions of these villages enabled the programme to allocate funds for the electrification of poorer villages.
As a result of these measures, the cross-subsidisation, and a special bulk power purchase tariff, the utility was able to finance the rural electrification programme and have a reasonable return on its investments.

Subsidy to relieve the poor

Munasinghe (1990) emphasises that one should be aware of the potentially perverse effects of subsidies, such as electricity revenues obtained from the urban poor being utilised to subsidise the rural rich.
Mustanoja et al. (1991) notes on the basis of a study into the social and economic impact of electrification in Ethiopia that the results – albeit that the research was not specifically directed at rural areas – tend to confirm the findings of others: better-off households benefit more than the poor from subsidised tariffs since they can afford to purchase appliances and thus increase electricity consumption.
There is indeed sufficient evidence that the middle and more wealthy classes benefit more from subsidies on electricity than the poor. Research in urban areas of India (Manzoor Alam 1999) suggests that of the total subsidy on electricity some 83% goes to the middle and wealthier classes and only 17% to the poor. Essentially, cross-subsidies can have a perverse effect in that the poor urban households subsidise the electricity consumption by better-off rural users.
Subsidy programmes, if applied, should therefore be well designed and the beneficiaries carefully targeted. The effects outlined above could be avoided by a tariff system with which small consumers (up to say 35 kWh per month) are offered a low, so called, “life-line” tariff. Such a tariff does, in general, not jeopardise utility operations and the impact on larger industrial and commercial consumer tariffs is often modest.
A “life-line” tariff is often believed to be necessary when reform of the electricity sector is planned or implemented (UNDP 1997).
Another method which is used (for instance in some urban areas of South Africa) and which helps the poor to obtain access to electricity, is the possibility of paying only part of the connection fee together with the use of a prepayment meter and an associated tariff. The tariff covers the energy component plus a surcharge for re-payment of the remaining connection costs.

Cross-subsidy to achieve uniform tariffs

In many countries, consumers in rural areas are often cross-subsidised by consumers in urban areas. In industrialised countries, rural electrification was seen as a way to modernise, and a policy was developed to subsidise rural consumers by urban consumers. The major arguments underlying this policy were (Hourcade 1990):

- Equal access by all citizens to public services including electricity.
- Inter-regional solidarity for reasons of national unity.
- Positive effects of electricity on rural development and living conditions.

As long as the number of consumers in rural areas is small compared with those in urban areas, the impact on the general tariff will be modest.

Without cross-subsidisation, the tariff difference between the most favourable urban area and the most unfavourable remote location could be well over 100%. The average will usually be in the order of 30% (Hourcade et al 1990). It is noted, however, that this figure is lower than that calculated for Ireland[19].

Hourcade et al (1990) argue that cross-subsidisation from urban to rural consumers is increasingly prevented by the demographic situation in developing countries. When electrification started in developed countries the average ratio of rural to urban population was 0.7 and it approached 3 in developing countries. Many decades later, 78 million urban residents in Western Europe are easily able to cross-subsidise electricity for 44 million rural residents. They note that the 86 million urban residents in South-East Asia (1980 figure) would hardly be able to cross-subsidise the electricity supply to 285 million rural dwellers.

A judgement regarding the opportunity for cross-subsidisation should not be based on the number of residents in urban and rural areas. Consumption levels in both areas are much more important in decision making. Generally urban areas include large industrial and commercial consumers and the consumption of urban households is often much higher than that of rural households.

Hourcade et al. are correct in arguing "price equalisation to the benefit of rural regions gives grid based electricity a false appearance of competitiveness compared to less subsidised alternatives". This is notably the case with energy conservation programmes and autonomous generating facilities. The latter have the advantages that investments can be made more in line with actual demand growth and they also offer the opportunity to exploit local available resources.

Munasinghe (1990) argues that reasons for cross-subsidy must be well justified and quantified including the corresponding efficiency benefits. He also states that it may be better not to cross-subsidise but to focus on promoting the productive use of power in rural areas because these types of consumers are more likely to be able and willing to pay higher prices. The resulting revenues could then be used to subsidise tariffs to poorer households. In fact, this principle has successfully been implemented in Thailand by the Provincial Electricity Company during the rural electrification programme (ESMAP

19 In Ireland rural prices around 1970 were lower by over 29% and urban prices higher by almost 9% than they would have been without cross-subsidisation; despite a government subsidy on capital costs for rural electrification of 50%; see further Section 3.1.

1997B). The strategy of promote productive uses indeed increased revenues from rural areas through which the electrification programme as a whole was supported.

2.7.3. Rural electrification planning

In developing countries, rural electrification is either treated as a stand-alone project or as part of a country-wide distribution expansion programme. In both cases it is extremely important that objective criteria for village selection are developed and applied in order to avoid interference such as the lobbying of politicians (ESMAP 1997B).

Munasinghe (1990) argues "there does appear to be a general link between high levels of access to electricity in rural areas of a given country and the period of time for which serious electrification efforts have been pursued. Therefore, nations which have longstanding, well established rural electrification programs, with strong government support, tend to have fared better".

The planning of distribution systems has to be based on a philosophy and be carried out systematically. Lakervi and Holmes (1995) distinguish strategic, or long term, planning dealing with the main grid configuration and the associated future investments, from grid planning covering individual investments in the near future and construction design. The latter deals with the structural design of each network component. An important feature is the area coverage: the extent of the area (and thus the number of consumers and their distance to the grid) to be served.

As is clear from Chapter 3, area coverage is a commonly used parameter. The type of coverage defines, on the basis of certain selection criteria, an area in terms of number and classes of connections and a time frame.

Mason (1990) observes that "systematic planning of distribution systems is particularly poor in those developing countries where the utilities are attempting to meet targets for connecting a prescribed number of villages to the grid. This often results in meandering grid systems which are inadequately equipped for future expansion, prone to outages and which show excessive voltage drops and line losses".

The electrification of new areas is often seen as the first priority and so existing systems are not reinforced in time and service reliability is jeopardised.

Hourcade et al (1990) argue that a distribution grid has a dynamic nature and that additional investments are needed during the development process. Considering a connection rate of 99%, they distinguish three development phases:

- the extension process;
- the densification of the grid;
- the reinforcement dynamics.

These phases can more or less be recognised in every distribution system, since most grids were initially planned for specific end-uses [20].

They also conclude that the price equalisation and other funding mechanisms systematically favour a single technical option, to wit the central grid system. The more-or-less automatic funding of the central grid solution hinders the identification of innovative technological paths such as the application of new decentralised energy sources, simplified electrification systems and energy efficient equipment.

Less capital intensive and more flexible solutions are needed to speed up the electrification of rural areas and for this purpose Hourcade et. al advocate funding mechanisms that are "technology neutral".

Mason (1990) also concludes that a more sophisticated analysis of the most cost-effective ways of meeting rural energy needs is needed that, takes into account all the other possibilities. She notes that the cost of grid-supplied electricity is underestimated and that this is particularly true where small and/or distant population centres are connected.

On the other hand, Mason also found that mini-hydro installations were very expensive if they were constructed and operated by utilities, and that PV Solar Home Systems were less costly in remote areas but otherwise the use of solar PV was not the least cost economic option.

She also observed that small scale biomass gasifiers were the least cost alternative for generating electricity in the more remote areas but, because biomass technology has to be adapted to the specific fuels available in the various areas, the lack of local technical expertise could cause problems. Other problems experienced with renewable energy projects included poor operation and maintenance because of weak technical and managerial capacity, and the influence of institutional and cultural situations and deterring government policies.

Mason concluded "it is unlikely that rural energy needs will be met to any significant extent by biomass, biogas or PV systems in the present situation of low oil prices and the state of the technology".

It is noted that Mason's aim was to identify the least cost option and that in the decade since her research the technology of renewables has made substantial progress and the costs have fallen considerably.

The traditional approach using grid extension remains appropriate for urban and industrial areas and for rural areas with a well-developed demand. For rural and remote areas with a low demand, central grid based electricity supply is very sensitive to demand growth and in general is too costly. For these situations decentralised generation facilities are more appropriate. The application of hybrid systems such as diesel sets in combination with PV, hydro and wind-

20 See for instance Section 3.4.

turbines, strongly depends on local circumstances and they tend to be technically rather complicated.
Currently available PV systems can easily be adapted to individual wishes but can only satisfy modest demand. A cost-benefit comparison between grid electrification and PV electrification is difficult because of the differences in technical features. A comparison could best be based on the basis of service delivered and not on a kW basis.
PV systems are, in financial-economic terms, a lower risk bearing option when compared with the large and future-oriented grid extensions because no initial over-investment occurs. Another important advantage is that PV systems can be supplied off the shelf.
From the point of view of electrification planning, PV systems are often considered as a kind of pre-electrification but, in the light of the priorities and medium term possibilities of the rural population, it is a fulfilling option.
Both PV systems and solar thermal systems are suitable for local servicing which enhances employment and reduces dependence on distant expertise. In this context, it is noted that “appropriate technology” is less related to the technology applied than to the way the equipment is designed and manufactured and delivered with the relevant instructions.

2.8. Comments and conclusions

Since, in 1987, the World Commission on Environment and Development (Brundtland Commission) introduced the term “sustainable development”, this notion has been at the centre of the development debate. The 1992 United Nations Framework Convention on Climate Change in Rio de Janeiro underlined the importance of sustaining the earth.
The Brundtland Commission defined sustainable development as “meeting the needs of the present generation without compromising the needs of future generations”.
This implies that the eco-capacity of the earth must be shared with future generations. It follows that the world should be reluctant to deplete fossil fuels and rather it should develop and deploy advanced and acceptable technologies for power generation and use.
If society fails to deploy appropriate technologies on both the supply and the demand side, and adapt human behaviours and attitudes, the present problem of unsustainability will likely grow exponentially.
The supply and consumption of energy should be coherent with the concept of sustainable development (Turkenburg 1993). Abdalla (1994) argues that once environmental degradation is acknowledged as a serious problem, the effective implementation of policies promoting energy efficiency and sustainable development may be constrained by institutional and economic barriers. However many energy sources will become economically feasible sooner if

subsidies for hydrocarbon sources of energy are eliminated and their prices include the costs of the pollution associated with their use. It is emphasised that, apart from “life-line” tariffs, direct subsidies on energy should be avoided and the environmental impact costs of energy internalised.

Another essential aspect in the pursuit of a more sustainable society is meeting the needs of the poor of this generation. Poverty should not only be seen as living at subsistence level and lacking appropriate education opportunities, but also as a lack of access to modern power supplies and the associated services.

Terhal (1995) notes that the pursuit of a more sustainable society implies a consolidation of the world population, acceptable impacts on the various ecological systems, and an acceptable mean level and distribution in fulfilling the material needs throughout the world. This requires a philosophy, morality and structure of society which differs significantly from the present one. Opschoor (1995) argues that social and technological innovations are required both nationally and internationally, to achieve sustainability.

Ashford (1999) suggests that sustainability requires innovation, and in this respect also a new generation of designers and managers to exploit human ingenuity. The transformation from the present situation to a sustainable world is a far-reaching process, often referred to as the sustainability revolution (Meadows 1992). There is indeed reason to believe that humanity is on the threshold of the next revolution.

Electricity is not a primary necessity of life. The greater proportion of the population living in developing countries does not have access to electricity and many households rely completely on biomass.

Traditional energy technologies have been developed over a long period of time to meet the specific needs of the rural area and should not be ignored (Abdalla 1994). However this does not mean that most rural dwellers, in particular rural industrial and commercial consumers, do not want access to electricity. On the contrary, the services possible with electricity are highly valued and the willingness of the customers to pay relatively highly for this commodity exists although the purchasing power of a large number of rural dwellers is small.

There are indications that socio-political longings, and the spreading communication as a result of intensive marketing of telecommunications and other electronic equipment, will induce a growing demand for electricity, even in the poorest areas.

Essentially rural dwellers want improved lighting, heating, video and audio; electricity can provide these services conveniently. Moreover, many people in rural areas associate electricity “in itself” with well-being.

Although the basic needs, as perceived by developing countries, include poverty eradication, industrialisation and employment generation, there are social and political pressures in many Third World countries to electrify rural areas. Electricity, because of its flexibility, versatility and increasing pervasion, is

essential if the rural areas in the developing world are to rise significantly above the level of subsistence.
The industrialised world, and some parts of developing countries, have already become accustomed to the use of electricity as a reliable and readily available commodity for the industrial, commercial and domestic user. Progressing unification will gradually force the international community to satisfy the material needs of the global population as a whole and energy, particularly electricity, will play an important role in this respect.

The question is no longer whether rural areas will be electrified, but when. One cannot bring a halt to the use of electricity, only the way it is generated, distributed and applied, and the form in which it is presented, can be influenced.
The contribution to energy related global pollution by the industrialised world is still larger than that by the developing countries. This fact is often used to claim that this pollution problem is solely a matter for industrialised countries.
But all countries are in the same boat and have a common responsibility, not only with regard to the environment at large but also to the alleviation of poverty, and to the development of those areas that lag behind.
There is no doubt that the global village will face a number of problems in meeting the expected growth in demand for energy services over the coming decades. The main question will be how the increasing demand for energy services can be met in the most efficient, sustainable, and environmentally and socially acceptable ways. There is no doubt that electricity will play a major role.
Electricity has a number of advantages including the opportunity for fuel diversity and deploying locally available resources, decentralised power generation and a guarded control of environmental pollution. In spite of the impact of electrification on wellbeing however, electrification does, in general, not satisfy all energy needs and even the wealthier rural households continue to use multiple energy sources. Any national energy policy should take this into account and therefore an integrated approach to all energy services is needed.
Another important aspect when defining an energy policy is that in many communities, women are the users but often not involved in the relevant decisions. As regards rural electrification the motivations for increasing the participation of women can be different (Skutsch 2000):
If empowerment is the prime consideration, women should be represented on decision-making bodies.
If efficiency gains regarding the delivery of the service are the aim, they are seen as a segment of the market for which certain products and services, and the way in which they are delivered, are important.
The previous sections highlighted the importance of rural development. The population in rural areas grows fast and additional employment is necessary both for this reason and to compensate for the redundancies in agriculture. In most developing countries, the processes in rural agricultural industries need further

modernisation. All these developments require modern forms of energy and in this respect electricity plays an important role because of its suitability for irrigation purposes and for the processing and storage of agricultural products.

There is no doubt that the emergence of commercial and industrial activities is an important issue in the rural development process. Another important element in the development process is supporting the interests of the middle class of a rural society. Kaplan (1999) argues that economic growth is strongly related to the emergence of a middle class.A sizeable middle class more-or-less guarantees stability, investment and employment, and such a class will not emerge if an adequate infrastructure, including modern forms of energy, is lacking. The benefits of rural electrification should also be looked at from this perspective.

From the previous sections it seems that the most common objective of rural electrification is the promotion of rural development.

Rural electrification is but one aspect of rural development and it is often just one of the possible options for satisfying the energy needs of the rural population. All aspects of rural development must be considered together and it is important that the electrification of specific areas is placed in the proper context with respect to other development priorities. With such an integrated approach the risk of neglecting socio-cultural values could be minimised.

Munasinghe (1990) notes that the importance of rural electrification in the development process has been recognised in a number of studies and evaluations, and that presently most developing countries see electrification programmes as a part of their economic development efforts. He, and also Foley (1993), are right in arguing that an integrated national energy planning and policy analysis is necessary to provide an appropriate reference frame for formulating a rural electrification strategy.

The importance and benefits attached to electricity require electrification to be considered as a fully fledged component in the development process. The idea that electricity should be seen as something for a more advanced stage of rural development, is no longer supportable.

One of the most important issues with rural electrification is the comparison between the costs and benefits. If affordable tariffs are taken as the basis, a cost-benefit analysis of a rural electrification project will usually result in a negative outcome. The electrification of rural areas, however, should not be assessed as an independent activity, but as one of the components of a rural development programme. In fact, the question should not be whether electrification of certain areas is economically feasible, but what society is prepared to spend in the development of that area.

The benefits of electrification for rural households are often limited to improved lighting and (a better) supply for audio and video appliances.

The economic benefits of electrification are often related to a higher productivity in the agricultural sector and an increasing number of industrial enterprises. But

in many rural areas the productive use of electricity is limited, certainly during the first years after electrification. This can perhaps partly be attributed to the fact that most utilities in developing countries do not give priority to this sector resulting in limited marketing. Further, the tariff structure and the unreliability of the service might also be impediments.
Obviously, the actual costs of rural electrification have to be determined, but one should also ask the question what it would cost society, in quantitative and qualitative terms, if rural areas remain deprived of electricity.
Nziramasanga (1995) argues that, as with the analysis used to determine the viability of roads and water supply, the analysis of the economic benefits of rural electrification should encompass the whole economy and that the provision of electrical energy to rural areas may be viable if all the beneficiaries share the costs.

Most impact studies have concluded that the expected socio-economic benefits have not been achieved and that to some extent they are not likely to be achieved at all. It is however noted that the results of past research into the socio-economic benefits of rural electrification generally refer to electrification projects which have been designed and realised more-or-less independently from other activities.
Experience[21] revealed that the impact of rural electrification could have been higher if other conditions would have been satisfied. There is reason to believe that, in the past, in many electrified rural areas, further development has been limited as the consequence of a lack of credit facilities, continued use of old-fashioned technology, lack of entrepreneurial and skilled labour and supporting services. This supports the earlier observation that rural electrification should be part of an integrated rural development plan and not, as has often been the case in the past, a stand-alone project or programme. Because of the need for this integrated approach, private rural electrification initiatives would require special conditions.
Another important aspect of rural electrification is the way in which it is approached. In the past, utilities have generally conceived the electrification of rural and remote areas as a techno-economic activity. Large scale and industrial electricity supply is predominantly a technical/administrative activity, but this does not apply to rural electrification. Apart from the technical and economic issues, the rural electrification also involves such aspects as social, ethical, institutional, political and cultural. The success of the rural electrification programme in Thailand was partly as a result of the clear overall national policy and government commitment, but also of a careful attention to political issues, customer service, service promotion, and marketing and community involvement (ESMAP 1997B).

21 See for instance Section 3.1.

Although energy needs in rural areas are usually modest, rural energy supply cannot be forgotten in considering how the depletion of natural resources and environmental degradation can be reduced.

In this context it is noted that the electricity supply to many rural areas offer opportunities for the deployment of modern decentralised renewable energy technologies.

This is also confirmed in the energy policy papers of development banks. The World Bank for example, issued in 1996 a report "Rural Energy and Development; Improving Energy Supplies for Two Billion People" in which the importance of, and their commitment to, an adequate energy supply in rural areas were emphasised. This report also addresses various aspects of the deployment of renewables in rural areas.

Stimulated by the liberalisation of the power sector, private capital is increasingly invested in large power projects that can give an acceptable rate of return. Donors seem to focus on rural energy supply with its low rate of return.

To a number of industrialised countries investments in sustainable energy projects in rural and remote areas are an attractive opportunity for so-called "greenfunds". These funds offer a limited return on investment but have fiscally attractive features.

It should however be noted, and this is particularly true for the poorest countries, that sufficient financial resources can only be made available if the international community gives priority to the development of rural areas in the developing world. The energy sector in these poor countries should therefore be used as an instrument to realise socio-economic rather than political objectives.

Chapter 3

Rural Electrification in Historical Perspective

This chapter, which is a key part of the research, deals with the historical aspects of electricity supply to rural and remote areas. The importance of historical research should not be underestimated, because it creates the possibility of identifying analogies and analysing the experiences gained with alternative arrangements. That is the reason why in this chapter rural electrification cases in both industrialised and developing countries are described and analysed in some detail. These cases have been selected on the basis of the extent and quality of the available information, the diversity, and the involvement of the author in some of the activities.

Power utilities with less advanced rural power systems may recognise specific situations and then benefit from the information in some of the descriptions. To that end, a few cases are described in greater detail than actually required for the scope of this research.

In the context of this study, a special interest is taken in such issues as the initiators of the electrification, the institutional arrangements, the financial aspects, the technology applied, the market place and the impact of electrification.

Given the time available, it is impossible to study a large number of cases. Moreover, literature which specifically addresses countrywise electrification of rural and remote areas appeared to be rather limited. The selected case studies are based on the available literature and personal research and they refer to both grid-based and decentralised systems. Together they provide a cross-section from which indicative conclusions can be drawn.

The concluding section of this chapter analyses the main findings of the case studies focusing on the institutional structures, the technology and on the financial aspects.

3.1. Rural electrification in Ireland

In Ireland, quite a number of towns got electricity up to fifty years before rural areas and rural electrification only really commenced in 1946 when a national electrification scheme was adopted.

In 1880 the Dublin Electric Light Company was established and in 1889 the provincial town of Carlow had public electric lighting installed which was supplied from a generator in a flour mill some four miles away. Subsequently many other towns got electricity and, by 1925, 161 separate electricity undertakings existed in Ireland, most of them operating DC systems of various voltages (Shiel 1984).

Although many banking and business interests, and also the Farmers Party, advocated private enterprise, a state-sponsored national electric utility (ESB) was established by the Electricity Supply Act of 1927, more or less in connection with the realisation of the Shannon hydro-electric scheme. The main arguments in favour of a national state-sponsored or ‘semi-state’ corporation were:

- A widespread and well programmed extension of the electricity grid was pursued with a corresponding large capital expenditure.
- Compensation for the existing undertakings required financing.
- Given the economic circumstances and the long term return on investments, capital was unlikely to come from private investors.
- The social and economic objectives of the electrification scheme forbade foreign private investments in the infrastructure on the prevailing commercial terms.
- Ireland had only become independent in 1922 and the idea that foreigners would have significant control over an undertaking of national importance was considered reprehensible.
- The programmed development of a national electricity infrastructure would be hampered by local politics and municipal boundaries and this could only be avoided by an organisation responsible for the generation and nationwide distribution and sale of electricity directly to customers.

The ESB (Electricity Supply Board) was created as a separate organisation which had to implement relevant national policy but with maximum freedom of operation.

Existing local electricity utilities were taken over by the ESB, technical expertise developed and customer-oriented activities organised on a district basis. These district organisations were, within the allocated resources, more or less autonomous in providing full electricity services. To promote the use of electricity and to educate, advise and persuade the consumer, an appropriate tariff policy was developed and a sales organisation (including outlets for the sale and repair of electrical appliances) was established. The price per kWh charged by the existing utilities was five pence and the ESB could offer a unit price of only one pence for electricity from the Shannon hydro-electric scheme.

In 1946, the ESB supplied 380 GWh of electricity from the hydro-electric power station and a coal power station to some 240,000 consumers, mainly in urban areas. A 38 kV sub-transmission system supported by a 110 kV transmission system, connected the main urban load centres. The distribution voltage was 10 kV.

At this time, of the total population of nearly 3 million, 39.9% received electricity from the national grid and some 1.4% from local enterprises. The remainder, more than 58% of the population, had no access to electricity (ESB 1944).

The rural areas with a population of over 1,700,000 and a potential of 400,000 connections, were still deprived of electricity. Only about 12,000 of these potential connections were in villages with more than twenty houses, the remainder were isolated dwellings (CIRED 1981).

3.1.1. Rural electrification scheme

The promotion of rural electrification in Ireland could be regarded as a classic case-study in the communication and eventual acceptance of innovation in a largely ultra-conservative society (Shiel 1984).
Shiel argues that the social, economic and cultural factors played such an important part in the project that further research by some social scientist or historian would be worthwhile.
In the foreword of Shiel's book "The Quiet Revolution", Tom Walsh notes that, in spite of many constraints and barriers, the national semi-state utility ESB succeeded extremely well in the electrification of rural Ireland. Apart from the commitment of the electricity supply board, two important factors contributed to the success of the project.
The board called in other than engineering disciplines, and barriers such as costs and reservations against the installations were surmounted through a participative community approach with local committees.
The electrification scheme was seen as a very important step towards rural development but it was also argued that further advance would have been possible with a well-planned programme of integrated rural action (T. Walsh, foreword Shiel 1984).

A report by the ESB (1944) noted that at various meetings of the World Power Conference the great value of rural electricity supply as a means of improving social conditions in rural areas had been emphasised and that, as in other countries, research work was necessary "to evolve properly designed and dimensioned farm machine units with electric drive suitable for use on farms in Ireland as farmyard machinery at present in use is designed for hand drive or for oil engine drive".
The document concluded that elsewhere "electricity supply to rural and farming communities has been a gradual process realised only over a long period of time and has entailed much educational work, very extensive organisation, the investment of a great deal of capital and the carrying out of extensive construction work".
The report continues with: "before any progress can be made …. clarity must be obtained on the fundamental question of the provision of finance; the major factor governing the monetary return which can be secured on the capital investment will be the rates of charge which the rural community will or may be prepared to pay for electricity supply".
In May 1939 the government had already approached the utility to discuss the feasibility of a national rural electrification programme. The extension of electricity supply to rural areas was inevitable and the only issues of doubt were the timing, the methods used, and the manner of its financing (Manning 1978). And it was also clear that subsidisation would be necessary which would require relevant legislation.

As a contribution to the discussion on rural electrification, the ESB prepared a proposal which suggested forming "rural supply areas, each operated as a separate unit with its own staff, with its own rates of charge and with separate accounts books and controlled centrally, rather than by local co-operatives" (Manning 1978). The ideas outlined in the proposal were based on experiences with rural electrification in a number of countries and, generally speaking, they became the basis of the approach to the electrification of rural Ireland.

3.1.2. Institutional aspects

A major question at the time of the development of the electrification scheme was whether the activity should be undertaken by the Electricity Supply Board or by another organisation. In this respect a report based on experiences with rural electrification in other countries gave valuable information (ESB1944). This report was later issued in a slightly modified form as a White Paper.

This report, which was produced by the Electricity Supply Board at the request of government, argued that the organisation must be approached from two main considerations: the technical and the administrative. From the technical view-point an area based plan was necessary; and in the case of Ireland, the areas were more-or-less determined by the existing sub-transmission and distribution system. The development of rural electricity supply was based on the extension of the existing grid into the rural areas.

The report addressed two possible forms for the organisation: administration by co-operative associations of rural dwellers, or administration by the Electricity Supply Board. It was argued that both forms were feasible but preference was given to the latter for a number of reasons:

- It was considered that the relatively high investment per consumer would have a negative impact on the establishment by rural dwellers of co-operative associations for electrical development.
- The organisation and management of electricity supply requires a high degree of specialist guidance.

Further, experiences with co-operative electricity supply organisations played an important role in the decision to entrust the national electric utility in Ireland with the management of rural electricity supply.

3.1.3. Decentralised organisation

When discussing the management of rural electricity supply by the national utility, the report argued that two different activities had to be distinguished: the technical, and the non-technical. The first group of activities included the

operation, maintenance and repair of the distribution facilities and the technical aspects of consumer installations and appliances. The non-technical activities included meter-reading and the collection of revenues.
The groups of technicians in charge of the operation and maintenance of the existing medium voltage facilities were charged with the technical activities in electrified rural areas as well. The report noted that only limited technical attention was required for the distribution facilities, provided that the equipment was properly designed and constructed.
The attention needed for the consumer installations however would depend largely on the quality and maintenance of the installations in question. Provided that there was some training on the consumer side, an electrician would seldom be necessary on the premises of the consumer.
The non-technical activities would require regular visits to the premises of the customers which would involve high costs due to the distance between dwellings. The economic execution of these activities has proved to be a problem in other countries and the solutions appear to be linked to the habits and customs of the rural dwellers and with the communication facilities. The existing meter-readers/collectors in the villages were also charged with these activities in the rural areas and it was decided to read the meters only three times per annum.
The Rural Electrification Scheme would require the construction of 125,000 km of sub-transmission and distribution line, the erection of 100,000 transformers and the connection of 280,000 premises. Each year some 10,000 km of lines had to be constructed and over 30,000 premises connected. Within the context of the scheme, “rural” did not include villages with over 250 residents and isolated single loads over 100 kVA.

In view of the extent of the scheme, the ESB established a separate and fairly autonomous and decentralised organisation for planning, construction and realisation. The principle of the district organisation had already been introduced in 1929 and proved to be both efficient and effective.
The ESB set up a rural electrification office charged with the overall carrying out of the scheme. The manager of this office had a very high level of authority and discretion and delegated much of this to the district and area engineers. The materials division, the technical division, and the development division formed the structure of the office.
Each month, Rural Electrification Organisation News was issued to keep the rural staff informed of the progress of the electrification scheme. This publication played an important management role as it also acted as a vehicle for the exchange of views and ideas and as a chronicle of the ins and outs of the staff and their activities.

3.1.4. Area approach

The decentralised organisation of the ESB had a geographical basis and each of the ten rural districts had a district headquarters. These districts had, for the purposes of the rural electrification project, a number of geographical units which usually matched with parishes since the area and the number of premises involved were considered appropriate.

Each area, typically around 65 square kilometres (see Table 3.1), was electrified in one go provided they satisfied a certain fixed charge revenue related to the cost of electrification. A proposal to the ESB for the electrification of an area had to be made by a local committee, representative of the different parts of the area.

Table 3.1. *Typical area rural electrification scheme Ireland (Dowling 1956).*

Area	65 square kilometres
Population	2,200
Number of houses	500
Number of consumers	360
Length three-phase 10 kV line	11 kilometres
Length single-phase 10 kV line	42 kilometres
Length low voltage line	42 kilometres
Number three-phase transformers	2
Number single-phase transformers	75
Maximum length low voltage line	550 metres

In many parishes, the priests and others saw, in rural electrification, a possibility for the development of local industries and an improvement in the living circumstances of rural people. On the basis of this belief they, and the members of the parish council, persuaded rural dwellers to participate and to co-operate in the construction activities.

The electrification lead to an immense change in Irish rural society. Better housing, water on tap, and modern appliances greatly enhanced living standards in rural homes (see Figure 3.2). “The rural community, which now more than ever includes many non-farming families, has developed into a strong and articulate element playing a full part in the life of the nation” (Shiel 1984). In the 1980s rural population was growing after falling for decades.

Table 3.2. *Degree of penetration of electric appliances in a rural area in Ireland eight years after electrification (in 1947). (source: Dowling 1956).*

Appliance	Degree of penetration (%)
Electric irons	77
Washing machines	15
Vacuum cleaners	22
Refrigerators	10
Electric cookers	31
Electric water pumps	27

3.1.5. Tariffs and funding

The funding of the rural electrification scheme was a key issue. It was argued (Shiel 1984) that some form of subsidy was needed because the majority of the rural dwellers had a very low income. In more industrialised countries, the ratio between rural and urban population allowed cross-subsidisation within the utility. In Ireland however, cross-subsidisation would cause unacceptable price distortion because of the relatively large number of rural consumers (400,000) compared to urban consumers (250,000). The issue of subsidy, and also that of return on investments, appeared to be frequent topics in the discussions between the government and the Electricity Supply Board.

Since electrification, uniform tariffs for electricity had been maintained in villages and towns and the question arose whether the same principle had to be adopted for rural areas. In Northern Ireland uniform national tariffs were adopted but in a number of other countries tariff policy was based on the principle that each area had to bear its own costs for the supply (ESB 1944). A uniform tariff is administratively simple but the main concern was that non-uniform tariffs were expected to be met with opposition and difficulties in the country on the grounds of discrimination. Consequently, it was decided to adopt uniform tariffs for the whole country.

Another important aspect was related to the criteria on which the fixed charge to individual consumers would be calculated. Over the world many methods have been, and still are, in use to calculate fixed charges. The method used by ESB was based on the floor area of the dwelling and outbuildings and it had the relative advantage that there was some relationship to the quantity of electricity used for lighting and to what the customer could afford.

The underlaying principle was that, on the average, the sum of the fixed annual charges paid by the consumers in an area should at least cover the fixed annual costs which were estimated as 12% of the capital expenditure for the distribution infrastructure in that area. This estimate was based on an interest rate of 5%, a depreciation of 2.5% based on a period of 22.5 years, a sinking fund of 0.5% and administration, maintenance and repair costs of 4%. It is noted that the ESB included both depreciation and a sinking fund which reduced the requirement, in the 1927 Electricity Act, to provide for some development from the ESB's internal flow of funds.

Capital expenditure, and thus fixed charges, obviously depended on the population and load density but also on the number of consumers to be connected. The ESB analysed, for some trial areas, whether the required rate of return of 12% could be achieved with an acceptable degree of coverage. The analysis revealed that a coverage above 90% would be very uneconomic but that below a coverage of 90% the rate of return rose rapidly. A supply could be offered, at standard rates, to 86% of the premises in the trial areas but it was expected that some 20% of the premises would reject supply. The ESB concluded that bringing electricity to the remaining 69% would give a return of 9.7% and thus that a capital subsidy of some 50% was necessary to avoid annual deficits (Dowling 1956).

Experience showed that, in the first few years, the average number of householders connected remained at about 60% but improved in the years thereafter so that after some ten years the overall average increased to approximately 75%.

With the exception of the years from 1955 to 1958, the ESB received 50% government subsidy on capital expenditure for rural electrification activities. In 1955 the government withdraw the subsidy with the result that the rural electrification account of the utility projected substantial losses by the end of 1958.

The minimum return on investments changed from time to time and fluctuated between 5 and 12%. In 1947, a special service charge (an annual additional amount to be paid by the consumer) was introduced for premises which did not satisfy the return on investment figure due to its higher connection costs.

During the whole rural electrification period of some thirty years, political pressure has often been exerted on the government to fund the electrification of even the most remote areas.

By 1976 some 98% of all rural premises were connected, in practice with a large indirect cross-subsidy from the urban areas. Bristow (1972) analysed the cross-subsidisation within the ESB and concluded "in the year 1968/1969, rural prices were lower by over 29% and urban prices higher by almost 9% than they would have been in the absence of cross-subsidisation at the then consumption levels".

Capital expenditure since the start, including grid reinforcement, was about 110 million Pounds of which 25% had been provided by government subsidy.

3.1.6. Conclusions

The lessons learned and the changes over the years can be summarised as follows (Shiel 1984 and CIRED 1981):

- Electrification appears to have been a very important step towards rural development but it has also been argued that further advance would have been possible with a well-planned programme of integrated rural action including electrification.
- The decentralised organisation structure on a geographical basis has proved to be both efficient and effective.
- The participative community approach with local committees appeared to be effective.
- The national semi-state electric utility was successful in carrying out the rural electrification programme but specific government subsidies were necessary.
- On many farms, electricity led to increase productivity and reducing costs. As electrification spread through the areas, existing businesses developed into sizeable suppliers of services and, in particular, equipment manufactured using electrical tools. Although the availability of electricity enhanced industrial activity, the most important developments in rural industries emerged under the influence of the grants and other support for rural development organisations and small industries programmes.
- Thousands of 2.5 and 3 kVA distribution transformers used in the grid had to be quickly replaced by larger ones because of cost and capacity.
- Although some improvements in the network structure appeared to be necessary, experience with the restoration of supply after storms has shown that a fast response and adequately sized repair organisation can give a higher overall standard of service than investing in the network for the same cost. Apart from a few areas, the reliability of supply to rural consumers is presently not dissimilar to that in urban areas.
- It is noted that, when compared with farms in other European countries, most Irish farms of the time were small and well scattered, and the standard of living was expected to remain very low for a long period. To reduce costs the design of the rural grid was based on three-phase 10 kV backbones and 10 kV single-phase (phase-phase) distribution lines. Generally speaking, the single-phase supply has met the needs of the customers but in the 1970s demand for three-phase supply increased as a result of increased farm power requirements. Investigations have revealed that the lack of a three-phase supply did not hamper agricultural activities but that the availability and costs of single-phase motors increasingly created problems. In many cases the use of single-phase to three-phase converters provided a solution but for the larger loads a three-phase supply appeared the best solution.

- On the supply side, the only aspect of the use of single-phase which needed particular attention was the equal share of the phases in the load to maintain a power system balance.
- Originally an annual consumption of 800 - 1000 kWh per house was assumed. The initial average consumption seemed to be 500 kWh and varied from approximately 300 to 700 kWh depending on the type of farming and the economic conditions in the area. An analysis of the change in consumption in two areas five years after electrification (average consumption 1891 and 1224 kWh respectively) revealed that 55% respectively 75% percent of the consumers used less that 500 kWh per annum and 22 respectively 16 percent had a consumption above the average of 1891 and 1224 kWh. The average consumption in 1981 was 2800kWh.
- To supply over 400,000 consumers, 15,000 km of 10 kV three-phase lines, 45,000 km single-phase lines, 100,000 single-phase transformers and 45,000 km low voltage lines were needed on top of the 38 kV sub-transmission system.
- The number of installed reclosers had to be increased.
- To satisfy the growing demand, the number of 38/10kV feeder stations has had to be increased and in 1983 their were some 350 (917 in 1946).
- Activities in the 1980s included the installation of capacitor banks and voltage regulators to maintain voltage accuracy, and the optimalisation of the supply system based on a cost benefit approach with the electricity not supplied as one of the parameters.

3.2. Rural electrification in the Province of Ontario

In the early decades of this century, about half of the rural population in the Province of Ontario lived in hamlets or small villages and the other half, mostly farmers, lived in scattered dwellings. This situation made extensions of the electricity grid to supply the rural population expensive.

In the province of Ontario the sale of electricity to communal groups in rural areas has been done on a trial basis. Although the principle of co-operative associations had been applied in many other areas, the results with electricity supply were disappointing and direct sales by the Hydro-Electric Commission was introduced.

In 1906 the Hydro-Electric Commission of Ontario was established to provide electricity in bulk. By 1920 the Commission was supplying electricity to the local distribution companies of all cities and villages, but power supply to rural areas was still in its infancy. Unlike the prevailing practice in the United States of America, the Commission applied for permission to distribute electricity itself to rural consumers.

In 1921, the Government decided to subsidise the cost of rural transmission and distribution lines by 50%, and from 1924 the costs of the distribution transformer and service connections were also subsidised.
In the 1920, areas were only electrified if sufficient revenues were secured to cover the capital costs of the extension. Later, this criterion was withdrawn and the Government made provisions for possible deficits in the revenues and put these in a suspense account to be re-paid later. To that effect a "Rural Power Service Suspense Account" was established in 1930.
This procedure made it possible to charge, for a certain period, a rate which would otherwise result in financial problems for the rural power district.

The same year saw, in line with the policy to promote agriculture, the approval of an act to provide farmers with loans for the service connection, house wiring and electrical appliances. The costs of the latter proved to be an important obstacle in the electrification programme. For these loans an interest rate and a maximum amount and term (five years) were set (R.J.Jeffery 1938, quoted in ESB 1944).
The basic principles of the rural electrification scheme developed by the Commission can be summarised as follows (ESB 1944):

- Rural power districts were formed.
- The geographical dimensions of the power districts, typically 250 km², were mainly determined by the distances which could be economically bridged with sub-transmission lines from a distribution centre.
- The Government subsidised 50% of the initial investment costs.
- In the districts where even with the maximum service charge a deficit arose, the Province of Ontario settled the deficit as a loan until all districts combined operated with a surplus.
- Each rural power district paid for the operations and maintenance of the distribution system in their area and created a fund for the future replacement of equipment as well as for a sinking fund to cover the investments made by the Commission.
- A rural district could in principle be provided with electricity if three ordinary farms, or their equivalent, per 1.6 km of line would be connected.
- The tariff was based on a service charge and a consumption charge. The service charge depended on the individual load demand. The Commission had eleven classes of rural service with a range of demands from 0.75 kW to 15 kW coupled with a minimum required number of consumers per 1.6 km between respectively 6.8 and 0.7 (Table 3.3).

A standard service charge was set for each individual power district and the charge was reduced if the number of consumers per kilometre of line increased.
Before 1930, the service charge was strictly based on the objective of immediately avoiding deficits, and as a result many ordinary farmers could not afford to have electricity.

The service charges given in the table were introduced in 1930, together with legislation which made the Province of Ontario a guarantor for the financial performance of the rural power districts. The latter made a long term approach possible.

Table 3.3. *Classification of services for Ontario rural power districts in 1930 (Source: ESB 1944).*

Class of rural service	Service	'Units" per consumer	Approx. number of consumers per 1.6 km line	Demand permitted in kW	Nett annual service charge $ct	kWh per month at initial rate
1B	Hamlet Light	2.25	6.8	0.75	16.20	30
1C	Hamlet Light	3.75	4.0	2.0	25.20	30
2A	House Light	1.90	8.0	1.0	18.60	30
2B	Small farm serv.	3.50	4.3	2.0	25.20	30
3	Light farm serv.	5.00	3.0	3.0	30.00	42
4	Medium farm serv.	5.35	2.8	5.0	32.40	70
5	Medium farm serv.	7.50	2.0	5.0	45.00	70
6A	Heavy farm serv.	12.50	1.2	9.0	55.80	126
6B	Heavy farm serv.	12.50	1.2	9.0	63.60	126
7A	Spec.farm serv.	20.00	0.74	15.0	83.40	210
7B	Spec.farm serv.	20.00	0.70	15.0	100.20	210

Note: Prior to the construction of a distribution line, the agreed connection of consumers equivalent to a total of 15 "units" per 1.6 km line had to be secured. In 1938 this requirement was reduced to two ordinary farms or 10 "units".

The initial rural service charges did not cover the actual costs but the underlying assumption was that an increase in the number of consumers per length of line, and the increased consumption, would lead to more economic operation.
At the beginning of the electrification of rural areas the service charges were relatively high and, as a result, the more wealthy people and remunerative dwellings were connected first. This procedure appeared to have the positive effect that a solid basis was formed, and opportunities were created for the gradual future connection of consumers with less spending power.

The rate of return on investments varied from approximately 13% at the beginning, to 10% in the later stage, of the programme. These figures have been corrected to exclude the effect of subsidy.
After the second World War power stations were constructed far from load centres and this resulted in long extra high voltage lines crossing vast areas. Some of the rural communities living near these lines could be supplied with electricity through special technical solutions such as capacitive coupling systems and the Illiceto system[22].

3.3. Rural electrification in the United States of America

It is noted that the conditions in the various areas of the United States of America are so diverse that a discussion of the development of rural electrification in this country can only be done in general terms.
Although electricity was supplied by investor-owned utilities to quite a few urban areas in the country before 1900, rural areas remained unconnected for many decades as it was uneconomical and not attractive for private investors. The investor-owned electricity supply industry in the United States has always considered electricity as a commodity.
In 1910, only 2% of farms had electricity and there was no prospect of more widespread electrification of rural areas (Nye 1990).
In the first and second decades of the twentieth century, a few co-operatives were established to distribute electricity in rural areas but, in general, rural electricity supply was done, more- or-less fortuitously, by existing investor-owned power utilities supplying load centres. However, the technology for electricity supply to rural areas was available.
In the first decade of the twentieth century, groups of people in the United States became concerned over the increasing disparities between urban areas and the rural areas where the majority of the population lived, and over the migration of hundreds of thousands of rural people to the cities. The report of the “Country Life Commission” in 1909 summarised the conditions in rural areas, particularly with regard to the farming community, and made several recommendations such as the improvement of roads, better schools and sanitation, electrification by co-operative organisations and by using power from government-owned hydro-electric power stations and the provision of a telephone system.
A few years later, in 1913, the National Electric Light Association (NELA) presented a report on the electrification of rural areas. Although the report was positive on electricity supply for certain irrigation projects, this umbrella organisation of investor-owned power utilities and the manufacturers of electrical equipment concluded that urban areas were a far more attractive

22 See Section 4.3.1.

market and that there was no justification for the electrification of the average farm (Nye 1990). Some farmers started installing small hydro-electric generating units, and also wind turbine generators and expensive oil-fuelled engines were used although only a minority of farmers could afford them.
In 1923, the “Committee on the Relation of Electricity to Agriculture (CREA)” was formed by representatives of the power industry, equipment manufacturers, farmers’ organisations, and the government to investigate the potential of rural areas as a market for electricity. On the basis of a demonstration project it was found that agricultural production could be increased considerably and overall costs decreased if farms were electrified. These conclusions, and the feasibility of widespread rural electrification, were confirmed by demonstration farms in Ontario which received electricity from a hydro-electric power station (Nye 1990).
Also in 1923, the report of the “Giant Power Survey Board” of Pennsylvania gained nationwide attention and, although the proposal did not materialise, it indirectly led to other investigations such as that of the Power Authority of the State of New York (PASNY). In 1931, a report concluded that the construction costs of rural distribution lines could be reduced substantially and that not only was widespread rural electrification socially and economically desirable but it was also financially feasible (NRECA 1985).
The United States investor-owned power supply industry however had carried out its own research and concluded, as a result of the experience with twelve rural demonstration lines, that electricity supply to rural areas was far from profitable and they remained uninterested in extending electricity supply to sparsely populated regions.
In the twenties an investigation by the Federal Trade Commission, into the public relations practices of the investor-owned utilities, revealed that over a number of years millions of dollars had been spent on systematically influencing public opinion using unacceptable methods.
The establishment by the government of both the Tennessee Valley Authority Power Generation and the Rural Electrification Administration in the thirties, can be seen as necessary responses to the attitude and procedures of many investor-owned power utilities in those days (Nye 1990).

3.3.1. The Tennessee Valley Authority

Traditionally, the USA has largely depended on funding from the private sector for the electricity infrastructure, although government financed power stations do exist. Federal government became involved in power generation through the development of rivers for navigation and irrigation, and the dis-satisfaction with the pace of electrification in rural and remote areas by existing power companies.

The Tennessee Valley Authority (TVA) was established in 1933 and was owned by the federal government. It originally had as its objective to develop the impoverished valley but became also involved in hydro-electric generation in the area. The involvement of the federal government in power generation had also to do with the “preference principle” of a 1906 law which assured that “the benefits from federal projects would flow to the people rather than to private interests” (NRECA 1985).

The inspiration for the multiple use of river systems partly stemmed from the ideas of the American conservation movement. Already in the first and second decade of the century, a group of socially conscious engineers emerged who had the idea of combining social and economic development with power generation to create a new society with model communities (Nye 1990).

But in those days it was also questioned whether the regulation of the investor-owned electric utilities was efficient. Some felt that the TVA could provide a yardstick by which to measure the operations of investor-owned power companies (Vennard, in OGEM 1963). Despite the existing investor-owned companies objecting, it was decided that the TVA would also generate, from hydro, electricity. TVA has always been a wholesaler of electricity rather than a distribution company.

Swidler (1985) argues that the Tennessee Valley Authority was in fact an experiment. In the 1930s only three 3% of the farms in the valley were electrified and the TVA became aware of the difficulties in expanding the uses of electricity in an impoverished area during the Great Depression. One of the results was that the TVA helped in creating the “Electric Home and Farm Authority (EHFA)” with the purpose of arranging, with manufacturers, for the production of simple, low-cost appliances, such as refrigerators and washing machines. The appliances were sold through regular dealer channels with EHFA assuring the necessary credits. The EHFA appeared to be useful in the transition to an electrical economy.

Another spin-off of the TVA project was the creation of rural electrification co-operatives which distributed electricity in their areas.

In later years, the TVA supplied electricity to 160 municipal and co-operative distribution utilities which served a combination of rural and urban loads. The Authority also purchased a number of electric utilities, sold its distribution facilities to the newly formed municipal and electric co-operatives, and operated the generation and transmission installations.

Swidler (1985) argues that the combination of rural and urban loads in one supply area proved to be of great advantage in the spread of rural electrification. The advantage was that the financial basis of the co-operative remained sound as a result of the already partly electrified and economical attractive urban supply area in spite of the more uneconomical electrification of sparsely populated areas.

Swidler concludes on the basis of the TVA experience that:

1. A semi-autonomous electrification authority, of which the daily operations are not influenced by the more bureaucratic procedures of non-business organisations, is necessary to achieve sufficient flexibility, effectiveness and efficiency.
2. Sufficient funds must be secured well in advance to allow for proper planning and to continue operations.
3. Rural electrification programmes usually need external financial support, at least in the first stage, but the amount of support should be inversely related to customer density per mile of line and customer ability to pay.
4. Appropriate economical criteria are extremely important. The pursuit of an area-wide coverage and the maintenance of financially sound operations conflict, and it is often a wise policy, at least at the outset of electrification, to give priority to the electrification of the relatively large and prosperous regions of the supply area.
5. Prices should be set well in advance and based on an appropriate tariff policy. The system that has been applied in the United States of America produced uniform tariffs for the whole utility at a level which supported a rural service and which regarded the ability to pay of the small consumers. In this respect, the combination of electricity supply to rural and remote areas with the operations of a large and prosperous utility seems obvious and is the easiest way to maintain financial integrity.
6. Co-ordination with other rural development programmes is necessary, in particular with those that enhance agricultural productivity. Modern agriculture depends heavily on electricity for irrigation, maintenance tools, food conservation, information services and so on. A programme, or a group of programmes, should not be limited to the supply of electricity but should also provide for the installation of appliances, particularly those for productive use.
7. Engineering standards should be the same for each rural electrification project and must be set nationally.
8. The scale of rural electrification projects should be such that the project benefits from economies of scale. In this respect, small, discrete projects are not usually justified.
9. Local resources should be employed as far as possible.
10. It is doubtful that investor-owned utilities can play a large role in the electrification of rural areas because of the limited opportunity to achieve a reasonable return on investments.

3.3.2 Establishment of the Rural Electrification Administration

The seeds of the formation of the Rural Electrification Administration (REA) can be found in the socially and economically poor situation of rural communities at the time, the problems caused by the depression, and also in the dissatisfaction of the rural population with the very slow electrification of rural areas and the attitudes of the existing power utilities. It is likely that the latter has had a strong influence on the development of the REA into a form of national movement and the development of a system with rural electricity co-operatives.

In the first decades of the century, rural electrification had been considered in economic terms but during the 1930s the social aspects also emerged. At the same time, a government -supported electrification programme was considered necessary to help solve the problems of the rural areas.

In his proposal of 1935 for nationwide development of rural electrification, Morris Llewelllyn Cooke stated (NRECA 1985):

- Works with a public character such as the large-scale electrification of rural areas can help conquer the depression.
- As a federal rural electrification programme would have influence on the general level of the rates, and on regulation in the power sector, it is probably the beginning of real control of the electric industry.
- To enable large scale rural electrification, national government has to assume control and responsibility for the whole programme.
- One of the reasons for the limited electrification of rural areas is that power is generated in distant central power stations which forces the construction of expensive transmission and distribution lines. For this reason independent diesel and hydro-electric power stations will be needed in the areas to be electrified where no adequate and reasonably priced electricity can be obtained from an existing grid.
- To achieve low rates, the use of electricity has to be stimulated as much as possible.
- Existing legislation in some states has to be adapted to enable the creation of power districts.
- In the Department of the Interior, a Rural Electrification Agency manned by socially minded electrical engineers should be established. This agency must co-operate with other departments regarding the planning of relevant developments.

On the basis of Cookes proposal, the Federal Government’s Rural Electrification Administration (REA) was established to financially support the electrification of rural areas.

In fact, the REA was one of the New Deal Programs that were developed by the Government in the thirties. The Rural Electrification Act of 1936 provided for an initial programme of ten years. Since 1939 the REA has been an independent lending agency under the Department of Agriculture of the United States.

In the 1940s the REA became a permanent agency and the government extended funding to cover electrification of all areas with a payback period on loans from 25 to 35 years.

In 1942, a number of rural electric co-operative leaders established the National Rural Electric Co-operative Association (NRECA), also on the basis of the co-operative ideas. NRECA is a national membership and interests organisation and has, at present, over 1000 rural electric co-operatives as members. Since 1962, NRECA, in collaboration with the United States Agency for International Development (USAID), has offered its services to other countries in the field of electrification.

Over the years, most of the REA funds have been directed to co-operative organisations in order to realise distribution lines in rural areas, but in more recent years generation and transmission facilities have also been financed. The latter facilities were only financed where power was not available to satisfy demand or, in the case of an existing power system, where linking to the available facilities would prove more expensive than new facilities.

Loans are repaid from the revenues of the co-operatives. For many years the interest has been 2% p.a., and since 1945, the maximum payback period has been 35 years. The REA has funded over 1000 rural electric co-operatives and only two loans, representing a negligible amount, have been foreclosed (NRECA 1988). Since 1973, REA has had a revolving fund out of which new loans can be made.

Vennard (in OGEM 1963) argued some thirty years ago that the original objective of the REA had been achieved but that the organisation and the subsidies continue. Currently, power system expansion and reinforcement still need appropriate funding. Capital is still provided by the Government but supplementary financing is secured by the National Rural Utilities Co-operative Finance Corporation (CFC).

3.3.3. Activities of the Rural Electrification Administration

The main task of the Administration was to make funds available for co-operative associations of the rural population, to local authorities and to private power companies to finance electrification of their rural areas. The REA not only provided loans at low interest but also assisted the organisations in technical, management, legal and accounting matters.

For instance the REA, in collaboration with manufacturers, developed new designs of distribution equipment which were more appropriate for rural electricity supply. The REA also provided courses on relevant subjects such as the effective and efficient use of electricity and on accounting practices. In this context it should be noted that the co-operatives were purposively created “grassroot” consumer organisations and that their members, although the population was familiar with co-operatives, had only limited experience with running such an organisation and with electricity supply.

A rural area was defined as an area, outside of the villages, having a population in excess of 1500 and the REA determined that 3 connections per mile of rural

distribution line were necessary to cover the costs. In 1945, this condition could be moderated as a result of additional funding by the Government.
The condition for feasibility was thus very simple: a minimum of three premises (usually farms) per mile of line. The REA aimed at simple and modular approaches for specifications, manuals and so on. The REA did not approve the use of funds to finance way-leaves in the areas to be connected to the grid.
There were people that wanted to have electricity but they were too far from the mainline, or lived in areas where not enough neighbours signed up. During the sign-up period, farmers were encouraged by Government representatives to apply for a loan for an electricity supply.
The people in the rural areas were not united in their demand for electricity, and education and guidance by REA staff was needed. One of the experiences of the sign-up teams was that it was better to explain the benefits of electricity in the presence of the farmer's wife (NRECA 1988).
The education of co-operative consumers about electricity and its uses has always been one of the REA's focusses. A guide for members of REA Co-operatives was prepared and a number of magazines such as "Rural Lines", "Rural Electrification News" and "Rural Electrification Magazine" were issued to keep the staff and the members of the co-operatives informed. These activities contributed to the group spirit and also had a marketing effect. The involvement of the rural population was further enhanced by the screening of a thirty-minute documentary film about co-operative electrification, and by official ceremonies after the completion of a distribution system.
In 1938, some 400 rural electrification projects in 45 states were in progress and these involved about 400,000 farms and 2,000,000 people. Some 600,000 km of lines had been constructed and some 780,000 rural consumers connected by 1941 (NRECA 1985).
Around 1940, California, New Jersey, Massachusetts and Connecticut all claimed to have at least 80% of all farms electrified (ESB 1944). In the Southern States, however, the electrification rate was still between 10 and 20%.
In 1947, there were still 2.5 million farms that were not electrified. In the same year the REA also introduced funding for a rural telephone service.
In 1961, 98% of all farms had electricity and of these 51% were served by rural electric co-operatives, 43% by investor-owned companies, and 6% by others.
Swidler (1985) argues that the activities of the REA prompted many investor-owned utilities to intensify electrification of rural areas in their supply regions. Today, the rate of electrification is about 99%.

3.3.4. Rural electric co-operatives

The REA assessed the developments in other countries and decided to foster the establishment of grass-root organisations that would build and operate distribution lines themselves.

The familiarity of the people in rural areas of the United States of America with co-operatives was advantageous but the support of the REA staff appeared to be necessary in order to get the organisations going.
The co-operatives are owned by the customers themselves and could thus be described as “self-help electrification” organisations. Membership of the co-operative was available to each inhabitant of the area by paying an annual fee (US$ 5 in the thirties).
Local leadership and the efforts of the committed few, were the driving forces behind the activities. These people canvassed others in their areas to apply for membership of an electricity co-operative.
The members of a co-operative elect the board of directors which develops general goals and objectives, as well as broadly-outlined policies and procedures, and which appoints the top level manager(s). Given the commitment of co-operatives to democracy, communication has always been considered to be of prime importance (NRECA 1988).
The establishment of an REA co-operative in an area meant the start of an electricity enterprise with a staff of possibly more than fifty persons depending on the number of projects and the degree of maturity of the electricity infrastructure. In the thirties, the recruitment of managers, office staff, technicians and linemen was not a problem and office space was available because of the low occupancy in rural areas.

It should be noted that many co-operatives did not limit their activities to electricity supply but also promoted commercial and industrial activities in rural areas. For instance, many crossroads communities became business centres including shops for electrical appliances.
Vennard (in OGEM 1963) noted that electricity co-operatives were eligible for low interest loans, were excused from paying federal income taxes, and got discounts from the power companies in their standard wholesale rate.
According to NRECA (1988), rural electricity co-operatives, in general, pay both state and local taxes on the same basis as investor-owned companies, but because co-operatives do not make profits they do not have to pay income taxes.
A typical early co-operative had 800 members living on nearly eight hundred square kilometres of land with 400 kilometres of line. 75% of the customers were farmers.
More recently, an average Rural Electric Co-operative would have 55 employees, own 3,000 kilometres of line and serve 7,400 connections (NRECA 1988). The typical investment in 3,000 kilometres of line amounts to $ 12.5 million.
Presently 10.5 million premises (over 25 million people) in the United States of America are served by rural co-operatives. These co-operatives own about 3.2 million kilometres of distribution line which gives an average of 3.2 connections per kilometre of distribution line.

Table 3.4 shows the average number of connections, and the revenues per length of line, for rural co-operatives, investor-owned and publicly-owned utilities. These figures should be interpreted carefully because of the great differences in the features of the distribution facilities and consumers.

Table 3.4. *Connections and revenues per line length for different utilities (Source: NRECA 1988).*

Type of utility	Connections / kilometre line	Revenues / kilometre line / yr
Rural co-operative	3.2	$ 2,800
Investor-owned	23	$ 34,000
Publicly-owned	38	$ 42,000

The key factor in the success or failure of a rural electricity system is the cost of the wholesale power, which accounts for almost half of the cost of providing electricity to rural customers.

3.3.5. Conflicting interests

In the United States of America, the government has always provided an overall regulatory framework for utility operations which applies equally to investor-owned companies and co-operatives. Emission standards and licenses for new electricity supply facilities are issued by the government which also approves tariffs. However, a very important difference between investor-owned and non-profit utilities is that the latter have “preferential access” or “first right of refusal” with regard to power produced by federally-owned and operated generating systems. This is important because the price of electricity from these power stations is usually lower than from investor-owned sources.

From 1925, small co-operatives were formed by communities which did not want to wait for electrification of their areas in the very distant future, or who were ignored by the private utilities. Private companies were forced by the State Public Service Commission to sell electricity at wholesale rates to these co-operatives. Private utilities at times spent more effort on killing these co-operatives than on expanding rural services. Practices included gaining control by the purchase of a member’s stock at a premium, and then discontinuing the less profitable lines and increasing retail rates. Another common private-utility practice in those days was to erect a “snake line” which zigzagged across the countryside to reach the profitable customers (Nye 1990).

When the REA was established, the existing investor-owned power companies had already operated power stations and transmission lines and had gained experience with electrification.
These utilities strongly opposed the establishment of the REA although the organisation would help stimulate demand which could be met by the investor-owned power stations.
In 1935, the REA asked the investor-owned utilities to suggest a programme for the electrification of rural areas. The Rural Electrification Committee of Privately Owned Utilities produced a proposal which appeared to be far too expensive and extremely vague about rates for the rural consumer. Moreover the utilities were not co-operative at all and used the time needed for further discussion to construct “spite lines”[23] through proposed REA districts and thus considerably weaken the feasibility of future co-operatives (NRECA 1985).
The REA was initially intended to provide loans to existing utilities, but in view of their previous history, and the more recent experience with these utilities, this approach was rejected in favour of financial support to non-profit organisations and co-operatives.
A survey in 1940 revealed that since 1936 there had been some 200 “incidents” between co-operatives and investor-owned utilities. The latter performed activities which were called “cream-skimming” and some of these activities had a negative impact on the plans of co-operatives which not only intended to cover the easy-to-reach and more densely populated areas but also more remote premises.

3.3.6. The technical facilities

In the United States of America, the original distribution system in urban areas was an ungrounded three-phase, three-wire system with an extensive use of single-phase transformers connected phase-to-phase. For rural areas a multi-grounded system was applied with an extensive use of single-phase lines. More sophisticated conductors and other changes enabled the REA to develop distribution lines which were some 40% cheaper than the traditional ones.
Originally, the REA focussed on the extension of distribution lines in rural areas and depended almost completely on external power supplies. In the thirties and forties, the available opportunities to purchase sufficient power reduced although federal hydroelectric projects planned during the new deal and the war period were being commissioned.

23 “Spite lines” were built (some of them overnight) by local power companies right through proposed (co-operative) service areas. These lines were in fact “cream-skimming” activities with the aim to hurt new rural electric co-operatives.

During these decades diesel power stations were built to satisfy demand, and generation and transmission co-operatives were also formed to take advantage of REA funding. This again fuelled the conflict between investor-owned utilities and the co-operatives, compromises and partnership arrangements were necessary.
In later years, multi-megawatt steam generating plants were built, some of them fuelled with local available lignite or with uranium.
At present the rural co-operatives purchase some 60% of their electricity from federal government generating facilities and the remainder is generated by co-operatively owned power stations.

3.3.7. Electricity demand

In the thirties, an average rural dweller was expected to consume 40 kWh per month with a radio, an iron and some lights. Intensive load building activities were undertaken by the REA in collaboration with manufacturers including special offers for appliances. For instance, manufacturers developed inexpensive “lighting packages” suitable for a six-room house.
A survey in some areas twelve months after electrification, revealed much higher degrees of penetration of appliances than originally expected (Table 3.5). This obviously had an effect on consumption.

Table 3.5. *Degree of penetration of electric appliances in rural area in the United States of America twelve months after electrification.*

Appliance	Degree of penetration (%)
Electric irons and radios	84.3
Washing machines	63.2
Vacuum cleaners	48.2
Toasters	35.5
Electric motors	27.1
Electric water pumps	16.2

In 1960, consumers used an average of 357 kWh per month and by 1970 consumption had risen to 687 kWh per month.
Most rural electricity co-operatives are still suffering from a lack of diversity among their consumers. About 75% of co-operatives’ revenues come from farm and residential consumers which have very similar load patterns.

Annual consumption in rural areas has increased from 6.8 billion kWh in 1950 to over 26 billion by 1960 and the load has doubled every seven years.

3.3.8. Conclusions

In the early decades of the 20th century, the investor-owned power utilities limited the electrification of rural areas to those in the vicinity of load centres. The result was that, in the twenties and thirties, the electrification of rural areas in the United States lagged far behind major European countries. It is fair to say that the decision by the government to support the Rural Electrification Program of 1935, and the way it became organised was influenced by a number of factors:

- The expectation by the American government that the rural population would organise electricity supply to their areas themselves, was not fulfilled (Nye 1990).
- The increasing disparity between urban and rural areas.
- The awareness that government control was needed for rural electrification programmes.
- The success of the Tennessee Valley development programme.
- The approach and attitude of investor-owned utilities in the early decades of the 20th century and the demand for better regulation in the electricity supply sector.

Although times were sometimes turbulent and the conflicts bitter, it seems that the American Rural Electrification Program has been successful, and that electrification has completely changed life in the rural areas (NRECA 1985). Home appliances have reduced the burden of household work and the efficiency and productivity of the farms have improved considerably. A number of factors contributed to the success of the programme:

1. The programme was introduced at a favourable moment: the country was in the midst of a serious depression and the programme not only created employment but also fostered solidarity. The programme was largely the result of initiatives from individuals rather than the political elite.
2. The organisational structure based on co-operatives and on the principle of “one member, one vote” was the most appropriate, given the circumstances.
3. The programme was not a political whim but a long-term commitment which made it more independent of short-term political influences. After Moreover, the programme has always had strong political support from the national government.
4. The availability of long-term, low-interest loans.
5. The financial, technical, managerial and educational support which could be given to the co-operatives by the Rural Electrification Administration as a national government agency.

6. The intensive marketing campaign in collaboration with manufacturers of home and industrial appliances.
7. The existence of a national co-operative organisation which could, at the national level, promote the interests of the co-operatives.

Although people in rural areas were more-or-less familiar with co-operative ideas, each newly formed REA electricity co-operative could be considered as a "grassroots" organisation. This implies that the organisations had to go through a learning process. Possibly that the features of a learning organisation, and the far-reaching decentralisation, favourably contributed to the overall success of the programme.

The original idea to leave, as was the case with urban areas, the rural electricity supply to the market sector did not work. The government had to take responsibility and control, and purposively developed financing schemes were necessary.

The performance of the Tennessee Valley Authority, the Rural Electrification Administration and others proved and still proves that government-owned organisations in the field of electricity supply can be effective and efficient.

There is no reason to believe that the conflicts between the investor-owned utilities on the one hand, and the Rural Electrification Administration and the electricity co-operatives on the other, have been the result of competition in the electricity supply sector. The experiences have shown that in the electricity distribution sector proper legislation is necessary to avoid sub-optimalisation.

3.4. Rural electrification in the province of Friesland

Friesland is one of the more rural provinces of the Netherlands and covers an area of some 3,700 square kilometres including a number of islands. In 1912 the number of inhabitants was approximately 370,000 which has since increased to 600,000.

Arable and dairy farming, and the associated industry, have historically always been the most important means of earning a living but, in recent decades, tourism has gained importance.

For a proper understanding of the electrification of the province of Friesland, it is worthwhile to begin by summarising the development of electricity supply in the Netherlands as a whole.

Hesselmans (1995) distinguishes three phases in the electrification of the country: the first phase from approximately 1880 to 1910, a second phase from 1910 to 1949 and a third one from 1949 onwards. During the first phase, small local power stations provided electricity to limited areas, in the second period electricity supply was organised on a provincial basis with one, or sometimes more, power stations and a "central" grid.

1949 marked the establishment of the Samenwerkende Electriciteits Productiebedrijven (SEP) as a result of the growing co-operation between the provincial electricity utilities in the field of electricity generation. The period after 1949 is characterised by a more nationally oriented electricity supply, Hesselmans concludes that this phase is still continuing as the generating and distribution utilities are considering ever closer co-operation.
It can however be argued that a fourth phase can be recognised: the period of the restructuring which started in the mid-eighties. Although the third phase is marked by co-operation at a national level, both the generation and distribution were still organised along provincial lines. Starting in the eighties, the latter has been abandoned through the restructuring and mergers in the electricity supply sector and, as a result, a number of interprovincial utilities have been formed. The transition from co-operation in the sector to restructuring and mergers, prompted by international (EEC) legislation, can clearly be considered as the emergence of a new organisational structure and approach.
The provincial based organisational structure of the electricity sector was, at the time, largely inspired by the pursuit of full area coverage of electrification. The present restructuring is rather aiming at a further improvement in the power sector's financial performance and strength.

3.4.1. The first electricity systems in Friesland

In 1912, the province contained eleven towns and over 350 villages, with a total population of some 360,000. The population of a town could range between a few hundred and forty thousand. Most people lived in small villages in rural areas.
At that time, seven towns and more than 10% of the villages had a gas supply, while one town and 23 villages had, to some extent, electricity.
Electrification of Friesland started in 1910, when direct current power stations were set up in two villages. One of these was realised as the result of a private initiative, in co-operation with the local council, to contract an electricity company to install a generator and a lighting system. The objective was to improve the quality of the lighting system. The other power station was established following the initiative of one of the farmer members of a local co-operative dairy factory. The surplus capacity of the dairy factory's steam engine was used to drive a generator which supplied the village with electricity. This combination of co-operative dairy factory plant and an electricity generator was established at several other locations in the province, including one of the Frisian islands.
In 1911, power stations were introduced in five more villages in Friesland. In three cases, more powerful alternating current plants were employed to supply multiple villages or a complete region with electricity. In the following two years, power stations were introduced in three more villages. In those days,

power stations predominantly supplied electricity to their immediate surroundings.

In 1912, a power station was set up in the provincial capital, originally intended to supply only the capital itself with electricity. Already by 1913 however, plans for the electrification of several neighbouring rural communities were established (VDEN 1926). To achieve this, a power cable company was set up, with the communities involved and a distribution co-operative as its members.

The power stations at this time supplied from 7 kW to 150 kW of power, whilst the costs per kWh varied widely: US$ 0.27 in some of the most expensive areas, down to US$ 0.11 in urban areas.

Power stations were usually set up on the initiative of private people, often in the form of a co-operative enterprise; but sometimes the town councils took the lead in the electrification process. After only a brief period, these newly established electricity companies each had typically between 100 and 600 private and corporate customers. These included many small businesses, such as bakers, who used electricity to improve the lighting and thus the working conditions of their businesses.

In those days, electricity was solely used for lighting, which led to fierce competition with the gas companies, which had dominated the lighting market up to then. In some towns with a reliable gas supply, local councils opposed the introduction of electricity, fearing that the competition between this new energy source and the existing gas installations would lower their revenues. However, areas with no access to gas welcomed the electricity systems, seeing them as important stimuli for further regional development. Here it should be mentioned that, during previous decades, already some effort had been put into improving the isolated situation of many villages, among other things by building better roads and constructing waterworks. By the end of the nineteenth century, a certain degree of economical prosperity had been attained, leading to all sorts of private initiatives, such as the establishment of co-operative dairy factories. In effect, already just after the turn of the century, a demand arose for the use of electricity as a means of powering machines (Commissie van IJsselstein in De Goey 1991).

In those days, the organisational prerequisites for local electricity supply systems were apparently often determined by political and religious circumstances.

As Jansma (1990) observed, communities of a predominantly socialist nature had a preference for municipal exploitation of the electricity supply; orthodox protestant towns usually leant towards an independent co-operative society, whilst an association under the leadership of a local co-operative dairy factory was the typical organisation in mixed liberal-catholic villages. Inadequate research data are available however to draw any general conclusions on the basis of these observations.

In spite of the fact that knowledge of co-operative organisational concepts was common among the population, as a result of events taking place at the turn of the century, co-operative electricity companies were rarely introduced.

In those days, the establishment of a power station required general permission from the department of Public Works, which could be readily obtained, especially in the early days of electrification. As a result, the number and diversity of power stations quickly grew out of control, prompting the province in 1914 to issue a bylaw in order to provide some degree of regulation for the provincial electricity supply.
Most of the smaller electricity companies had already disappeared by the beginning of the twenties: generators were quickly rendered obsolete as a result of technical developments in terms of reliability; also direct current had many limitations, one of which was high line losses. In addition the exploitation of larger power stations proved much more economical than the smaller power stations. Other points taken into account were the low degree of diversity in an electrified area and the low load factors, with values between 0.1 and 0.2 being quite common. As a result of this, the operators of small power stations were often quite happy to join the provincial electricity company, established in 1916. Some operators, with a progressive approach, had already switched to larger alternating current stations to supply larger areas with electricity, and they saw their objectives frustrated.

3.4.2. Government intervention

In the first ten to fifteen years of the twentieth century, the initiatives of rural communities, private individuals and municipalities generally resulted in decentralised power systems.
Research had shown, however, that the future prospects of individual power systems were poor, and that a district oriented power supply system would have many advantages. In 1912, an expert was commissioned by the province to devise a plan for the electrification of the entire province. The plan showed that, even with an interest-free loan, the financial state of a company running one large, new power station linked to a provincial power grid would be very poor for the first two decades of operation. An intermediate solution was to split the province into four districts, based on the four largest existing power stations, and to build power lines between these stations. When the demand for electricity had increased sufficiently, a new and larger power station would be built. The provincial decision was postponed because central government was in the process of defining legislation covering electricity supply. The lack of adequate legislation resulted, as the Provincial Executive stated, in “a purely anarchistic freedom” (quote from Jansen 1990), which prompted the province of Friesland to issue a bylaw in 1914, designed to limit the foundation of new electricity systems and to prevent further uncontrolled growth.
This bylaw stated that the supply of electricity was subject to provincial permission, and that a power station had to be based on an effective and centralised way of supplying electricity to the entire province. In Friesland

however, this centralisation was based on the aforementioned four districts, each with its own power station, rather than the whole province.

Meanwhile, a central government committee had reached the conclusion that a district-based electricity supply system would be the best way to achieve fast and economic electrification of the whole nation. As the radius of each district was determined as some fifty kilometres, close co-operation between town councils would be required, something which the committee felt was unlikely to happen.

The committee also concluded that the provinces were not the appropriate authorities to organise electrification, since provincial boundaries did not always coincide with the divisional lines for economically viable electricity supply systems. For this reason, the central government was considered as the appropriate authority to organise national electrification.

In political debates, most parties expressed the fear that the existing private and municipal electricity companies might let their own interests prevail, with the result that less profitable areas would be deprived of access to an electricity system. In the first decade of the twentieth century there were indeed town councils which regarded the electricity business mainly as an attractive way of increasing their revenues (De Goey 1991).

Consequently, a government monopoly on the production, transmission and distribution of electricity seemed to be the only way to secure common access to this service of national importance. The central government could more easily provide the necessary funds and clear the way for setting up a high voltage power grid. This solution was however doomed to failure since the provincial approach was effectively already in force, and no agreement could be reached on a national scale.

A general consensus was reached that the provinces should guarantee the electrification of the economically less profitable areas as well, something which was an important issue at both the provincial and the national level. The development of rural areas was of great societal importance, whilst electrification was considered to be an economic activity. The financial aspects of area coverage were not altogether unimportant, but were made subservient to social and political interests.

The choice of a provincially organised electricity supply system was therefore made by political bodies, with the interests of the rural areas as the decisive factor.

A system of governmental licences was set up, in which licences were given exclusively to public bodies and district power plants. The increased diversity in electricity users played an important role: the demand for electricity could be more evenly spread over the day, leading to a better use of the facilities. The overnight draining of the polder areas played a particular role in this development (Hesselmans 1995).

The licensee was bound by law to supply electricity to anyone applying for a connection within the area covered by the licence. Furthermore, the electricity companies were required to operate as non-profit institutions, and the electricity rates had to be approved by the minister in advance.

Provinces were not always keen on setting up their own power stations, one example of which is the province of North Brabant. Hesselman (1995) notes that Blässing (1992) takes the view that this has a certain connection to the liberal opinions of the time. The government's task should be to provide the necessary preconditions, but to remain impartial to the socio-economic structures. Despite this, the province choose to have a provincial power system with a central power station. This was based on the belief that with both private people and town councils, the expected revenues would play a deciding role in the electrification of the region. The question as to whether investor-owned utilities should be preferred to publicly owned utilities was nevertheless never considered important.

3.4.3. Municipal and co-operative utilities

At the beginning, the electrification of the province was a localised process, taking place mostly in rural areas. Co-operative societies and (to a lesser extent) municipalities played an important role in this process.

In 1916, after the establishment of a provincial electricity company, most of the decentralised co-operative and municipal power stations were shut down, and the electricity supply to local companies was taken over by the provincial electricity company. When establishing the provincial electricity company, the assumption was made that the municipalities would have a certain degree of autonomy regarding the electricity supply and would take care of the low-voltage distribution. The province would be responsible for the medium and high voltage distribution to large-scale consumers. The VDEN (1926) concluded that the efficiency of this system heavily depended on close co-operation between the supplying and distributing companies.

This aforementioned system was in place for many years; often however, the profits of the municipal companies went into the council chest, thus keeping the electricity rates rather high. At that time, municipal electricity companies employed their own technical and administrative staff, such as a cashier/ book-keeper, a chief mechanic, and one or more mechanics. This not only resulted in a relatively costly administration, but also stood in the way of uniform electricity rates. For these reasons, plans were soon drawn up to assign all of the electricity supply network (including the local distribution) to one party.

The exploitation of the distribution grid could be carried out more efficiently by the provincial electricity company; by appointing meter readers and bill collectors in every village, all of the administrative tasks could take place centrally, in the main office. Furthermore, an assistant mechanic, capable of

carrying out small maintenance and repair tasks could be appointed for each transformer zone. The rest of the work could be completed by personnel from the district offices, which were set up at the same time.
During a later stage of the electrification process, the number of new connections in the rural communities fell, and the provincial electricity company started to take over technical and administrative management duties of the distribution companies, as a result of a management agreement with town councils. In some cases, the company would take on the construction and exploitation of connections, but only after the town council or the co-operative society had guaranteed a certain level of electricity consumption, so as to ensure cost-effectiveness.
In 1937, it was decided that the provincial electricity company's goal should be the direct supply of electricity to all consumers in the province. All the remaining municipal and co-operative electricity companies (with the exception of the capital's electricity company) were dissolved by government law in the 1940s.
On the West Frisian islands, power systems were set up as a result of private or council initiatives; these systems were mostly diesel fuelled. In one case it was combined with a co-operative dairy factory.
These systems functioned autonomously for many decades, but could never be exploited in a cost-effective manner. Only in the 1970s did the power consumption of most islands grow sufficiently to make a medium-voltage connection of the islands to the provincial power grid profitable.

3.4.4. The Provincial Electricity Board

After the national government decided that electricity supply should take place at the provincial level, advice was sought in the Friesland province on setting up a provincial electricity supply system.
Initially, a supply system with province-wide coverage seemed impracticable, and so experts put forward the suggestion of dividing the province into districts, which could be electrified in turn. These proposals however did not align with the goals of the provincial government, which were to achieve full electrification, based on social and political considerations. This latter goal called for a long-term approach, which was difficult to determine.
Meanwhile, the demand for electricity in the province had risen much faster than initially expected making the construction of a single, efficient power station which could supply the entire province with electricity a more attractive option.
Whatever approach was chosen it was recognised that the financial situation of an electricity company would be poor at first, and several organisational options were considered.
If the province commissioned another party to supply electricity, this company would then have to receive some sort of financial assistance. Also, any

commercial company would primarily serve its own interests and as a result, the electrification of rural, and thus unprofitable, areas would be at risk.
Another option was for the province to establish a company of its own, and subsequently contract out the exploitation to another party, but it was feared that this would lead to a conflict of interests between the province and the lease-holder. With a co-operative society, on the other hand, there was the risk that the province would have too little influence.
Some argued that a corporation structure would have the advantage of a greater freedom of action in relation to politics, which would facilitate company management. An acceptable amount of provincial influence could however be guaranteed through the contribution of funds. Also, because the economic viability of a provincial company had already been demonstrated, the decision was made in 1916 to establish a purely provincial electricity company, all the shares of which were owned by the province.
Research by the Vrije Universiteit in Amsterdam has shown that the choice of a corporation or a pure provincial company depended mainly on the political composition of the provincial government (Hesselmans 1995). The provincial electricity company was however turned into a corporation in the 1980s, to facilitate co-operation with other companies.

The primary objective of the electricity company was to produce and transmit electricity, in order to meet the demand for electricity in the entire supply area in the most economic and efficient manner. To achieve this, the following basic principles were applied: the production of electricity was to take place mainly in a central facility, the company was to operate on a commercial basis, notwithstanding the fact that making a profit is not the company's objective; the provincial treasury should not suffer as a consequence of the company's operations, and the low-voltage distribution system should preferably be commissioned to town councils (under the same principles), whereby the provincial electricity company can, if desired, play a guiding, counselling and assisting role (VDEN 1926).
Immediately after the establishment of the provincial electricity company, times were difficult. The demand for electricity rose sharply partly because of a low availability and the relatively high prices of coal, gas and petroleum. High costs were incurred as new facilities had to be set up, partly to replace local power stations. The shortage of building materials slowed down the expansion of the power grid, and the resulting stagnation in electricity consumption growth threatened the company's turnover. Between 1920 and 1922, it was possible to expand the power grid over a large part of the province, but the increased costs, including fuel, could not be adequately compensated for mainly because early contracts with large-scale consumers had set a fixed electricity rate for a period of many years.
These circumstances had left the company in a very poor financial state, and it was clear that the company could not operate in a cost-effective manner, with

the given demand. Even though the general prosperity had risen considerably, and the province could compensate to some degree for the financial problems through the electricity rates, by 1923 the losses of the provincial electricity company had become so structural that provincial intervention was unavoidable. Severe measures were taken: a reorganisation of the electricity production department was carried out, including a staff cutback, and contracts with certain consumers were revised in order to establish a more realistic ratio between electricity rates and fuel prices. Further, the province contributed to increased solvency by means of interest-free loans. In addition, the province took the strategic decision to take on the responsibility for distribution networks and the supply of electricity to small-scale consumers. This was to prevent municipal and distribution companies from primarily concentrating on profitable activities, or impeding electrification in favour of their gas companies.

This decision was also related to the objective of achieving a higher turnover, which required much attention to be given to acquisition, something which could only take place effectively if one party was solely responsible for the entire electricity supply.

In the twenties, promotional activities were scaled up considerably, and the provincial company promoted itself by presenting information about electricity in schools and by setting up courses, aimed at consumption development.

By 1927, the growth in turnover had made it possible to lower the rates for small-scale consumers, and to take over several municipal electricity companies. In 1928, the provincial electricity company achieved an operating profit for the first time, and by 1939, all the accumulated losses had been repaid.

In 1924, a transmission and distribution network was already set up in a large part of the province, providing an excellent springboard for the electrification of the entire province. Between 1916 and 1924, the connection rate increased from about 5% to 30%, based on an average household size of five people and a population that grew from 380,526 to 397,029.

The province’s power system was based on four districts, each with a central supply point, connected to the province’s capital using overhead transmission lines. The overhead power lines to the districts were initially suitable for voltages up to 10 kV, but could be upgraded to 50 kV. Many of the underground distribution lines were also capable of voltages up to 10 kV.

The sixties and seventies saw an upgrade of medium-voltage distribution lines, necessitated by the concentration of cattle breeding activities, the mechanisation in the agricultural sector, and the introduction on a large scale of milk cooling tanks.

3.4.5. “Decentralised unless…”

For many years, the organisational structure of the provincial electricity company was based on the districts which had a certain degree of operational autonomy. This district system was abandoned only in the sixties, to be replaced by a central organisation and administration, which also handled requests for connections, power grid planning and the implementation of these plans. The provincial service departments were left with a strictly administrative function and they also had to perform switching operations guided by a central grid operation staff.

Following an elaborate internal corporate reorganisation, a decentralised system for the medium and low voltage distribution grid was re-established in 1990. Based on the adopted principle of “decentralised unless”, regional electricity distribution offices with a large degree of operational autonomy were instituted. This revival of a decentralised structure and the degree of decentralisation was prompted by the dissatisfaction among some groups with the performance of the centralised organisation, the need for a better service towards, and a closer contact with, the customers and a possible co-operation with regional gas distribution companies.

Since then, the provincial electricity company has merged with another provincial company, and in 1997 an evaluation of the performance of the regional offices established that another approach would be more cost-effective. Moreover many clients appeared to prefer the settlement of their questions and complaints over the telephone. The regional offices were closed down and a callcentre was established in the headoffice. It is noted that in recent years effective callcentres became possible because of the developments in information and telecommunication technology. The focus of the callcentre is on reacting to incoming calls of clients albeit a callcentre could be used for other business activities as well. Whether the service provided by utility callcentres is better than that of near-customer offices, is still to be evaluated.

3.4.6. Recent developments

In the eighties, the electricity company merged with other electricity companies in the northern part of the Netherlands, to form an electricity production company whose task it is to supply the parent companies with electricity. This development followed new legislation from the national government, intended to separate the large-scale production of electricity from the distribution of electricity, combined with horizontal integration of the distribution of several forms of energy. The electricity company consequently placed its central production facility in a combined subsidiary company, and formed an energy company which purchased several regional gas distribution companies. In the nineties, new European legislature, the desire for cost reduction and corporate strength, has led the energy company to merge with other Dutch energy companies.

Another development which emerged during the eighties was the revival of decentralised production of electricity. Since the second decade of this century, electricity supply has been based on a central grid: the distribution grid was predominantly supplied from central power stations. In the last two decades however, small scale wind turbine generators and combined heat and power units have been introduced into both rural and urban distribution areas. As the grid design was based on a central approach, the integration of decentralised power generation has caused technical problems in a number of cases, and prompted an upgrade of the medium voltage system.

3.4.7. Conclusions

The drive for electrification originated locally all over the Netherlands. Private individuals, existing companies and later town councils started the introduction of power stations. Developments in the province of Friesland took place accordingly, and rural areas were responsible for the majority of initiatives for setting up and constructing power plants. This development was encouraged by the fact that most of these areas lacked an adequate gas supply, together with government decrees from the end of the nineteenth century intended to make rural areas more accessible.

Electrification started out with decentralised power systems which were, however, soon rendered obsolete as a result of technological developments. As central production of electricity became a more viable option, both common interest and national legislation made the province take charge of electricity production and transmission, while local distribution continued to be the responsibility of town councils. Particularly during the phase of promotion and expansion of the power grid, a provincial electricity supply, governed by one party, proved to be the most effective management strategy, offering the best warranties of area coverage. An increase in the electricity company’s turnover by means of consumption development was one of the main prerequisites for the company’s cost-effectiveness.

Electrification was considered to be more than an economic activity by both the national and the provincial governments, and it was considered a matter of common interest to introduce electricity into the countryside. The financial burden, mostly arising from achieving coverage in rural areas, was not insignificant, but it was considered of secondary importance to social and political issues. Also, it was generally agreed that only provinces could guarantee the electrification of less profitable areas, which led to the establishment of electricity companies on a provincial basis.

Apart from upgrading the rural medium-voltage distribution grid in the sixties and seventies, there has been no need for specific rural electrification programmes, either in the province of Friesland or in the rest of the Netherlands. During the first decades of the provincial electricity company, and in particular during the infrastructure construction phase, government financial support was required; which was supplied in the form of interest-free loans. After the reimbursement of these loans, all costs were covered by the proceeds of normal operations. The provincial electricity company's rates were slightly above the national average.

3.5. Rural electrification in Bangladesh

In Bangladesh, the governmental national electricity utility the "Bangladesh Power Development Board" was originally the sole supplier of electricity to the whole country. The Power Development Board operated central power stations and interregional transmission lines and served large load centres. However it appeared to be unable to extend services to rural areas.

At present, three government ruled organisations are still responsible for part of the electricity supply in the country: the Bangladesh Power Development Board (BPDB), the Dhaka Electricity Supply Authority (DESA) and the Rural Electrification Board (REB).

In the last few years, as part of the ongoing power sector reform, several other electricity companies have been established such as the Power Grid Company of Bangladesh (PGCB), the Dhaka Electric Supply Company (DESCO), the Rural Power Company (RPC), and other Independent Power Producers.

3.5.1. Rural Electrification Programme

The Rural Electrification Programme of Bangladesh must be seen within the context of a much wider development plan adopted by the Government of Bangladesh: "the state will adopt effective measures to bring about a radical transformation in rural areas through .... the provision of rural electrification ... and remove disparity in standards of living between the urban and rural areas." (quoted in Shamannay 1996). This "radical transformation" has various dimensions, including economic and social ones, and the development of democratic principles.

Since its beginning in 1977, the rural electrification programme in Bangladesh has been administered by a government agency, the Rural Electrification Board (REB), and implemented by a number of area electric co-operatives. This organisation is similar to the way the rural electrification programme in the United States of America was organised during the thirties and forties (Theuer 1995).

The objectives of the REB centre around supporting the development of rural areas and the improvement of the living standards of the rural population with particular emphasis on the poor. This includes the promotion of participation by the rural population in a society based on democratic principles. Consequently, the programme needs to address both the electricity supply for productive use,

and for the provision of electricity for social purposes including that to poor households.
The REB in collaboration with the National Rural Electric Co-operative Association of the United States has designed the rural electrification plan. Since its inception some 15 donor countries, through the Government of Bangladesh, funded the Bangladesh Rural Electrification Programme.

3.5.2. Organisational aspects

The implementation of the rural electrification programme is based on an organisational structure with a central agency and member-owned co-operatives, the Palli Bidyut Samities (PBS). This structure was selected from three institutional alternatives: an adapted (existing) Power Development Board, an autonomous agency with locally operated sub-divisions, and an autonomous agency with locally organised co-operatives.
The latter option has been chosen because[24]:

- It has the highest probability of success in developing and administering a rural electrification programme in Bangladesh.
- It contains all the ingredients that have made rural electrification programmes successful in other developing countries.
- It meets the objective of providing the opportunity for the rural population to participate in the process of electricity supply to their areas.
- It offers a low cost opportunity to electrify rural areas.

The REB is obliged to supply "electricity to each and every village of the country". The supply areas of the REB however do not include certain municipal areas, industrial areas, important towns, cantons and universities which have already been electrified by the Bangladesh Power Development Board (REB 1994).
The Rural Electrification Board has the authority (USAID 1996-1):

1. To establish electricity generation, transmission and distribution systems in the rural areas
2. To take measures to ensure the effective use of electricity to foster rural development with special emphasis on increasing the use of electric power for economic pursuits ......
3. To determine ... the criteria for rural electrification
4. To organise the prospective customers into formal and informal organisations, for the purpose of execution and management of schemes and providing related services ….

24 Commonwealth Associates/NRECA, 1978 quoted in Shamannay 1996.

The REB can be compared with a utility holding company with many tens of operating units (USAID 1996-1). The board provides loans to PBSs to construct distribution systems in their areas and to purchase the materials needed. After completion, the operation and maintenance of the distribution systems is performed by the PBSs.
Since 1977, sixty-seven electricity co-operatives have been established in various regions of the country. The rural co-operatives are, in principle, independent entities in which the consumers are both the members and the owners. During the first years following establishment these PBSs are managerially and technically supported by the Rural Electrification Board which is, in turn assisted by the NRECA from the USA. The Rural Electrification Board operates a uniform accounting system and management procedures, and also has a comprehensive training programme.
The REB appoints the management of the PBSs. Apart from the first term of three years, the consumer-members of the co-operative elect the PBS board of directors. The actions of the board are subject to approval of the REB and consequently the government effectively rules the co-operatives. It is further noted that the government appoints all members of the REB board.
The PBSs need to operate within policy rules and operating procedures issued by the REB which obviously limits the flexibility of the co-operatives. Services to the consumers and the collection of the revenues are carried out by the PBSs.
An assessment of the existing organisation of the Rural Electrification Board (USAID 1996-1) revealed that decision-making, even regarding routine operations, required the involvement of many hierarchical levels resulting in a cumbersome process and delayed responses of the PBSs to consumer requests. This situation is attributed to the fact that the REB is a government agency with inherent bureaucratic features. Since this is not likely to change in the near future, it has been suggested that the PBSs be given more authority and resources to manage the power supply in their areas.
The REB’s guidance and control of the PBSs was supposed to be reduced as the co-operatives matured but experience shows that the autonomy of the PBSs, albeit considered essential for the provision of adequate services to customers, has remained limited.
The findings of the assessment of REB operations can be summarised as follows (USAID 1996-1):

- Timely decision making is hampered by a lack of sufficient functional authority at the level at which the work is done. This is not (only) a matter of organisation structure but also of culture.
- The occupation of upper positions in the organisation by political appointees, generally for short terms, is often at odds with effective management.
- Improved strategic planning will increase effectiveness and provide information to middle management about the objectives of the organisation and the way they should be achieved.

- Appropriate management information systems are needed to supervise performance. These systems will provide the information needed for proper decision-making.
- Training needs and facilities need special attention.

The role of the REB should be broadened to include utility regulation in the field of electricity supply to rural areas. It has been recommended that the REB should become a member/consumer-oriented agency and, to that end, develop a Member Services Office (USAID 1996-1).
It has also been noted that the REB needs to remain a government agency because of its role in the funds made available by donor countries.
Most of the PBSs have demonstrated an ability to respond properly to customer problems. For instance, the PBS "one-stop" complaint desk for consumers appears to be effective, both in adequately responding to customer complaints and in recording problems and solutions. Notwithstanding this, the PBSs need to further enhance their customer service to include supporting renewable energy projects to benefit people in areas that will not be connected to the grid (USAID 1996-1). It has been suggested that the REB and PBSs address the problem of electricity supply to (usually poor) people living in very remote areas through PV systems. Although current PV systems are not economic for productive uses of the electricity generated, substantial improvements in lighting, needed for education and health purposes, could be achieved.

Timely actions by the PBS and/or the REB following major technical problems such as substation malfunctions, need to be improved. This would require sufficient resources, both financial and technical, to maintain the distribution systems and, moreover, a more systematic approach to maintenance. NRECA advisors have suggested that the PBSs should establish a central "Co-operative Service Organisation" which would acquire maintenance materials and other relevant services. Generally speaking, both the REB and the PBSs have had encouraging experience with contracting local expertise and services when needed for utility operations.
Many members of the PBSs have appeared to be rather inactive and reluctant to answer questions of (prospective) customers, and there is no general feeling that the members actually own the co-operative. There is some evidence that this has to do with a cultural hierarchy in the rural areas, the loss of income while attending PBS meetings, and with the fact that PBS membership does not offer any additional benefits beyond electricity supply. Active participation, by the population, in the policy making of the PBSs is thus limited.
Daily operations of the PBSs, in the sense of supplying electricity, generally do not provide any problems. However, the role of the co-operatives as agents for the development of their area has not materialised, despite the existence of a member services department.

Member education, and member information about utility operations, are two of the most important issues for a co-operative and in this respect the commitment of both the REB and the PBSs is necessary.
The provision of training through a variety of courses to the appropriate employees, appears to be both a must and a challenge. The effectiveness of overseas training courses was considered debatable because of the costs involved, the limited number of persons who could attend and the differences in technology applied (USAID 1996-1).

3.5.3. Electricity supply system

The electricity supply system is based on a central grid and all power is purchased from the Power Development Board. The REB and the PBSs also have the authority to generate their own power.
The principle of area coverage during electrification is followed. This concept includes the realisation of a basic distribution system (the backbone system) which allows the connection of an increasing number of consumers. Provided that funds are available, a system will be constructed if the number of domestic connections per kilometre of line is 22 or higher.
The technical standard throughout the rural areas in the country is based on the appropriate ANSI and IEC standards and includes a single-phase 11 kV or 6.35 kV distribution grid, 2.5 kVA or 5 kVA distribution transformers and a 220 Volt service system. Subtransmission is at 33 kV and the Power Board operates this system.

3.5.4. Performance and service quality

In 1976, less than 3% of the population in rural areas had access to electricity. The first PBS was formed in 1978 and in 2000 there were 67 PBSs. Since the establishment of the REB and the PBSs, 2,379,202 connections in over 26,221 villages have been established and over 105,131 kilometres of distribution line have been completed (as per June 1999). Of these connections 82.8% were domestic, 11.7% small commercial, 2% industrial, and 3.1% for irrigation purposes. In addition over 7,000 street lights have been installed.
The total invested amounts to some US$ 1billion giving average costs per connection of approximately US$ 420. These costs only cover the distribution system and not the generation and transmission facilities, the service connections or house wiring. Some 20 million people in rural areas benefit from the electricity provided under the programme.
This success has been possible because of the strong commitment of the Government and the management of the REB to electrify the rural areas coupled with the technical, managerial and financial support of various donor countries.

The electricity rates of the PBSs are set to cover the operation and maintenance costs of the distribution system plus the service debt, and to create acceptable business reserves. The commercial and industrial users heavily subsidise domestic consumers.
The rural electricity co-operatives are regarded as successful in technical and managerial terms. In 1981 the total distribution system losses were 28,8%, a figure which has reduced since then to some 16%[25]. Mason (1990) notes that, although the technical losses in the distribution system must be considered rather high, system operation and the collection of revenues were good. In 1999, the average bill collection rate was 94%. The financial viability of the PBSs is an important subject of concern and in this context it has been recommended that the emphasis should be on intensification and further development of the systems now in operation. Although the programme has been very successful up to now, external financial and technical support remains necessary. Management, planning, co-ordination and monitoring were considered to be the other subjects for future assistance.
A survey in electrified areas (Shamannay 1996) revealed that 75% of the respondents judged the performance of the PBSs as acceptable. One quarter of a group of leaders were not satisfied and even complained about the attitudes of the PBS staff.
The respondents like electricity for lighting for the following reasons (in order of preference): the quality, the comfort, safety, cost effectiveness and environmental friendliness. About one- third of the consumers mentioned complaints with the bills. The PBS female consumer- advisors are well known.
The demand for electrification is such that many people are dissatisfied with the pace of electrification. The main complaint however refers to frequent load shedding by the national Power Development Board. The limited availability of electricity induces electrified households to keep other lighting systems as backup.

Power is purchased by the PBSs in bulk from the Bangladesh Power Development Board, and currently this organisation faces a generation capacity shortage. As a consequence, many PBSs experience almost daily load shedding, a situation which seriously affects the viability and reputation of the co-operatives. The frequent power outages lead large consumers of the PBSs to install their own generators which leaves the grid operating costs to be covered by the smaller consumers.
This situation has led to a feasibility study on the installation of decentralised generating plants (USAID 1996-2). PBSs are interested in installing their own generators for peak lopping purposes and thus reducing the risk of load

25 This figure excludes the high loss lines and consumers recently taken over from BPDB/DESA.

shedding. A consortium made up of large consumers, the Rural Electrification Board and the PBSs (Theuer 1995) could finance these generators. In December 2000 a 70 MVA gas fired power station was in operation and three 10 MVA power stations were in the stage of being commissioned. These are all Independent Power Producers and shareholders include the REB and a number of PBSs.

Many consumers, particularly in the older PBSs, are prepared to pay up to 10% more for electricity provided that the service is more reliable. The willingness to pay more for increased reliability is greatest for the smaller industries and least in the large industries (Table 3.6).

Table 3.6. *Willingness to pay more for increased reliability of electricity supply. Refers to small, medium and large industrial enterprises in new (<5 years) and older PBSs. (Source: Shamannay 1996).*

Response	Small (old)	Small (new)	Medium (old)	Medium (new)	Large (old)	Large (new)
Yes (%)	86	40	73	60	25	-
No (%)	14	60	27	40	75	-
Total	100 (n=21)	100 (n=15)	100 (n=11)	100 (n=5)	100 (n=4)	-

3.5.5. Features of supply areas

The supply area of each co-operative covers, in general, 1000 to 1300 square kilometres with 15,000 to 17,000 consumers and includes 10 MVA substation capacity and some 800 km of distribution lines.

During the fiscal year 1993/1994 seven additional PBSs were formed. The average area of these PBSs was 1760 square kilometres, and the average length of distribution line per square kilometre was 0.9 km (varied from 0.58 to 1.06 km) and the average number of proposed connections was 12.9 per square kilometre (varied from 8.7 to 15.9 per square km). In these PBSs, the distribution of proposed connections was: domestic 82.7%, commercial 13.5%, industrial 2% and 1.8% irrigation. (REB 1994).

In 1994 the consumption pattern of the PBSs was domestic 31%, small commercial 7%, irrigation 27% and industry 35% (REB 1994). Thus the industrial and irrigation customers use over 60% of all the electricity distributed against some 30% originally expected (Schiller 1996).

The load factor varied between 26% and 56% in a number of PBSs (REB 1994). Because of high peak demands, the load factor of most of the PBSs is low which obviously contributes to a high unit cost. It should be noted that increased demands from the irrigation sector in some PBSs has caused overloads and thus a decrease in distribution system reliability.

The establishment of PBSs and the intensification (reaching more consumers in an electrified area) are considered equally important because the population provided with electricity, even in the mature co-operatives, remains low (20 to 30%). Thus electrification of a rural village does not mean that all the villagers will have an electricity connection.

The average annual consumption of various consumer groups selected from ten PBSs with at least five years of existence are given in Table 3.7 This table also shows the "per connection" maximum and minimum consumption calculated as an average figure per co-operative.

The consumption of domestic and small commercial consumers are similar.

Table 3.7. *Average annual consumption various consumer groups in ten co-operatives (derived from Shamannay 1996).*

Consumer category	Average consumption (kWh)	Maximum consumption (kWh)	Minimum consumption (kWh)
Domestic	330	456	234
Small commercial	356	462	231
Industrial	14666	39959	5659
Irrigation	4801	8260	680
Street lights	395	640	193

The average domestic and small commercial consumption per connection appears to increase with the degree of maturity of the electricity supply system. Figure 3.1 shows the relationship between the average "per connection" consumption and the age of the co-operatives. These figures, which have indicative value only, have been determined from the data of ten PBSs aged 5, 7, 9, 11 and 14 years respectively. The average annual growth of the "per connection" consumption by domestic and small commercial consumers is about 5%.

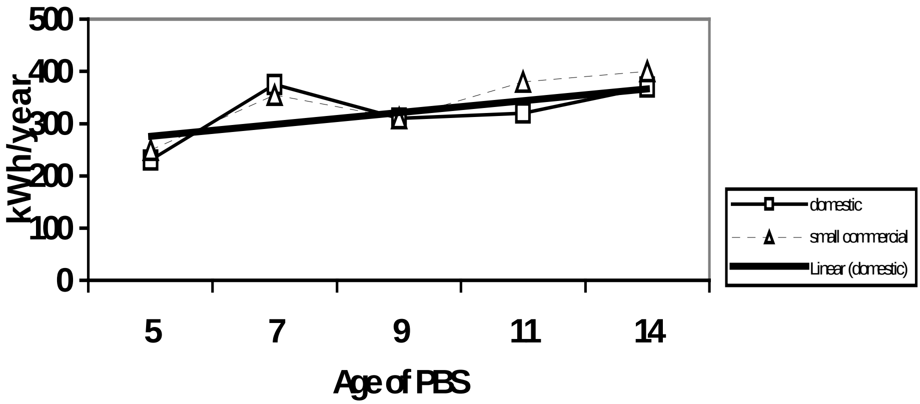

Figure 3.1. *Growth domestic electricity consumption per connection as a function of age of co-operatives (average for 10 PBSs). The numbers of PBSs underlying the average value: 1 for age 5 and 7, 2 for age 9 and 3 for age 11 and 14 (Source: USAID 1996)*

3.5.6. Electrification Impact Assessment

Theuer (1995) states that migration to the cities has virtually halted as a result of the improvement of the living conditions in the rural areas of Bangladesh due to electrification. He also notes that many of the co-operatives show significant sales growth in the categories of domestic consumers, commercial and larger industrial users, and for irrigation purposes.
He claims the following benefits:

- Kerosene lamps have been replaced by electric lights.
- Radio and TV are now commonplace.
- Many new industries and jobs have been created, particularly for women (mainly in the textile industry).
- More efficient irrigation methods have been introduced resulting in increased agricultural productivity and an expanding agri-business sector.
- Active and democratic participation of the citizens in the operation of the co-operatives.

It is however not clear on what evidence these statements are based.
In 1996, an in-depth “Socio-economic Impact Evaluation” of the Bangladesh Rural Electric Programme was undertaken (Shamannay 1996). This was claimed to be the first socio-economic assessment since the Rural Electrification Programme began in 1977.
The report of the impact study notes that, despite the comprehensive nature, the work is only a snapshot and that periodic participatory monitoring would be needed to overcome most of the limitations attached to this method. Never-

theless, the study should be considered as very valuable and there is more than sufficient reason to consider that both the conclusions and the recommendations are well founded.
The evaluation study by Shamannay included both qualitative and quantitative impact assessments. A comparative measurement of the economic impact of electrification was based on questionnaires completed by representative groups in a number of areas, both in electrified and non-electrified villages. To achieve reliable qualitative data on the impact of electrification on people's way and quality of living, use was made of the Participatory Rural Assessment technique[26] involving some 150 villagers in various areas.

The major findings can be summarised as follows.
Economic impact: A direct result of the electrification programme is the employment of nearly 6,000 people (of which 25% are women) at the REB (some 1,100 people) and the 54 PBSs. As an indirect result, another 22,000 people are employed in organisations that support the electrification programme.
The commercial sector has experienced, on average, a 34% increase in turnover as a result of the prolonged opening times and the more attractive and secure atmosphere. Although electric lighting costs 60% more than other options, the commercial sector is willing to pay this provided that the electricity supply is reliable.
In PBS areas where, in addition to electrification, other infrastructure such as roads, health services and educational facilities has been developed, the economic effects are greater and larger industrial enterprises (with more than 50 employees) have particularly been established in these areas.
Small industries (with less than 10 employees) were far more numerous than larger industries. Most of these small industries sell their products to local markets and they often respond rapidly to the provision of electricity alone.
The study concluded that in villages with electricity supply, the income in electrified households is, on average, 22% higher than that in non-electrified households, and about 50% higher than that of households in non-electrified villages.
Electric-powered deep tube irrigation is rated by the respondents as providing the maximum economic gain, and electric lighting the least, although the latter is the most valued benefit, followed by the opportunity to reduce time-consuming household activities and to watch television.

Social impact: Electricity has become an integral part of rural life and fulfils the hopes and aspirations of the beneficiaries. The population perceives the electrification of rural areas as much more than bringing the "new light" into the

26 See for instance: L.F.Salmen 1989.

areas. A man in a remote village in Bangladesh considered electricity as being “freedom” (Shamannay 1996 cit. in Schiller 1996).
The survey revealed that 41% of the respondents believed that electrification had resulted in a significant improvement in their living standard while 54% thought that there had been a positive change to some extent. Whether old or young, male or female, electricity was considered to be the most important component in improving the standard of living.
Although electrification appeared to improve the average living standard in developed PBSs (over 5 years old), the differences between the poorest and richest households grew in the electrified villages. Those who can afford to invest in electrical appliances that support income-generating activities, benefit the most.
Better opportunities for women, reduction in the isolation of the areas, educational and health care advantages, and greater incomes were generally mentioned as the most striking advantages. The socio-economic assessment also revealed that in electrified villages in Bangladesh the non-electrified households also enjoyed some benefits of the increased economic activity and improved health care in the village.
96% of the respondents mentioned the very positive impact of electrification on education and the availability of information as a result of better lighting, and the increased involvement of women in the education of the children.
The socio-economic situation of women in electrified areas has clearly been improved through the mechanisation of various time-consuming activities, the improved dissemination of information and the opportunity for relaxation and to work and stay outside of their households.
The report concludes that the original fear of some experts over a very slow development in the electricity demand, and the inability of the rural population to pay for the service, has not materialised.
Field observations during the study seem to indicate that many migrants to urban areas returned to their villages after electrification, mainly because the opportunities for employment and the standard of living were improved.

Cultural impact: Inward looking villages have become part of the global village. The possibility of watching television is perceived by many rural dwellers as a reduction in their isolation and as a recreational opportunity; but there are also less positive feelings, particularly regarding the negative influence of foreign cultures and the potential waste of time.
Although the PBS structure is a good basis for the participation of the population, there is a feeling among respondents that the existing societal structure and culture in the rural areas is not readily compatible with co-operatives.

Environmental impact: no adverse and irreversible impact on flora or fauna has been found. Television was used to support tree planting campaigns resulting in

a significant rise in the number of trees planted. Following the increased quantity of water used in electrified areas, there is some fear that the ground water level will fall with possible negative effects.
A number of people were electrocuted and three main causes were identified: contact with live distribution overhead lines (41%), improper use of appliances (45%) and inappropriate house wiring (14%).

Institutional impact: Very few of the member-consumers of the co-operatives appeared to understand the way in which the co-operative organisation works and the roles of the board and the members. The results of the evaluation revealed that the participation of the consumer-members in the policy and decision making process and the PBSs as a social organisation has not developed as expected.
On the basis of the findings, Shamannay also made a number of recommendations including the following.

- Incentives and other measures for load management during peak periods need to be developed.
- Improved information to consumers about load shedding caused by a shortage of generation capacity which is beyond the control of the PBSs, is necessary.
- The consumer-members of the PBSs should be better informed about the features of co-operatives and their ownership. The advisors could receive additional training to play an active role in this aspect.
- The role of co-operatives in the development of the communities and areas should be enhanced. The PBSs should have the authority to collaborate with local government, banks, NGOs and private entrepreneurs to foster activities were electricity could be used effectively.
- In already electrified areas, the physical and social infrastructure should be promoted by the PBSs to support further development. The PBSs should also develop and implement a long-term plan for the productive use of electricity.
- The inspection of overhead lines, house wiring and appliances should be improved to reduce electrocution risks.
- The PBSs as a whole should become more powerful, and the organisation should become more transparent. The Member Services Department should receive a more pronounced position in the PBS organisation. Relevant training programmes, for instance on human resource development and marketing, should be provided.
- The opportunities for power generation by the PBSs alone, or in joint ventures with private investors should be assessed.

3.5.7. Decentralised power generation

The Bangladesh Power Development Board is facing a substantial shortage in generation capacity which forces load shedding during peak periods in order to maintain power system integrity.

In 1995, load was shed on 220 days and for more than 763 hours in total (8.7% of the year). The total peak load of the PBSs was about 270 MW and, on average, some 70 MW was shed resulting in an estimated sales reduction of over 6% (USAID 1996-2). In those years the government initiated power sector reform to attract private investors, but the situation in 2000 was even worse. This repeated load shedding hasa severe adverse impact on the financial performance and the image of the PBSs.

Various industrial enterprises that are sensitive to supply interruptions, are considering the possibility of installing their own generators, and a number of them have already done so. The installation of private power plant by local industries leads to an under-utilisation of the existing distribution facilities and a substantial reduction in the revenues of the PBSs. If the sales to local industries by some PBSs were halved because of industrial self-generation, the retail rate would need to be increased by up to 25% to maintain the existing operating margins.

This situation, which is expected to continue for several years, has led to a recent study that addresses the potential, and the implications of, power generation by the PBSs (USAID 1996).

Within the existing legislation, the Rural Electrification Board and PBSs are allowed to generate power. Joint power production activities between the PBSs and local industrial consumers would appear to present the following problems:

The existing commercial structure of the co-operatives.

- The perception of the co-operatives by industrial consumers and the reluctance of the latter to co-operate with government-ruled entities.
- The possibility that industries which are supplied with natural gas can produce their own power cheaper (and more reliably) than if purchased from the PBS.
- Industries that have their own generation facilities are not allowed to sell excess electricity to the grid.

Given these problems it has been suggested that, in the current circumstances, and with the need for a fast response, the PBSs should own and operate decentralised power stations based on gas engines.

Table 3.8 gives an overview of the perceived benefits and drawbacks of such small-scale power generation by the co-operatives alongside to grid supply.

The study also showed that power plants from 1 to 10 MW using gas-fuelled engines could supply electricity at a cost of 2.5 to 4.5 USct per kWh, depending on load factor (Figure 3.2).

Table 3.8. *Aspects of small-scale power generation with gas engines by rural co-operatives (derived from USAID, 1996).*

Advantages	Disadvantages
1. Fast and effective response to power shortage	1. Fuel efficiency lower than with co-generation and/or combined cycle power generation
2. Reduction in impact of supply interruptions on consumers	2. May require foreign exchange
3. Relatively small investment	3. Additional staff for operation and maintenance needed
4. Facilities can be moved to other locations or used for peak lopping in the future	4. If no gas available, more expensive LFO to be used
5. Transmission grid reinforcements not necessary	5. Only viable in areas with acceptable load factors and customers that are very sensitive to supply interruptions
6. System losses reduced	
7. Standardized and more cost effective alternative to self generation by industries	
8. Avoids loss of major revenue sources	
9. Better use of existing resources	
10. Easy for sponsoring by donor agencies	

These costs are based on a gas price equivalent to that for large-scale central generation. Under these circumstances, small-scale generation using gas fuelled engines is competitive with the current rate for grid supplied power. However, because of the higher fuel price, small diesel power stations should only be used as a back-up facility in rural areas.

The following options for additional power generation in the supply areas of the PBSs have been analysed in the USAID study.

1. Realisation and operation of a power station using a co-operative's cash reserves plus additional financing by a commercial bank and/or government through donor agencies.
2. Realisation and operation of a power station using a co-operative's cash reserves and additional financing on an equality basis by local investors/ industries and/or a commercial bank.
3. Realisation and operation of a power station using a co-operative's cash reserves and additional financing by an equipment supplier.
4. Realisation and operation of a power station by a domestic enterprise under a BOO, BOOT or BLT scheme[27] with additional financing by the government, foreign investors and the co-operative.

27 BOO: Build, own and operate. BOOT or BOT: Build, own, (operate) and transfer. BLT: Build, lease and transfer.

5. Realisation and operation of a power station by a foreign enterprise under a BOO, BOOT or BLT scheme with possible participation of a co-operative.

The analysis revealed that schemes such as BOOT, BOT, BOO and BLT are inappropriate for these small (standardised) projects, mainly because of the complexity and costs of the arrangements, and the relatively long lead times of the schemes. Financing by an equipment supplier could result in an un-competitive price and also difficulties regarding the terms and conditions of the financing.
A power station constructed and operated by the co-operative is distinctly preferable provided that the PBS has adequate cash reserves. Local consumers and/or banks would preferably provide additional financing.
The rural 33/11 kV substations typically have a maximum transformer capacity of 10 MVA. The capacity of a decentralised power station in limited by the local load and the capacity of the transmission line and the substation transformer.
The preferred location of a decentralised generating facility is near the substation except in those cases where local industries could use waste heat. Industries and substation located together would be the ideal solution.

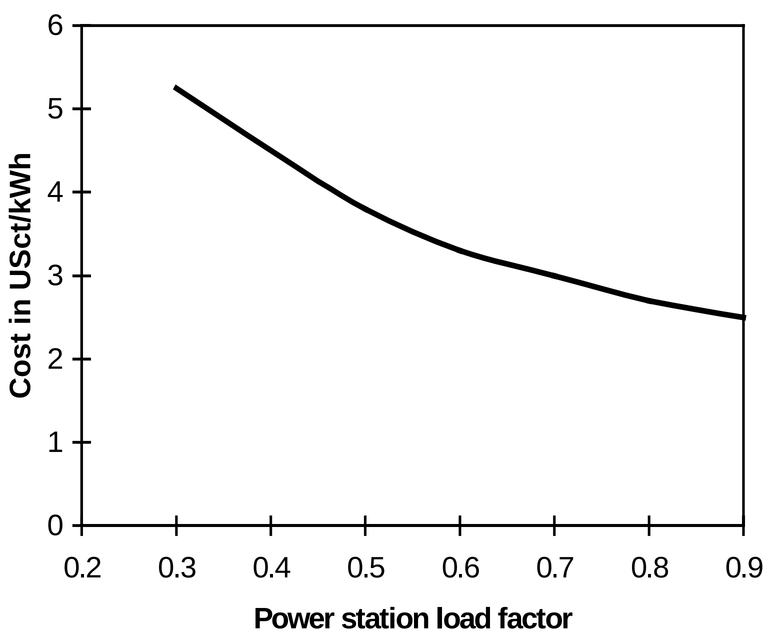

Figure 3.2. *Unit production costs as function of load factor. Based on unit size 1 – 2 MW; investment costs US$ 600/kW; amortisation period 10 years; interest 10%; O&M costs 3% of investment costs (source USAID 1996).*

3.5.8. Conclusions

The REB is obliged to supply “electricity to each and every village of the country”. Recent field work (Zomers 2000) revealed that the Government of Bangladesh is committed to realise this challenge before 2020. Politically, electrification is taken as bringing electricity into the rural areas. But the electrification of villages does not imply that all potential consumers will be served. The connection rate within a village heavily depends on the affordability of the population to pay for a service connection and the available budget for the extension of the local distribution system. A recent World Bank estimate suggests that with the present rural electrification rate of 200,000 a year, only about 22% of the households will achieve, in 2010, a connection to the rural grid. With an annual rate of 400,000 this would be 32%. With the latter rate 50% of the household would be connected in 2023. It seems justified to conclude that grid based electricity alone will not be sufficient to meet the electrification challenge.

Moreover, the Rural Electrification Programme reaches increasingly areas of the country that are more expensive to electrify. These more remote places cannot economically be supplied with grid-based electricity. The deployment of renewables such as Solar Home Systems, seems to offer the best opportunities for these places and there are indications that the Government of Bangladesh and the Rural Electrification Board are in the process of preparing relevant policy plans and implementation strategies.

Although the Bangladesh Rural Electrification Programme is regarded as very successful, there are indications that the co-operative ideas have not, after nearly two decades, developed as expected. There are indications that this is partly related to the cultural circumstances in the rural areas of the country. The assessment report recommends propagating the co-operative ideas more intensively. To that end, it is proposed to establish a long-term programme for the development of democratic values, leadership and practices, and to encourage members to participate in the activities of the PBS.

However, the question arises whether such an approach would be effective or if it could lead to undesired tensions in the rural society. This question is relevant because the present societal and cultural circumstances in the rural areas of Bangladesh are not considered to be very compatible with the co-operative organisation.

The establishment of agreements between rural industries and the electricity co-operatives for joint power generation is hampered mainly by legislative restrictions including the fact that industries are not allowed to sell excess electricity to the utility. Schemes such as BOO, BOOT and BOT are judged unsuitable for small-scale power generation in rural areas.

The task of the REB differs from that of the PBSs. The PBSs focus on operation and maintenance of the distribution systems to achieve a reliable electricity supply. The results of the assessment indicate that the PBSs should have more authority to operate as independent utilities. The direct customer approach of the co-operatives with a “one-stop complaint desk” and female advisers has worked well.

The emphasis of the REB’s mission is on overall planning including securing donor funding, the development of policies and procedures, the purchase of materials and the supervision of the PBSs. The study suggests that the REB’s future activities should focus on supporting of the co-operatives with regard to the generation and distribution of electricity.

The Bangladesh experience confirms that, although electrification plays an important role, it supports development more effectively if it is in combination with other infrastructural measures.

The small commercial and industrial sectors in rural areas attach great value to the security of supply. It was not the rate, but the unreliable electricity supply, that induced rural industries to consider installing their own power generation facilities.

The growth in electricity consumption by both domestic and small commercial consumers over recent years is estimated at 5% per year and the assessment study also revealed that the extent of electrification, even in the mature co-operatives, remains relatively low (20% to 30%). The share of the total rural electricity consumption by industrial consumers and irrigation is high (on average over 60%).

The imbalance between the load and the generation and transmission capacity results in regular and protracted load shedding, and this underlines the importance of proper co-ordination between the generation and distribution of electricity, with regard to both the technical and financial planning of the infrastructure.

3.6. Aspects of rural electrification in some other countries

This section briefly describes certain aspects of rural electrification in some other countries. These countries were selected on the basis of available documentation and the descriptions mainly draw on the of research carried out by the Electricity Supply Board of Ireland in the early 1940s and on interviews by the author with owners and operators of small-scale power stations.

These descriptions contain information about the institutional backgrounds of a variety of electrification efforts, private initiatives and the associated problems encountered, the performance and costs of decentralised power stations, and the efforts of utilities to satisfy environmental requirements. The information is used to further substantiate the analysis of rural electrification history in Section 3.8.

3.6.1. Sweden and Norway

Because of the availability of water resources, small-scale hydro-electric power stations were used the basis for electricity supply to rural areas in both Sweden and Norway. In 1924 some 1700 small hydro power stations were in use in Sweden, of which 60% supplied direct current, and their average capacity was 10 kW (ESB 1944). Due to the use of DC voltage, the supply area of these power stations was, for technical reasons, limited to a group of farms or a small village and this was obviously a major drawback of these systems.

In the rural areas of Norway similar developments took place. Table 3.9 gives examples of the small-scale hydro-electric power stations which were build in the municipality of Sør-Aurdal from 1908 onwards. Most of the DC power stations were decommissioned in the fifties and the AC stations in the sixties and seventies.

One of the few private AC power stations still in use is at Høgfoss Elverk, shown in Figure 3.3. The Høgfoss power station is owned by two families and has been in operation since 1916. Each of the owners is entitled to half of the revenue. The head is 40 metre and use has been made of a natural lake fitted with two small dams.

A Myrens Verksted Francis turbine from 1915 drives a 1000 rpm generator, output 400 Volts AC, 50 HZ, which can supply 130 kW. The unit provides electricity for one large and one smaller farm and 10 houses using a step-up transformer and a 5 kV single circuit overhead line of some 5 km. Some forty years ago the generator was replaced and some further modifications have been made.

In the beginning, 91 consumers were connected in addition to the owners of the plant, and each of them had a maximum load relay set at 500 W. In those days, electricity was only used for lighting purposes. The consumption in kWh of the consumers have never been measured, the criterion for payment was the load.

The present consumers are also connected to the distribution grid of the utility but that facility is normally used only as a back-up. The power station does not run in parallel with the grid although often power could be supplied to the grid. In 1992/1993, the maximum load amounted to just under 100 kW. Existing legislation in Norway seems to require owners of power stations with a capacity of over 100 kW to pay the government a certain amount annually.

Even without supplying the grid the power station is apparently profitable, but because the consumption is not measured a price per unit cannot be calculated. Although modifications and repairs have been carried out, the costs of the power station can be regarded as written off. Figures were not available to ascertain whether a completely new power station could be cost-effective (Høgfoss Elverk 1993).

Nearby, a private power station was in use until 1985, the Ølmhus Fallet Kraftverk. This one had a Pelton turbine with a head of 15 metre and an AC

generator of 50 kVA, 750 rpm. This power station had three owners and had 29 consumers each with a maximum load relay set to 500 watt.
Frequently on this site more electricity could be generated than was consumed but occasionally the water supply was limited. This had a negative impact on the availability of electricity supply with the result that several consumers switched to grid supply when this became available. The power station has never supplied electricity to the grid.
Due to damage to a turbine bearing the unit is no longer used. Repair would not economically be justified even if the electricity price was tripled.

Table 3.9. *Small-scale hydro-electric power stations in Sør-Aurdal, Norway (source: Sør-Aurdal Kraftandelslag 1977).*

Name of power station	Year of construction	Capacity (kW) AC/DC	Number of subscribers
Olmhus Elverk, Hløera	1908/1909	22 DC	14
Langvassbekken, Hløera	1910/1911	28 DC	7
Bagn Lysanlegg, Bagn	1910/1911	12 DC	
Bagn Lysanlegg, extension	1911	50 DC	
Storebros Tresl, Bagn	1910		50
Storbekken L, Garthus	1911	30 DC	20
Dalingbekken, Begndalen	1913	64 AC	53
Busua Elv, Hedalen	1914	32 DC	35
Høgfoss Elv, Begndalen	1916	130 AC	91
Reinli Lysv, Reinli	1921	17 DC	
Hløera Kraftv, Hløera	1925	50 AC	29 (in 1953)
Aamot Lysv, Reinli	1943		
Øtgard Lysv, Reinli	1945		
Stavedal Lysv, Reinli	1945	40 DC	15
Tollehaugen Lysv, Reinli	1945		
Liagrenda Lysv, Reinli	1944/1945	45 DC	
Ole Haugs Lysv, Reinli	1943	17 DC	
Kvaal og Bøn L, Reinli	1945	4 DC	
Skinnerud Lysv, Reinli	1945	5 DC	
K.Boens Lysv, Reinli	1945	4 DC	
Storebrofoss Kraft, Bagn	1943	1320 AC	
Storebrofoss, extension	1948	350 AC	

Figure 3.3. *Høgfoss Elverk, Begndalen, Norway.*

In the forties, pressure was exerted on the political parties of Sør Aurdal to provide municipality-wide electricity. In 1947 a limited liability company was established which became responsible for the distribution of electricity to the whole municipality and for the purchase or own generation of power.

Presently there is a renewed interest in small scale hydro power stations. This development is probably due to one or more of the following aspects:

- problems with further utilising national hydro resources far from load centres;
- objections by environmental groups to the planning of a large-scale gas-fuelled power station;
- the desire by electricity distribution companies to reduce their dependence on the wholesale supply company;
- the possibility for the municipalities to exploit local hydro resources and to generate additional income on the basis of a share in the production of the power station.

This development led, in 1996/1997, in the Sør Aurdal supply area to the approval of a concession to Oppland Energiverk for the realisation of the 2 x 4.75 MW run-of-river Eid power station. The investment costs were US$ 2000/kW and annually some 53 GWh is generated.

There are also plans to utilise small streams on private properties to generate electricity for heating purposes. With increasing electricity prices, this aim is understandable since heating accounts for approximately 50% of total domestic electricity consumption in Norway (Table 3.10). This is also the reason why in the countryside the use of locally available biomass for heating purposes is encouraged.

Table 3.10. *Typical annual electricity consumption for a four-person Norwegian family whose only power source is electricity (source: "Effektiv energiforbruk i boligen", NVE/ ENOK, Oslo 1996).*

Appliances	**Annual consumption (kWh)**
Space heaters	11,000
Water heater	3,500
Lights	2,000
Freezer	800
Clothes dryer	800
Cooker	700
Washing machine	500
Refrigerator	500
Coffee machine	200
Television	180
Heater car engine	180
Audio equipment	100
Iron	80
Dishwasher	500
Total	21,040

Potential owners of small-scale hydro schemes face a number of barriers including (NVE 2000):

- uncertainty about future revenues;
- difficulties in finding funding and selling power to the grid;
- complexity of the regulations and the large number of stakeholders;
- the required technical competence.

Around 1913 larger, state or privately owned, hydro-electric power stations coupled to high voltage transmission systems were developed in Sweden. Initially these systems were used to supply large industries and towns, but gradually a central grid supply replaced decentralised power generation in the rural areas. Around 1918 rural electricity supply gained momentum for two reasons: a shortage of petroleum-based energy forms and the relatively favourable economic agricultural conditions.

The private development of rural electrification was also advanced by the favourable social and economic position of the Swedish farmers in those days: 80% of the farmers owned their farms and their debts were moderate. Another aspect which facilitated the introduction of electrical devices in agriculture is said to be the feeling for, and interest in, technology by the average Swede.

In rural areas, electricity distribution systems were either owned and operated by the State Electricity Board or by local authorities, mostly as co-operatives buying electricity in bulk.

Many of the co-operative associations were technically and organisationally supported by the national utility but they financed their own investments by capital borrowed from the state or private banks.

In later years many of the rural co-operatives experienced serious problems due to technical deficiencies in the installations on the one hand and organisational shortcomings on the other. The situation can be summarised as follows (ESB 1944):

- The early accounting methods of many of the rural distribution organisations left much to be desired. This was encouraged by the fact that, in those days, co-operatives were not required to maintain proper accounts.
- The tariff policy was not always rational; in many organisations it was the practice to debit all costs, including the fixed costs, against the units of electricity consumed. This led to high prices per unit leading to a decrease in consumption and subsequently to even higher prices. Also appropriate rates had to be charged to each customer, whether they were a member of the co-operative or not.
- The State Electricity Board had to use its power, through conditions contained in the contracts for electricity supply, to have a tariff system adopted whereby all fixed costs were covered by, for example, service charges proportional to the size of the cultivated farmland, and independent of consumption.
- The development and operation of rural electricity systems by co-operative associations of consumers in Sweden has been the subject of criticism, both in Sweden and abroad. It appears that the associations needed extensive support by the State Electricity Board for the development of appropriate accounting systems, regulations and the planning of the distribution grid.

3.6.2. Denmark

The first electricity systems in Denmark were established in the towns of Odense and Købe in 1891 and in Copenhagen in 1892. From 1900 onwards wind turbine units generating direct current in combination with storage batteries have been used to provide electricity supply to individual dwellings in rural areas.

One of the results of co-operation in rural areas was the realisation of the Gudenaa hydro-electric scheme. The first ideas for a power station emerged in 1904 as part of a study into the possibilities of an irrigation system but the plan did not catch on very well. The impetus for the development of the water resources stemmed from the idea of an engineer that, in combination with the use of water for irrigation purposes, power could be generated to stimulate the agricultural and industrial development of the region. The availability of adequate electrical energy has certainly contributed to the development of Central Jutland (Nielsen 1993).

In 1909 the government decided to set up a commission of inquiry to investigate the various aspects of hydro-electric power generation including the transmission of the electricity to the surrounding areas. The idea appeared to be feasible but the government had no money available for such a huge project and advised that private investors and the municipalities should be approached for funding.

Notwithstanding the fact that the municipalities were not really interested, one of them applied for a concession and a government electricity committee started an assessment. Finally, in 1918, the concession was granted. The fact that the scheme was approved had also to do with Denmark's energy crisis following the first world war. At the time the country almost completely depended on foreign countries for its energy resources.

In 1918 a co-operative society for the power station was established. The members of the co-operation were, and still are, the municipalities and the local electricity companies of Central Jutland.

The Gudenaa hydro-electric power station has been granted a concession for the use but not the consumption of the water of the river. The concession stipulated that the responsibility of the co-operation includes proper water management and the environmental protection of the surrounding area.

The installed plant was commissioned in January 1921 and is still in use (Figure 3.4). Three 1100 kW, 214 rpm generators are driven by Francis turbines and the annual production varies from 10 million kWh to 15.5 million kWh. The average production is some 11 million kWh.

The head is between 8 and 10.5 metres depending on the downstream water level and the average annual flow rate is 21 m^3/sec, varying from 5 m^3/sec in summer to 60 m^3/sec in winter. The water level of the lake is maintained within close limits although one metre variation is allowed.

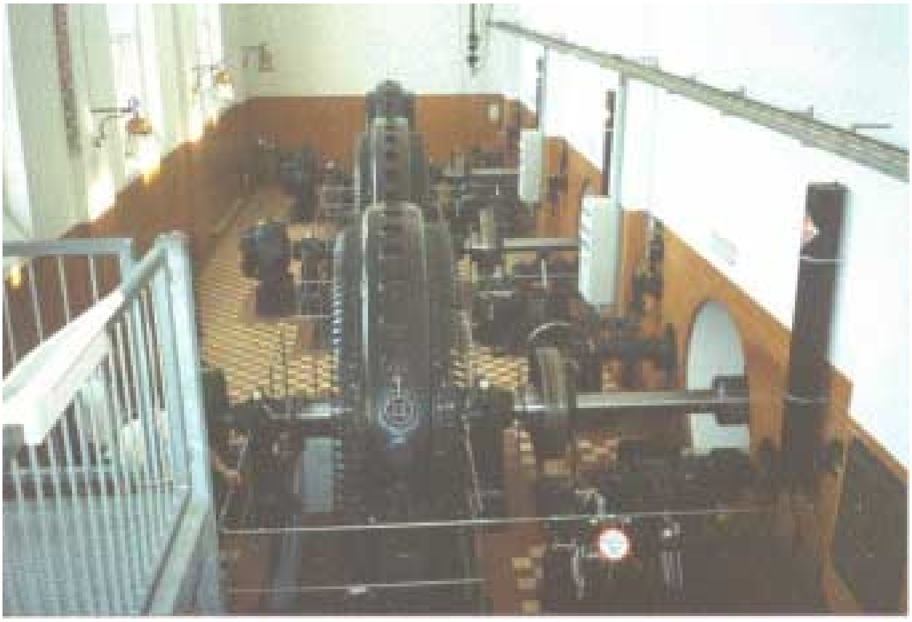

Figure 3.4. *Gudenaa hydro-electric power station, Tange, Danmark.*

The power station is semi-automatic in terms of maintaining the proper voltage and frequency level, automatic synchronisation and monitoring. The power station staff of six operate and perform the first line maintenance of the power station and of part of the river. They also monitor the fish stock.

The electricity is sold to the regional utility at a price corresponding to that of the energy generated by thermal power stations. In addition a renewable energy allowance of some 5 USct per KWh is received from the government. This allowance is also paid for electricity generated with wind turbines. The availability of the power station has been excellent since it was commissioned and a figure of over 99.999% has been claimed (Gudenaa 1993).

In 1911, Denmark had some 200 small electricity power stations which generated electricity for rural villages and their surroundings. In the thirties some 350 direct current power stations each supplied electricity to rural areas of approximately 20 square kilometres. Many other rural areas were supplied with alternating current from power stations in the larger towns via transmission lines. In 1940, approximately 85% of all rural farms and houses had electricity.

Rural electricity supply in Denmark has developed in two ways: the decentralised power systems usually organised and managed by co-operative associations of farmers, and the gradual extension of larger power systems from towns (ESB 1944).

3.6.3. New Zealand

Prior to public electricity supply in New Zealand, electricity was generated in conjunction with gold-mining activities. In 1884 a gold mine in Bullendale already had a generator for lighting purposes. This mine further commissioned, in 1886, a hydro-electric power station with a short transmission line to supply electricity to their equipment and lights.

Gold-mining may be said to have provided the initial push for the development of hydro-electric schemes in the rural areas of the country, but the desire to replace traditional lighting appliances by electric lamps was the rationale of most public electricity supply systems.

In 1886 legislation was amended to give local bodies authority to provide electric power for the benefit of residents.

In those days many urban governments considered electric power but were reluctant to install equipment. Around 1910 the interest of local authorities in public electricity supply grew. This was prompted by the success of the many small private schemes and by the development of alternating current equipment which made longer lines possible. The majority of these private schemes were based on hydro-electricity as was the case in Norway. However, until the fifties some remote places were provided with electricity from diesel generating plant.

In 1918 the Electric Power Boards Act provided for separate, elected, boards to carry out electrification projects and as a result many small power boards were established. Later, many of these supply authorities merged into larger ones such as The Otago Central Electric Powerboard (Chandler 1986).

In those days many small hydro-electric power stations were built and some were joint ventures between local authorities and mining companies. Moreover the development of hydro schemes could often be combined with irrigation schemes resulting in reduced costs.

Early hydro schemes were mainly “run-of-river” but these are now of less value since water flows and hence output, may be lower in certain months. Today, the availability needs to be as high as possible to achieve economic operation of small schemes, and therefore facilities to guarantee the continuity of water supply are necessary.

Later the Rural Reticulation Council was formed which financially supported rural distribution projects. It is claimed that in the forties the majority of farms had electricity supply (ESB 1944).

In those days remote places still had small private electricity supply systems but these were gradually taken over by public power boards. The incentive to have these small local enterprises taken over usually had to do with the continuity of supply.

Regional Power Boards purchased much of the power from State owned power plants and distributed it to the consumers in their supply area. Towns, villages and rural dwellings all came under the same utility and there was no differentiation in the rates charged to the various consumers.

3.6.4. France

By the second decade of this century most of the towns and industrial centres were electrified but some 40% of the population still lived in non-electrified areas. A national rural electrification programme was implemented with the result that in the thirties some 70% of rural dwellers were connected to the electricity grid.
The Ministry of Agriculture had the political responsibility for the rural electrification programme, and the managerial responsibility was with the Director of Rural Electrification. Counties and parishes were involved in the implementation of the electrification scheme and subsidised the cost of the infrastructure by some 12%. A subsidy ranging from 30 to 50% of the capital costs came from the Government while the National Agricultural Credit Fund provided loans at a reduced interest rate (ESB 1944).
The national utility Électricité de France, since its establishment (through nationalisation) in 1946, is responsible for the generation, transmission and distribution of electricity in the country. Prior to 1946, the electricity supply was devolved to many local and regional companies, and nationalisation aimed at unifying, rationalising and further developing the electrical power system (EDF 1998). Today, over 99% of all premises are connected to the electricity grid.

3.6.5. Germany

In many cities and industrial areas, the turn of the century already showed a remarkably well developed electricity supply system but many rural areas remained unsupplied (Herzig, in Fischer 1992).
In other countries small power stations supplying electricity to local areas were still the rule, but in Germany the first decade of the century already evidenced a number of districts which were supplied with electricity from a common power station.
Löwer (in Fischer 1992) argues that with the available technology there was technically no reason for a disparity between urban and rural areas in the provision of electricity. The electricity supply to the latter areas was not profitable and therefore relevant legislation was necessary to avoid many rural and remote places remaining unsupplied.
During the thirties there were heated discussions within the government of the Third Reich about the institutional principles of the energy sector. The debate focussed on two different principles: power supply based on public local authorities on the one hand, and a concentration of the electricity supply industry in a limited number of companies on the other.
The latter structure emerged and, as a result, many of the municipal and other smaller supply authorities disappeared along with a substantial part of industrial power generation.

Löwer (in Fischer 1992) notes that the decision by the "Energiewirtschafts-gesetz" of 1935 to concentrate the electricity supply industry, in fact had been prompted by three principles based on the prevailing views at that time: business activities by municipalities were not legitimate, any activity should match the capability of the municipality, and activities such as power supply were not allowed if they could be performed better and more economically by another organisation.

The same period saw another concept for electricity infrastructure which favoured a decentralised electricity supply. Although it has been suggested that this proposal was based on an anti "big is beautiful" approach, it was in fact rather a war economy concept. In terms of air raids centralised power stations are more susceptible (Löwer).

It is recorded that in the thirties considerable efforts were also made to support nationwide electrification and to promote the use of electricity. One of the reasons behind this aim was that electrical energy played an important role in the autarky and arms policies of the Third Reich. Around 1940 it was claimed that some 80% of rural farms were electrified, in some areas with state subsidies.

Although local distribution associations played a role in the electricity supply to rural areas, over the years the emphasis has been on large vertically integrated utilities which owned and operated larger power stations near cities and industrial load centres and inter-regional transmission lines. These utilities were either public or private or mixed enterprises (ESB 1944).

3.6.6. Thailand

Tuntivate and Barnes (ESMAP 1997B) have described the progress of the rural electrification programme in Thailand since its inception in the early 1970s. At that time, nearly all rural areas had only a low level of economic development, and electricity was only available in 10% of the villages. Nowadays over 99% of all rural villages have access to grid electricity.

The electricity sector in Thailand consists of three separate utilities: the Electricity Generation Company of Thailand (EGAT) responsible for generation and main transmission, the Metropolitan Electricity Company (MEA) serving the Bangkok metropolitan area and the Provincial Electricity Company (PEA) which is the distribution company for supplying all the areas outside of Bangkok.

In 1973, the government of Thailand approved an extension of the national grid to all the rural areas. This programme (which covered 25 years) was based on a pre-feasibility study, financed by the United States Agency for International Development (USAID). The Provincial Electricity Company first sought to confirm the government's commitment and assessed the affordability and the willingness to pay of the population in the supply areas. In close co-operation with the National Economic and Social Development Board, a master plan for the electrification of rural areas was developed as part of the country's overall development strategy. This master plan addressed all aspects of electrification, including guidelines for area selection, technical standards, organisation and management requirements for programme implementation, and distribution system operation and maintenance.

On the basis of the master plan, a detailed feasibility study was made with analyses of the individual investment projects and priority setting.

The Provincial Electricity Company (PEA), a largely autonomous government organisation, was charged with the actual implementation of the electrification programme. Electrification operations were carried out by a temporary Office of Rural Electrification (ORE) within the Provincial Electricity Board. Once the national grid had been extended to most of the rural villages, the ORE was dissolved.

This organisational approach appeared to be successful because the PEA could focus, via ORE, all its efforts on the implementation of the rural electrification programme and had complete control over the allocated budget.

In this respect Tuntivate and Barnes argue "conventional, vertically integrated electricity companies tend to concentrate on the more urgent and profitable business areas such as power generation and transmission, and on the distribution to urban, industrial, and large commercial customers. As a result they often find themselves in an institutional dilemma over what priority to accord to rural electrification, which is usually unprofitable for them".

The ranking of the villages to be electrified, was based on seven components and some quantitative information. The seven components included: proximity to the existing grid, accessibility by road, village size, number of expected customers in the first five years, potential agricultural and industrial electricity consumption, number of commercial establishments, and the extent of public facilities.

Normally, consumers were not required to pay an initial sum as a contribution to the costs of the grid connection. However, if villages could afford to contribute to the capital costs of electrification, a higher ranking on the priority list was possible. A 30% contribution led to a higher ranking and a 100% contribution could lead to immediate action to electrify the village. About 25% of the villages contributed by 30% but only 1% of the villages decided to contribute the full amount. There is some evidence that most of these contributions were not paid by the villagers but by a few individuals and by politicians securing local development funds.

To increase the number of household connections, the utility charged low connection fees and provided credit facilities to cover the costs of both the grid connection and house wiring. After a few years it appeared that local contractors provided such facilities and therefore the programme was terminated. These local contractors were called in by the utility to perform low-level technical activities with the aim of building local private capacity and reducing costs.

The government of Thailand adopted a national policy for electricity pricing. Rates were uniform for consumer groups, retail rate structures were the same for both the MEA and PEA, and larger users were charged more than ones with only a limited consumption. For the very small rural consumers (up to 35 kWh/month) a "life-line" rate is applicable.
In 1993, only 14% of the electricity consumption was related to PEA's unprofitable residential consumers (consumption < 150 kWh/month).
The rural electrification programme was successful because of a combination of factors:

- A firm overall national policy and government commitment.
- A dedicated distribution company with a special rural electrification office.
- A careful plan for system expansion avoiding excessive financial burden.
- A special billing programme to ensure revenue collection. Locally respected officials were hired to collect billed amounts from the customers.
- Cost consciousness and adequate control of the financial position of the Provincial Electricity Company.
- A system of cross-subsidisation from provincial urban to rural areas.
- A lower rate from EGAT to PEA for bulk power purchases. This rate was 30% below the rate paid by MEA and some 15% below normal bulk prices. This, in fact, also amounted to cross-subsidisation from MEA to PEA. It is argued that this cross-subsidy is justified because rural electrification contributes to the countries overall development and political stability. Regardless of the cross-subsidies, the average retail price is close to the long-run marginal cost of Thailand's electricity supply system.
- Avoidance of political interference, particularly in village selection, partly by the development, at an early stage of the programme, of a set of objective criteria.
- An adequate demand promotion strategy including market research, particularly in the area of productive use of electricity. In spite of these activities, the initial connection rate was only of the order of 55%, and five years after electrification 70% was reached.
- Careful attention was paid to community involvement and customers service including the setting and maintaining of performance standards.

There is no doubt that the rural electrification programme of Thailand was successful. It should however be noted that the Provincial Electricity Company, in the implementation of the rural electrification programme, had to rely on low-cost capital, grants, concessional loans from a number of foreign donors and cross-subsidies to avoid financial problems.

3.7. The development of the island power system on Vlieland

Vlieland is one of the Frisian islands in The Netherlands and has a length of 20 km and a width of 3 km. In 1939 the number of inhabitants was 400 but this number has gradually increased to over 1000 today. There are a number of hotels and restaurants on the island, the main residential area includes some 300 houses, and another 150 premises are located outside the village. Most of the inhabitants are involved in tourism and over 80,000 tourists per year visit the island.

3.7.1. Institutional aspects

In 1918, the municipality made a move towards the establishment of its own electricity supply authority. Although the authority was based on a municipality, it has always been supported on technical matters by the provincial electricity board. Following the second world war, the financial position of the local electricity utility was extremely weak, partly due to unpaid bills of the occupying forces, but mainly due to the difficulty in operating the power system economically. Although the design and operation of the system had always been the subject of frugality, and the limited operating profits had always been retained by the enterprise, tariffs were considerably higher than those on the mainland.

Expansion and reinforcement of the power station and distribution system were necessary but the financial reserves did not allow a realistic funding of the investments needed and a further increase of the tariff was unacceptable.

In 1952, political influence led the Provincial Electricity Board of Friesland to assume responsibility for the electricity supply on the island and to bring the tariff into line with those on the mainland.

3.7.2. Electricity demand

The history of electricity supply on the island may be said to have commenced in 1918 when a small power station with a 30 HP suction gas engine generating unit was commissioned.

In those days electricity was mainly used for lighting and the metering of the consumption was uncommon because of the lack of and the cost of meters. In many cases, electricity supply was based on a subscription, and in these cases premises could use one or two bulbs which were not supposed to be on for more than 1000 hours annually. If the annual inspection revealed a use beyond this limit, an extra charge of 50 ct (0.30 US$) per kWh was levied, which was a lot of money in those days.

In the early years, the maximum system demand was about 20 kW and in 1919 approximately 14,000 kWh of electricity were consumed. Up to 1932 electricity was supplied at 110 Volts DC and then at 220 Volts DC until 1963. Nowadays electricity is generated and supplied at 220/380 Volts, 50 Hz and in 1995 the electricity consumption reached 6,240,000 kWh and the maximum demand some 1350 kW.
The average annual consumption growth was 5.5% up to 1940 and consumption then remained stable until the end of the second world war. Since 1982, the maximum demand has increased by some 3% annually and consumption by some 5%. The annual consumption pattern has changed considerably over the years. In the 1920s most of the electricity was consumed in wintertime, but in later years there has been increased consumption in the summer due to the growing tourism.
Until 1940, the maximum demand still occurred in winter, as remains the case on the mainland. In the sixties the substantial growth in tourism resulted in the peak load now occurring in the summer.
The seventies saw a growth in touristic activities during Easter and Autumn holidays and, as a result, yearly peak loads shifted from summer to these periods. In 1995, the maximum load occurred during Christmas time, for the first time in the power system's history.
Obviously, the expanding tourism has had an effect on the demand load factor which has increased from the extremely low figure of 0.20 in the early sixties to 0.52 in 1993. In comparison, the 1990 load factors for the mainland supply area of the Friesland electricity board, and for the entire country, were 0.60 and 0.70 respectively.

3.7.3. Technical aspects

In 1980 the diesel power station was renewed completely after an investigation revealed that a submarine cable to connect the island electricity system to the Frisian mainland was not feasible. The utility ordered an automatic power station with four 600 rpm two stroke (cross-head) diesel-engines each linked to a 500-kW generator (Figure 3.5). This power station runs without spinning reserve and a load-controlled start/stop system is included. Load control based on a dP/dt of 3 kW/minute and on utilising the engine's short term overload capability of 10% appeared to be acceptable. An under-frequency system trips one or more MV distribution feeders if a sudden overload of the units in operation occurs. The power system on the island is supervised remotely from the utility headquarters grid control centre.
The initial costs of the power station were relatively high because of the remote location and specific requirements. For environmental reasons, and because of the additional cost of heavy fuel equipment for such a small power station, light fuel oil with 0.3% sulphur content is burned.

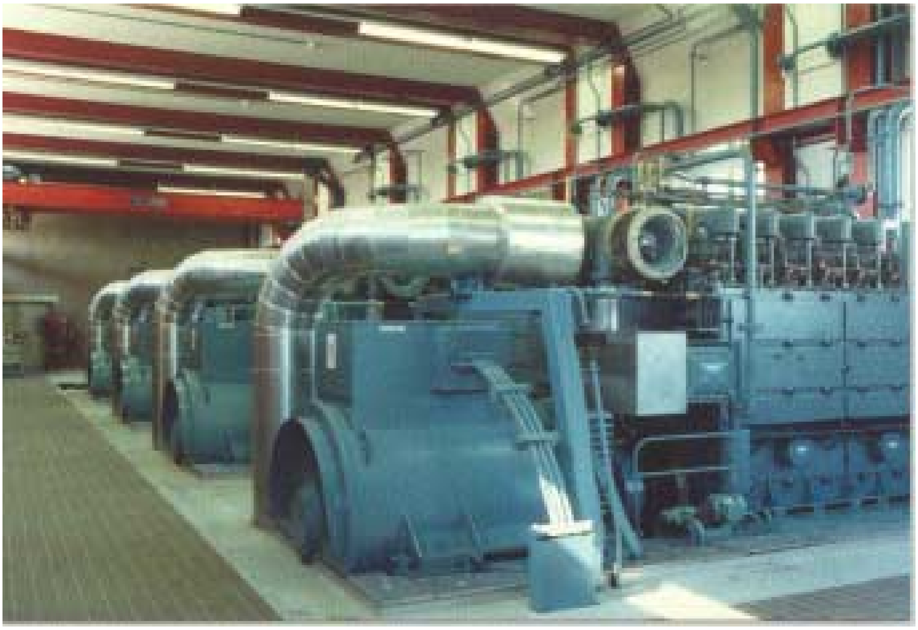

Figure 3.5. *Power station island Vlieland.*
(photo: Courtesy NUON, the Netherlands)

Apart from the additional costs due to burning low-sulphur fuel oil, some 10% of the power station costs have been spent on environmental related investments such as noise reduction and adaptation to the surroundings.
The objectives of automatic operation of the power station have been met: fuel consumption has been optimised, the number of man-hours needed for supervision has decreased and an acceptable availability of the electricity supply achieved. Over many years the availability of the electricity supply has been 100% on the low voltage side and 99.99% on the medium voltage side.

3.7.4. Heat and power supply

Some years after commissioning the new power station, a waste heat recovery system has been installed on one of the engines. Heat is supplied to a school, a home for the elderly, a number of houses and a swimming pool. Although this solution has improved the overall island energy efficiency, it has had limited success for a number of reasons. The heat recovery system influenced the engine temperature leading to a decreased reliability, and this one engine has had to be operated and maintained much more than the others.

Another impediment has been that, a few years after the installation of the heat recovery system, piped natural gas became available on the island at a modest price compared with low sulphur diesel oil.
In most of the dwellings gas-fired heating systems have been installed and in fact the island's potential for waste heat supply has never been fully utilised. An earlier study revealed that the payback period of a heat supply system to the village would be six years, and for the other premises over 10 years. Moreover, a 24-hour heat storage installation would be needed because demand and waste heat supply are not coincident.
In recent years, emission legislation has become more stringent and the new emission levels could not be achieved with oil fuel. The existing engines are only suited for diesel oil and, following a failure of the heat recovery boiler, it was decided to install an additional 300 kW combined heat and power unit with a gas-fired engine. Recently, one of the diesel engines has also been replaced by a gas-fired combined heat and power unit.

3.7.5. Manpower

The power station, including the medium and low voltage distribution grids, is operated by three electro mechanical personnel. These employees have received a broad training including mechanical and electrical aspects. Apart from holidays, they work five eight-hour days per week and one of them is, on a shift work basis, on standby during the other hours. Daily inspection is carried out by the local staff and monthly inspection by a technician from the utilities'head office on the mainland. Time-based maintenance is carried out by the supplier of the equipment assisted by one or more of the power station mechanics.

3.7.6. Powerstation performance

Table 3.11 shows an approximate breakdown of power station costs. The calculation is based on the initial investment cost, actual fuel consumption and a fuel price of 33 USct per litre, depreciation period 25 years and interest 7%.
Over a number of years the annual losses in the MV and LV distribution system (including transformer losses) appear to have been between 4 and 5%.
Each diesel engine is provided with a water to air cooling radiator with a double speed (Dahlander) motor-drive, and power station consumption is mainly determined by the demand for the motor-drive at high speed.
Power station consumption was always below 5% until 1990. However increased demand, a higher load factor, unfavourable ambient conditions, and a change in power station operation in connection with the commissioning of a CHP unit, has resulted in the motor-drive operating mainly at high speed. This

has resulted in substantially higher power station losses (over 7%) in recent years. To mitigate this problem, the fan motor-drives were adapted in 1994 to frequency control which has reduced power station losses to below 5% again.
From the operation and first line maintenance of the power station and distribution system, and a number of related activities (such as client metering, street-lighting), the number of man-hours per unit supplied to the grid can be calculated as 0.77 (0.52 for the power station and 0.25 for the distribution system. This figure excludes incidental technical support from head office.

Table 3.11. *Approximate breakdown of power station costs (1995 US$).*

Year	**1983**	**1993**
Peak load (incl. power station cool.syst.)	840 kW	1320 kW
Peak load (demand)	803 kW	1260 kW
Power station consumption	148,320 kWh	432,745 kWh
Annual demand(supplied to grid)	3,249,000 kWh	5,749,000 kWh
Investment costs per kWh	9.2 USct (38.5%)	5.2 USct (27.4%)
Operating costs per kWh		
Fuel	10.2 USct (42.7%)	10.5 USct (55.2%)
Lubrication oil	0.3 USct (1.3%)	0.3 USct (1.6%)
Operating labour	2.8 USct (11.7%)	1.6 USct (8.4%)
Maintenance costs	1.4 USct (5.8%)	1.4 USct (7.4%)
Total costs per kWh supplied to grid	23.9 USct	19.0 USct

3.7.7. Renewables and energy conservation

Because the mean annual wind speed exceeds 6 m/s, the possible integration of one or more wind turbines into the island grid has been considered. The most important constraints appear to be an appropriate location and the operation of a wind turbine of reasonable capacity alongside the existing diesel units. A location far from the power station would involve substantial costs for a cable connection, and problems were anticipated in maintaining acceptable system voltage and frequency.
Further research addressed the opportunities for energy conservation in the power station (Meulen 1994). The research revealed that, on the basis of current prices and operational circumstances, substantial savings could be achieved with advanced frequency controlled motor drives. The analysis of the 1993 power

station losses revealed that 98.5% of these were due to the motor drives and that consumption could be reduced by 24 to 34% depending on such variables as ambient temperature, wind speed and direction and the cooling rate of the radiators. A payback period of about three years has been calculated.

In 1994, the motor drives were equipped with frequency control and in 1995 power station losses appeared to be 34% lower than before.

In 1997, and similar to ideas on the Danish island of Samsoe and the German island of Pellworm, the suggestion was launched for a “carbon-dioxide free” island. A 1996 feasibility study had revealed that, in principle, the future heat and power demand of Pellworm could be met through biomass, rape-oil and bio-gas fuelled CHP units, thermal solar collectors, heat pumps, wind energy, autarkic PV systems and demand side energy efficiency improvements. A major problem was that the annual consumption could be met but not the peak power demand.

Samsoe (population 4400) is connected to the mainland by cable and light diesel fuel oil is used for heating purposes. To achieve the objective of a CO_2-free island, the measures would include changing customer behaviour patterns, use of high-efficiency technology on the demand side (including building insulation and renovation), use of local biomass resources and biogas for collective heat production, individual heat pumps and biogas-based CHP, solar thermal collectors, land-based and offshore wind turbines for electricity generation, PV solar and a fuel switch in the transport sector from fossil fuel to electricity.

Future power supply on Vlieland could possibly include wind energy, use of fuel cell based CHP units, PV systems and storage capacity such as batteries, hydrogen and mechanical devices. Other alternatives for satisfying demand such as hydro-electric power generation, utilisation of landfill and sewage gas, sea thermal gradient and wave/tidal power generation, waste and/or biomass based power generation either do not exist or are technically not feasible.

3.7.8. Conclusions

Because of the strong influence of tourism, the island is not a typical rural area but the experiences with the electricity supply can, to a certain extent, serve to demonstrate possible load growth on islands and in rural areas. The following conclusions can be drawn:

- Without subsidy the power system of Vlieland could not be operated economically with an acceptable tariff. Although the power system is well designed, and effectively and efficiently operated, costs per unit of electricity have always been substantially higher than the revenues which have been based on mainland tariffs since 1952. In fact, the revenues do not even cover operating costs ignoring the investment expenses.
- External technical support to the original municipal utility appeared to be necessary.

- Automatic control of the power station reduces manpower.
- Operating without spinning reserve can still provide acceptable availability and reliability of small-scale electricity supply provided advanced technology is used.
- An integrated approach to generation and distribution appeared to be effective but staff have to be trained to handle activities in both areas including client contact.
- Based on 1995 demand, the number of man-hours needed for operation and first line maintenance per MWh of electricity supplied to the grid was determined at 0.77 (for budgetary reasons split into 0.52 and 0.25 for the power station and the distribution system respectively).
- The opportunities to make use of the waste heat from the power station have been unfavourably influenced by the presence of natural gas as a cost-effective alternative.
- An integrated approach for all the community utility facilities could probably further reduce overall manpower needs and increase energy efficiency. A co-operation between the electricity supplier and the water and gas suppliers has never materialised, strategically nor operationally. As a result operations, including customer relations, energy efficiency and the deployment of human resources, were probably sub-optimal. A competitive environment was one of the causes of this situation but also the differences in management and in the allocation of profits by the provincial and municipal authorities contributed. Rural and remote areas with decentralised power systems can show resemblance to the island Vlieland and it would seem that the establishment of one single utility for electricity, heat, gas and water needs serious consideration from the point of view of customer relations and energy efficiency.
- As shown by the feasibility studies for the islands of Vlieland, Samsoe and Pellworm, an integrated approach covering all power supply options, electricity and heat demand, and customer behaviour is necessary to optimise these small-scale power systems. These studies also showed, in current circumstances (low fossil fuel price, high investment cost associated with renewable power generation facilities), that if hydro-power is not available, the realisation of a small-scale stand-alone and sustainable power system with the same degree of reliability is complicated and much more expensive than the traditional systems.

3.8. Analysis of the history of rural electrification in different countries

The cases that have been reviewed, and the limited economic growth in the first decades of this century, would suggest that apparently economic circumstances were not a decisive factor in the wide-scale electrification of rural areas in industrialised countries. The power of lobbies and pressure groups was probably a larger determinant.

Nye (1990) states that electrification is not an "implacable force moving through history, but a social process that varies from one time period to another and from one culture to another". Achterhuis (1992) reminds us of Nye's comment that many people in the United States of America believed that, with electrification, all important social problems and disparities would more or less automatically be solved, and that it would result in greater co-operation and socialism. In practice the case of the United States of America has shown that electrification initially led to an even greater disparity between rural and urban areas. There is reason to believe that the decision to use a co-operative approach in rural electricity supply is strongly influenced by disappointment that the expected results had so far failed to materialise. Achterhuis correctly concludes that no single technology will automatically solve social problems and that social pressures and political activities are always needed.

In general the political strength of the rural population is low and in many countries, the rural population had to rise up against neglect before any actions on the electrification of their areas were taken. These observations underline the importance of a pro-active and worldwide approach to the problems that rural populations experience, certainly as we move towards a global village.

At the beginning of this century, the electrification of rural areas was mainly a local issue and prompted by local concerns. None of the studies of rural electrification programmes in the first part of this century has provided evidence of motives for the implementation of the programme related to other countries.

This situation changed just before the second World War when, for instance, the rural populations of Ireland and the United States of America argued that their areas lagged behind when compared with other countries. Their actions eventually resulted in rural electrification programmes.

Fifty years on, we have to conclude that another, and even larger, part of the world still lags behind. This is similar to the situation in Ireland and the United States before the war and one would expect that the pressure to electrify the remaining areas of the global village will further increase.

There is however a salient difference between presently developing countries and the industrialised world around 1900. The latter already had reasonably developed economies and rural infrastructures and they could afford to invest in electrification. The economies of the majority of developing countries are weak and do not allow major investments in infrastructure.

The case studies revealed the common factor that local individuals and, in some cases, municipalities often took the first step towards electrification. In urban areas this happened during the final decades of the nineteenth century, and in rural areas in the first and second decades of the new century. These electricity supply systems were small and could only provide power to farms, small-scale

industries and nearby dwellings. The initial period was dominated by small power stations either stand-alone or linked to a rural dairy factory.
The private hydro-electric power stations in Scandinavia have been successful over a number of decades in supplying power to limited areas, and some of them have had about a hundred subscribers at certain times. In Denmark, hundreds of small wind turbine based generating stations, in combination with storage batteries, have been successfully in use.
The small fossil-fuelled power stations helped create demand but became obsolete within a decade of commissioning when technology advanced, and economies of scale could be achieved by building central power stations and AC transmission and distribution lines.

In many European countries, and also in the province of Ontario, a real structured approach to electricity supply to rural areas begun around 1915 when relevant legislation was developed. In the United States of America this happened some twenty years later and in Ireland in the mid forties.
An assessment (ESB 1944) revealed that in the forties the following electrification rates for rural farms were claimed: Denmark 85%, France over 70%, Germany 80%, and in New Zealand the majority of the farms were claimed to be electrified. The electrification rates for the rural areas of the various States in the United States of America varied from less than 20% to 90%. In Ireland 58% of the population, including the majority of the farms, had no access to electricity.
Considering the approach to rural electrification in the first decades of the twentieth century, a notable difference between many European countries and the United States of America is apparent. While in European countries emphasis was on government intervention and relevant legislation, the United States relied on initiatives from the private sector and market forces. Moreover, in Europe social and political motives played a more important role.

3.8.1. Government intervention and legislation

The first two decades of the twentieth century showed a rapid development of small-scale power systems. This proliferation, together with the simultaneous development of more efficient large-scale generating facilities and AC systems, led many governments in Europe and elsewhere to intervene.
In many European countries, electrification was considered to be more than an economic activity and the electricity supply to rural areas was seen as socially important.
Governments feared that without relevant legislation only the more profitable areas would be electrified, leading to a greater disparity between rural and urban areas. The social and political interests were very important, often more

important than the financial burden incurred by the electrification of uneconomic rural areas.
In the United States of America, however, social and political motives did not play such an important role in government policy during the first three decades of the century. In those days, the federal government of the United States, incorrectly as it turned out, expected that the rural population would organise the electricity supply to their areas themselves.
Nye (1990) concludes “Americans treated electricity as a commodity in the marketplace rather than as a service, and they allowed private companies to expand across both local and state boundaries, while usually restricting public power to isolated municipalities. (....). One of the effects was that rural electrification got very little attention and another was that tariff structures were much more attractive to large customers than to residential ones”. This could be repeated in other countries as the privatisation of the power sector proceeds.
In 1963 Vennard[28] argued “studies made by the Edison Electric Institute have shown again and again that all the power needed to supply the future needs of the people of the USA can be financed in the free market. This includes the reliable and economical supply of electricity to all areas of the nation and all classes of customers”.
Considering the experiences with rural electrification in both the United States of America and in European countries, this statement seems to be somewhat optimistic, assuming acceptable tariffs. In many European countries, rural electrification was supported either by special national programmes or by a legislative and organisational approach which fostered the electrification of both urban and rural areas.
In these countries either a national or a provincial power utility was generally considered appropriate in order to avoid municipal boundaries hampering the development of an economically justified electricity infrastructure, and to achieve an acceptable area coverage and sufficient uniformity in tariffs.
It is fair to conclude that at a national level, and in most cases, politicians have been far from pro-active. It is noted that at a later stage of electrification, government intervention became necessary to guide the developments with legislation and to help in funding rural electrification. However, legislation has often hampered energy-efficient joint power generation and the co-operation between private enterprises and the utilities.

3.8.2. Organisational aspects

In the early days of electrification the province of Friesland, and other regions of the Netherlands and many other countries, depended exclusively on

28 In OGEM 1963.

fossil fuels, mainly coal, for electricity generation. To benefit from economies of scale, large central power stations together with interregional transmission lines replaced the small-scale local power stations common in the first decade of the twentieth century. Naturally the corresponding organisation was also of an interregional nature, leaving the distribution, if not done by the organisation itself, to municipalities or regional co-operatives. In countries with widespread hydro-electric resources such as Norway and Sweden, the need to establish larger utilities was less pressing. The need for larger hydro-electric schemes emerged in later years after load and consumption had built up and projects were often financed by a group or co-operative of municipal utilities.

In the United States of America, the establishment of government-owned power supply facilities emerged during the thirties as a result of the political philosophy of those times linked to regional development projects. These government-owned utilities still exist and have proved to be both efficient, and competitive with investor-owned companies.

The experience of the electricity boards in Ireland, the Netherlands and Scandinavia confirms that the performance of government-owned utilities can be satisfactory provided they are able to operate at arm’s length from the politicians.

As appears from the previous sections, a major issue in rural electrification programmes has been whether implementation should be undertaken by existing centralised power utilities or whether local organisations should be established. Mason (1990) found that private operators have been running rural electricity systems in many countries but that very little is known about the extent of their operations. The little evidence available indicates that in many countries they provide only a limited service with many interruptions because of poor system design and inadequate operation and maintenance. In Indonesia about 18% of villages are served by small private operators but service tends to be poor. . A major reason for the failure of many private operators is that they are not subsidised like the public providers of similar services and that they lack managerial and technical expertise. There is some evidence that private operators in many countries have found it difficult to make sufficient profit to be attractive for the sector and they therefore tend to “skim” the market by providing peak service to the higher income households in a village.

The research by Mason revealed that from 21 countries where rural electrification projects have been completed 15 were carried out by centralised utilities, 5 have been very successful, 5 have been unsuccessful in terms of delays in construction and in terms of system operation losses. The centralised utilities which encountered problems with the implementation of electrification projects showed poor planning, inadequate staff, slow procurement and general inability to program and supervise construction activities. She observes that a major argument against using larger centralised utilities as the implementing agency for electrification projects is that “they are often highly centralised which would make construction of a large number of small-scale projects in rural areas more difficult to implement and operation and maintenance more difficult to control. In addition, it is argued that central utilities will always give priority to generation, transmission and urban projects because of the size of the projects and their greater technical complexity and not to mention the higher financial losses incurred from rural operations".

The conclusion is justified that in nearly all countries, separate organisations were made responsible for the implementation of rural electrification programmes. Power utilities that were responsible for these programmes generally adopted, for their rural electrification operations, a decentralised organisation on a geographical basis: the district structure. This structure proved to be both efficient and effective, at least in a period during which the electrical infrastructure had to be developed and consumption stimulated.

Co-operatives

In quite a few countries co-operatives have been successful, not only in the initial phase of local electrification but also during large rural electrification programmes. Most of these co-operatives were established as the result of initiatives of the beneficiaries and not because they were imposed by external authorities.

In Denmark co-operatives worked well, particularly for power stations. There have been a substantial number of small power stations in rural areas owned by co-operative associations of farmers, but there are also co-operatives of municipalities and local electricity companies.

The co-operative utilities in Sweden have been the subject of criticism partly because of the quality of their accounting systems. The electricity supply to rural areas in the United States of America, since the establishment of the Rural Electrification Administration, has been and still is a shining example of successful co-operative utilities.

Diallo (1996) considers the successful rural electrification co-operatives as "examples of innovative approaches when addressing small and fragmented markets, while also recognising the need to mobilise citizens to fully participate in the implementation of programs". Mason (1990) argues "the establishment of co-operatives is advocated as a means of decentralising rural electrification activities and focussing efforts on implementation of programs. One of the objectives would be to involve the local population in the activities of the co-operative so as to put pressure on management to carry out effective programs and operate the system efficiently. Since there would be greater pressure on the co-operative to cover its financial costs (given that there is no opportunity to cross-subsidise from urban consumers as with a larger company), billing and collection rates would be higher than for a centralised utility, losses would be lower and there would be more emphasis on increasing the rate of connection in energised villages so as to increase revenues".

In a number of countries such as the Philippines, Costa Rica, Bolivia and Bangladesh part of the consumers do not view themselves as members of a co-operative so that the ideal of local participation in utility operations is often lost.
In the 1970s and early1980s in the Philippines the co-operatives were quite successful although there were problems with theft and poor collection rates. Then the co-operatives became more politised and were used for development activities other than electrification. The consequences were mis-management by political appointees, financial performance deterioration as theft and non-payment increased resulting in inadequate operation and maintenance.
As Mason's research revealed, other experience with co-operatives has been very mixed. Because of the lack of political commitment co-operatives in Ecuador have all but disappeared. Brazilian co-operatives proved not to be very successful because of the lack of trained manpower, poor financial performance and lack of delineation of the state utility and co-operatives' area of influence. Co-operatives in Peru, Colombia and El Salvador have practically been legislated out of existence. On the other hand, those in Costa Rica, Chile and Argentina are still functioning quite effectively. The co-operatives in this country are financially viable but much of the capital expenditure has been subsidised through low interest loans. A uniform tariff for all residential urban and rural consumers also implies an urban to rural subsidy.
In Colombia and Egypt planning and construction functions were carried out by the central/state utilities but operations and maintenance and financial responsibility were handed over to local distribution agencies (in Colombia "electrificadores"). The appointment of Board officials by political authorities of the state and the respective municipalities caused such problems as poor operational performance, high losses and poor billing and collection rates in Colombia. In Egypt the local distribution companies have poor financial performance partly due to poor billing and collection rates.

Co-operatives tend to be more successful if other decentralised agencies have been effective within a country. Mason's research also revealed that attempts to make central utilities responsible for establishing or assisting co-operatives tend not to have worked, given that many utilities do not view such activities as being in their interest. In Bangladesh the central Rural Electrification Board is responsible for rural electrification planning and the realisation of the main distribution system and the co-operatives for operation and maintenance, and the development of the consumer base and the realisation of the service connections. This arrangement in which the Electrification Board acts as an umbrella organisation for the local co-operatives works well.
There is some evidence that the success of co-operative organisations, and possibly electric utilities in particular, is culturally and situationally determined. It is fair to claim that for co-operatives to be successful a certain culture needs to be present.

Nye (1990) argues with regard to the electrification of rural America "Creating rural co-operatives required intensive local planning by neighbours, and in the short term these associations rejuvenated communities. But over time the electrical machines that farmers adopted raised productivity...... Like the compact nineteenth-century city, farm communities that electrified dispersed. These results were culturally determined, as Americans used the flexibility of electrical power to atomise society rather than to integrate it. Electricity permitted them to intensify individualism, as they rejected centralised communal services in favour of personal control over less efficient but autonomous appliances".

He also states that the American system which is dominated by private companies but which also has municipal, federal and co-operative utilities "was hardly an inevitable result of the technology itself, but reflected the political and economic segmentation of the country".

One of the particular advantages of co-operatives is "community ownership" and another important aspect is the extent of communication. It is said that co-operatives need more deliberations to keep the members informed and to avoid conflicts of interests, when compared to companies.

Although the familiarity of a rural population with co-operative principles is important, the role of a stimulating, guiding and interested organisation cannot be overestimated. Most of the rural co-operatives in the countries discussed, needed technical, administrative and management support.

The participative community approach with local committees, as applied in the forties, fifties and sixties, appeared to be effective in Ireland and the USA. The principles of the district approach and the participative community approach are currently applied in a number of countries and for different purposes. For example, Dieleman (1996) reports an application entitled "Hygiene Education by Peers". This method involves education given to villagers by fellow villagers and, since it is a novel activity in Burkina Faso, intensive support and monitoring is necessary. Each village is divided into districts and in each district a man and a woman are selected from among the team members. The first results revealed that the motivation of the villagers was good, the involvement of the population in the planning cycle, the implementation and the evaluation was effective and efficient, and insights and behaviour changed for the better. More negatively, it appeared that village teams need more support during the evaluation stage of the cycles, and that women need to be involved more actively in activities. These findings more or less correspond with the experiences gained during the electrification of rural areas in the United States of America. It should however also be noted that, in the countries discussed, local leadership and the efforts of a few of the community were more or less decisive in the success of rural electrification.

3.8.3. Technology

In the early days of electrification, small-scale isolated power stations with local distribution systems were the only available option and these isolated systems satisfied early demands in many countries.

In Scandinavia, New Zealand, and probably in other countries as well, many small isolated hydro-electric power stations have been in use for many decades during this century but most of them have been de-commissioned, mainly because of cost reasons rather than outmoded technology. There is reason to believe that these small power stations would be cost-effective again if electricity prices increased and there are already indications that some of these power stations will be revitalised.

In the Netherlands, and in countries with similar fuel situations, the small-scale isolated power stations were fossil-fuelled and soon superseded by more advanced and economical technology and abandoned in favour of central grid connection.

In recent years however, decentralised power generation in both villages and rural areas has revived in the Netherlands and in other countries as a result of the pursuit of increased energy efficiency and reduced greenhouse gas emission.

With the early isolated power stations, widespread electrification was not feasible but more advanced technology was introduced in the twenties.

Vennard (in OGEM 1963) observes: “the development of improved transmission equipment and techniques brought about a radical change, making it possible for large central power stations to serve many communities and for groups of stations to form power systems”. These power systems evolved to the present regional, national and international systems. Casaza et al (1985) analysed the evolution of interconnections between regions in the USA and distinguished, between 1885 and 1985, four phases each of them lasting for some 25 years:

- the isolated plant stage;
- the individual system stage;
- the regional stage and;
- the multi-regional stage.

The first stage was essentially a power station near a load area, the second stage linked the isolated plants with their load areas to each other to form several isolated systems supplying major population centres. The interconnections between these areas were economically justified by the replacement of smaller units with larger, more efficient ones, increased use of hydro-electric power stations.

The third stage evolved because it provided savings by further reducing the required installed generation reserves by taking advantage of seasonal, daily and hourly load diversities between systems, by scheduling the production of energy at the lowest cost sources available in the region, by reducing operating reserves and by making remote hydro plants available to more users. In the fourth stage many regions were interconnected to further reduce generation reserves and production costs.

The structure of rural grids differs from country to country. In Ireland the development of the rural grid has been based on a 38kV subtransmission system, three-phase 10 kV backbones and 10 KV single-phase (phase-phase) distribution lines. In the United States of America and in the province of Ontario extensive use has been made of single phase lines, and in the province of Friesland of three-phase medium voltage lines and cables with single-phase or three-phase low voltage service connections.

Swidler (1985) concludes on the basis of the Tennessee Valley Authority experience that small, discrete rural electrification projects were usually not justified in terms of the benefits gained from the economies of scale because of the limited spread of the overheads. This is probably true for rural electrification based on a central grid as was the case in Tennessee Valley but not necessarily applicable for currently available standardised decentralised systems.

3.8.4. Financial aspects

A general conclusion is that rural electricity supply has always been considerably more expensive than the supply to urban areas. If the principle “the customer pays the real costs” were to be generally applied, the poorest of the rural population in particular would be unable to use electricity despite the fact that they usually consume a very limited number of units. On the other side, uneconomically low tariffs cause financial problems and without compensation utilities are not able to perform well.

Although there may be cogent social and political reasons for enhancing electrification, extensive rural electrification projects can have a very negative impact on the economy of a country, a province or a utility, and in most countries funding has been a major problem. The funding for the electrification of rural and remote areas therefore needs a special approach and subsidies on the investments and/or cross-subsidisation have been remedies used in the past.

In Ireland, France and in the province of Ontario, up to 50% government subsidies were given towards the initial investments, and in the United States of America and the province of Friesland, long-term, low-interest or interest free, loans were provided to finance the electrical infrastructure and/or to support the financial situation of the utility.

For decades, the utility covering the province of Friesland maintained uniform tariffs across the supply area which implies cross-subsidisation. It is accepted that the power systems on the Frisian islands, whether connected to the mainland by submarine medium voltage cable or equipped with diesel power stations, are heavily cross-subsidised. Without subsidisation, these small power systems could not be operated with acceptable consumer tariffs.

Because of the relatively large number of rural consumers, cross-subsidisation alone was considered insufficient in Ireland and thus supplementary government subsidies were necessary. It has been estimated that in Ireland, at the end of the sixties, rural prices were lower by some 29% and urban prices higher by almost 9% than they would have been without cross-subsidisation.
The government subsidy of 50% on capital costs reduced the interest and sinking fund share of the fixed cost charges by 2.75% which implied 23% lower annual fixed charges for the consumer. One of the principles adopted was that consumers would not be asked to pay a contribution towards the cost of grid and service connections.
If fixed charges were higher, the impact on demand was expected to be significant thus reducing the financial viability of (parts of) the electrification scheme.
Where central grid connections were used to electrify rural areas, electricity consumption had to be stimulated through consumer information and specific campaigns to enhance the earning capacity. In both the United States of America and Friesland electricity consumption increased earlier and faster than expected. This could suggest that rural areas which had already experienced some form of development, react differently from more untouched areas, if they are electrified.
In presently developing countries, the productive use of electricity in rural areas appears to remain rather limited, certainly during the first few years following electrification. This is perhaps partly due to the limited priority utilities attach to the small-scale industrial sector and hence the associated marketing. For rural industries that do not have a heat demand, an unreliable electricity service seems a far more decisive reason to switch to another power source than a high rate.

3.8.5. Rural development

There is some evidence that, in the USA, agriculture has been successfully encouraged by the electrification of rural areas. It should however be noted that other conditions that could lead to production improvement were fulfilled as well: roads, irrigation facilities and farmer credit schemes were available and farmers had access to markets.
In the final decades of the nineteenth century, prior to electrification, a number of measures had been implemented to foster the development of rural regions in the province of Friesland. These activities stimulated the development of the dairy industry including the establishment of co-operative dairy factories. In fact, rural areas had, to a certain degree, already been prepared for further development.
On many farms in Ireland, electricity led to increased productivity and reduced costs. The availability of electricity enhanced industrial activities, and existing businesses developed into suppliers of services and equipment manufactured with electric tools. But the most important developments in rural industrial

activities were achieved with the influence of grants and other support by rural development organisations and small industries' programmes. In Ireland it was also concluded that further advances in rural development would have been possible with a well-planned programme of integrated rural action.

Electricity is a highly valued commodity and it supports development effectively if combined with other infrastructural measures. The conclusion is also justified that, particularly in small-scale power systems, an integrated and well-organised customer approach is necessary.

Chapter 4

Nature and Scope of Developments and Trends

4.1. Introduction

There is no doubt that the electricity supply industry worldwide is facing major and fundamental changes. Insights into the various developments in the power sector will be of assistance in identifying the appropriate way to organise rural electricity supply.

However institutional developments should be interpreted with particular care because the incentives and backgrounds can be very different in each country. Industrialised countries with a mature electricity infrastructure for example, increasingly lay the emphasis on reduced life-cycle costs, improved efficiency and higher equipment availability. The situation in countries with a less mature infrastructure is very different. The utilities in these countries struggle with the planning, financing and implementation of an electricity infrastructure in order to promote economic development and to help improve the living conditions of large groups of the population. Developing countries will require substantial investments to fund their future energy infrastructure[29]. The expected energy growth is one of the reasons that the present energy systems and the strategy for satisfying the world's future energy need to be reconsidered. This requires a radical rethink on various aspects of global energy policy. The recognition of the need to review traditional energy policy can be seen as a turning point for the energy sector (WEC 1992).

In this chapter the nature and scope of the developments and trends in the power sector are identified and discussed. Current developments and trends can be grouped into five basic themes:

- the environmental constraints, and the pursuit of a more sustainable energy supply;
- technological advances;
- the performance of the power sector;
- societal trends;
- institutional developments.

These themes are separately addressed in the following sections. Technological advances are listed but only discussed in so far they are relevant for the power supply to rural and remote areas. The institutional developments are discussed in more detail because of their likely impact on rural electrification efforts. In the last section of this chapter the findings are commented and conclusions drawn.

29 According to an estimate by the World Bank some US$100 billion per year will be needed over the next decade for the electricity power sector in non-OECD countries (World Bank 1994b). In a "business as usual" scenario, developing countries would have to build some 3000 GW of generating capacity over the next 30 years.

4.2. Towards a more sustainable energy supply

Mankind has always used hydro-power, wind and biomass to satisfy its energy needs. The industrial revolution accompanied a power demand which was substantially above the possibilities of traditional energy resources. Fossil fuels, hydro-power, and later nuclear power became the dominant energy sources.

Although the developed countries currently consume the largest share of the total fossil fuel usage, substantial future energy growth is expected to come from developing countries.

Continued socio-economic developments and improvements in living conditions in the developing world will have a major impact on the world's energy needs. The global energy demand has been estimated to increase by 50% in the next 25 to 30 years, mainly in the non-OECD countries (WEC 1993).

Electricity does not produce emissions as it is used and it is thus, in this respect, less sensitive to the attitude and expertise of the user. The environmental issues of centralised electricity generation can thus be addressed at a higher level in the supply chain, where expertise can be made more easily available and relevant investments are often more obvious. Electricity can be produced from various forms of renewable energy sources and the energy mix used in its generation can be adapted to local opportunities and needs. Electricity can thus be seen as an appropriate vehicle for a sustainable power society.

In the developing world more than 70% of electricity is generated by thermal power stations. It is expected that for economic reasons and for reasons, of security of supply, coal will continue to be an important fuel for electricity generation, at least in developing countries.

It is generally accepted that the use of energy obtained from fossil fuels, is a major cause of anthropogenic greenhouse gases emissions. The WEC report "Renewable Energy Sources: Opportunities and Constraints 1990-2000" indicates that there is no reason to believe that our dependence on fossil fuels will diminish. This report concludes that, even with an ecologically-driven scenario, fossil fuels will have to provide at least 70% of the world's energy needs in the next few decades. As a consequence global fossil fuel related emissions will continue to increase.

Carbon dioxide is seen as the most important greenhouse gas and its concentration in the atmosphere is increased by fossil fuel combustion. It is argued (Lindzen 1994) that, given past trends, it is not at all unreasonable to expect substantial increases in CO_2 concentrations, and much present research focuses on the climatic response to an increasing carbon dioxide concentration in the atmosphere.

Vermeersch (1993) argues that the world's population has one planet in common and that the population growth and mankind's technological development has turned that planet into a single ecological system. Although there is still discussion as to whether part of the ecological system has already reached its limits of reversibility as the result of mankind's activities, it is accepted that the current approach is not sustainable.

It is conventional wisdom that an improvement in the development level of the global society will be increasingly at odds with the ecological health of our planet and with the available natural resources unless adequate measures regarding the energy system appear.

What is needed is a more effective and extensive use of all the available resources coupled with the mitigation of the environmental impact of our activities. In this respect, the dependence on fossil and conventional nuclear energy sources must be reduced through an increased reliance on renewables, and by promoting fuel efficiency, for instance, through the use of more advanced industrial processes and appliances.

There is a clear relationship between energy efficiency improvement and energy conservation on the one hand, and a reduced need for supply expansion, a decrease in fuel consumption and lower emissions of greenhouse gases during the electricity production process on the other.

Energy efficiency improvements in the conversion, distribution and end-use phases could potentially reduce capital requirements in developing countries, as well as environmental pollutants, by 30% or more and improve financial and operational performance of utilities without thwarting the desire to meet actual demand side needs (World Bank 1992).

A SEED (1991) report also confirms that energy conservation is a rational, cost-effective and rapid way for most developing countries to reduce energy costs.

The importance of achieving a more energy-efficient society through technological innovation, behavioural change and advancement of the use of non-polluting electricity production systems, is underlined by the assumption that over the next few decades the share of electricity in global energy consumption will double from its present level of 35%.

The World Development Report (1992) focused on development and the environment, and presented an alternative path which would lead to improved environmental conditions accompanied by rapid economic development and the eradication of widespread poverty. Choosing this path "will require that both industrial and developing countries seize the current moment of opportunity to reform policies, institutions and aid programs". The report proposed the following strategy:

- Take advantage of the positive links between economic efficiency, income growth, and protection of the environment. This calls for accelerated programmes to reduce poverty and remove distortions that encourage the wasteful use of energy and natural resources …. and expanded programmes for education, family planning services, sanitation and clean water, agricultural extension, and credit and research.

- Break the negative links between economic activity and the environment. Dramatic improvements in environmental quality at modest cost in investment and economic efficiency are possible. To achieve this will require overcoming the power of vested interests, the building of strong institutions, improving knowledge, encouraging more participatory decision making, and building a partnership of effort between industrialised and developing countries.

In Table 4.1, Murota et al. distinguish, macro-economically, four stages of industrialisation, each with specific energy needs. Murota et al. (1996) argue that a scenario with temporary carbon taxes on industrialised countries and an accelerated development of developing countries, could avoid a substantial part of the greenhouse gas emissions that are expected from the latter countries. Such a scenario is based on the assumption that an advanced economic development curbs the relative growth in energy demand and consequently the contribution to global warming would be, to an extent, a transitional problem.

Table 4.1. *Stages of industrialisation.*

Development stage	Industrial structure	Economic growth rate	Population growth rate	Energy consumption
Pre-industrial	mostly primary and light industries	low	high (declining birth rate)	mostly non-commercial energy; low growth
Industrialisation	mostly metal and chemical industries	high	medium (declining birth rate)	mostly commercial energy; rapid industrial demand
Mature industrial	mostly automobile and consumer electronics industries	medium	low	mostly oil and electricity; medium growth in residential and transport uses
Post-industrial	mostly electronic and information industries	low or negative	declining (ageing of population)	low and declining; various energy conservation means and energy resources

(Source: Murota et al 1996)

An accelerated development would require the rapid transfer of energy conservation and renewable technologies to developing countries. Lenssen (1993) argues that developing countries can "leapfrog" to the advanced technologies level by embracing improved efficiency and cleaner, domestic energy resources, and at the same time avoid billions of dollars of misdirected investments in infrastructure .

The scenario suggests that carbon taxes should be imposed on industrialised countries first, but, depending on the ability to pay, also on developing countries which have reached a certain development stage. Thus carbon taxes would effectively be used as a means to control carbon-dioxide emissions in developed countries only.

4.2.1. Environmental constraints

Mankind has always polluted the environment and depleted its resources, but only during the industrial era has it happened so extensively. Van der Wal (1995) distinguishes two different causes of environmental degradation: poverty and wealth. The latter is closely related to a modern industrial lifestyle or rather the behaviour which is typical of industrialised societies. The author notes that this specific lifestyle is only limited to industrialised countries in quantitative sense. For the sake of completeness, a third cause of environmental pollution should be mentioned: that of military actions.

A growth of the world's population and an improvement in the living conditions in developing nations, leads to an increased use of energy, particularly electricity. A business-as-usual approach would lead to a considerable increase in greenhouse gas emissions and a faster depletion of finite energy resources. It seems certain that the discussion on the possible impact of greenhouse gas emissions on the global climate will continue. This discussion presently even dominates the issue of finite energy resources, and the problems associated with nuclear power stations such as their reliability under a competitive regime and human failures and, moreover, nuclear waste treatment and storage.

Local, regional and global environmental degradation has social and economic impacts including human health problems, degradation of quality of life, loss of natural resources and reduction of economic activities. Although the awareness of ecological limitations is growing, the socio-economic impacts of environmental degradation are usually ignored.

Today many countries face transboundary pollution problems and their number will grow substantially in the next decades. When the effects of environmental problems cross national boundaries, solutions need to be based on common principles and rules of collaboration among sovereign states, backed up by persuasion and negotiation (World Bank 1992).

During the 1992 UNCED meeting on Climate Change in Rio de Janeiro many countries agreed on concerted actions to mitigate atmospheric pollution, but that does not mean that the priorities and perceptions in the countries are also the same (Verbruggen 1995). While the industrialised world emphasises actions to achieve sustainability and an international approach to global environmental problems, the developing world focuses on the development of its countries and the mitigation of local and national environmental degradation. The order of priorities of the developing world is understandable for a number of reasons. For instance, safe and sufficient fresh water, a prerequisite for life and essential for public health is still not available everywhere. One billion people in the developing world lack access to clean water and the number is still increasing (World Bank, 1992,1994). Water related diseases are estimated to lead to some 4.4 million deaths per year, and create numerous lifelong invalids (Schertenleib, cit.in Hoffer 1995). In several regions of the world more water is being extracted than nature is able to supply and replenish (Falkenmark 1994). In Africa water shortage is one of the main causes of ecological degradation (UN 1993).
Another reason why developing countries are reluctant to act regarding the extent of their contributions to the mitigation of global pollution, is the present ratio between the pollution caused by industrialised and developing countries. However for the economic development of the latter countries, large quantities of energy are needed and these will have the associated environmental impacts.

To assist developing countries in achieving sustainable development in compliance with emission reduction agreements, so-called flexible instruments have been proposed under article 12 of the Kyoto Protocol 1997. The Clean Development Mechanism (CDM) is such an instrument that could promote foreign investments in the energy sector of developing countries. In view of the sustainable energy opportunities offered by many rural areas in the developing world, CDM might be attractive to foreign investors and donors. To create an attractive investment climate, it is of utmost importance that an adequate institutional and financial environment is in place. Thus electricity supply to the rural areas in developing countries should specifically be addressed in national energy policies and rural development plans.

4.2.2. Growing importance of renewable energy resources

The reduction of carbon dioxide and other greenhouse gas emissions, in order to mitigate global warming, is one of the most important challenges for the future. Emission mitigation options include a wide range of end-of-pipe technologies, but end-use energy conservation through life-style change and improvements to the energy efficiency of industrial processes and appliances, and to energy conversion processes, should rank first. These measures are often cost-effective compared to end-of-pipe technologies and make end-users directly involved.

Substantial emission reductions can be achieved not only with energy efficiency improvements, but also through the use of renewable energy technologies. Johansson et al. (1993) advocate a renewables-intensive global energy scenario and they argue that in the middle of the 21st century renewables could satisfy 60% of the world's electricity demand and 40% of the demand for fuels used for non-electrical energy. They also note that a global commitment is needed to stimulate further development and market penetration of renewables, to adopt appropriate policies, and to transfer renewable energy technologies to developing countries.

The Renewable Energy Working Party of the IEA (IEA1999) argues that a sustainable energy system will evolve over the next fifty to one hundred years with renewable energy as the basis. Although the new energy system will largely depend on renewables, it is clear that mankind will still need large amounts of fossil fuels well into the 21st century.

All over the world renewable energy initiatives and demonstration projects are supported by various organisations. Some of them are intended to demonstrate the viability of power supply to rural and remote areas in developing countries.

The Danish island Samsø and the German island Pellworm, supported by the European Commission, plan to generate power on a carbon dioxide free basis. Samsø has a population of 4400 and a total energy consumption of 900 TJ/year (Samsø 1997). The available renewable energy sources include solar, biomass and wind and the planned scheme will be implemented over 10 years. For this purpose the "Samsø Energiselskap" has been established, consisting of the island municipality, the Commercial council, the Farmer's Association and the Energy and Environment Office. Table 4.2 indicates the contribution of the various sources to future electricity consumption.

Table 4.2. *Planned contribution of various sources to cover future electricity consumption on Samsø island.*

Source	Share
Land-based wind turbines (15 x 750 kW)	75%
Large biogas CHP plants (2)	21%
Farm-based biogas CHP plants (5)	2%
Household wind turbines (15)	1 - 2%
Solar cell plants (70, installed 35 kWp)	0 - 1%
Offshore wind turbines (15 x 1500 kW)	under consideration

A European Commission funded feasibility study revealed that a carbon dioxide free energy supply for the German island of Pellworm is possible (Eichelbrönner 1996). The island now has wind turbines with a total capacity of 1100 kW, a 300 kWp photovoltaic installation, and a 2000 kWh battery. It is also connected to the mainland grid by a medium voltage submarine cable. The experiences with this system have revealed that using battery storage is very expensive. In order to achieve a carbon dioxide free situation on the island, substantial conservation of both heat and power was first needed (and is possible in the medium term). Wind turbines, solar thermal and photovoltaic systems, heat pumps, biogas/bio-oil and particularly biomass plants appeared to have sufficient potential to meet the annual heat and power consumption. However, although on an annual basis the energy generated is sufficient, the problem of satisfying peak power demand has not yet been solved. The operation and maintenance of a system with such a diversity of equipment is rather complicated and needs advanced control equipment and well-trained human resources.

In the past decade numerous wind turbines, either stand-alone or in wind farms, have been installed. They run in parallel with local grids or supply power to decentralised mini grids, some of them in a hybrid scheme with a diesel generator. Some other renewable energy demonstration projects that have been developed and realised during the last decade are:

- The Kalbarri Photovoltaic System in Australia, a 20 kWp grid-connected demonstration plant supporting the local distribution system. The latter system is fed by a single 136 km long overhead line which suffers from rather high losses (Caddet 1998). A project with a similar aim is the 500 kWp photovoltaic system linked to the American Kerman substation. This installation supports the grid, reduces line and transformer losses, and helps in avoiding additional investment costs (Hoff 1995).
- The Neunburg vorm Wald 370 kWp solar hydrogen system. This German facility demonstrates the solar hydrogen energy cycle with hydrogen used for storage of energy. Although the experiences regarding utilisation factor and reliability are mainly positive (Dietsch 1996) it is noted that the integration of a rather complex system into an overall plant concept is sometimes more difficult than commonly believed. There are reasons to propose, from the point of safety, supervision and costs, this technology should be operated on a centralised scale (Szyszka 1996).
- The German Flanitzhütte photovoltaic pilot project. The Flanitzhütte community was, for many decades, connected to the main grid through old and unreliable medium voltage overhead lines. The utility decided to decommission the lines and install a hybrid system consisting of a 42 kWp photovoltaic system, a 480 kWh battery storage facility and a 40 kW LPG fuelled gas engine. For this situation, the life-cycle costs of the new installation appeared to be lower than replacing and maintaining the overhead lines.

- The German 1000 roofs photovoltaic programme. In this project, home owners have the option of installing subsidised photovoltaic arrays and delivering the electricity to the grid. Projects of this kind are presently being implemented in many countries, including the Netherlands.
- The 26 kW photovoltaic plant on Sagar Island (West Bengal) with 300 households connected via a local grid (Rahman 2000).
- The Carissa Plains (California) photovoltaic power plant of 5000 kW installed peak power (Markvart 1995).
- Photovoltaic plants in developing countries such as Senegal, French Guyana, Cape Verde, Algeria and the Marshall Islands with capacities ranking from 6.7 kW to 35 kW (Yaron 1994).

Table 4.3. *Indicative current and potential future cost of electricity from renewable sources (based on World Energy Assessment (advanced copy), UNDP, New York, September 2000).*

Option	**Current electricity cost** (USct/kWh)	**Potential future electricity cost** (USct/kWh)
Biomass electricity	5-15	4-10
Wind electricity	5-13	3-10
Solar photovoltaic electricity	25-125	6-25
Hydroelectricity (large)	3-8	3-8
Hydroelectricity (small)	5-10	4-10
Solar thermal electricity	12-18	4-10

Renewable technologies often appear to be comparatively expensive (see Table 4.3) but it can be argued that current economic viability assessments are based on a traditional approach. Alternative accounting systems based on realistic life-cycle costs, including all externalities, could show that these technologies are economically feasible.

Johansson et al (1993) argue that in current economic assessments the following benefits of renewable energy are not covered:

- Social and economic development and employment opportunities in rural areas offered by the production of renewable energy
- Restoration of degraded lands as a result of the incentives and financing provided by the production of biomass
- Reduced air pollution and abatement of global warming
- Fuel supply diversity and a likely reduction of energy price swings

- Reducing the risks of nuclear weapons proliferation as a result of the reduced dependence on nuclear energy.

But we should realise that both renewable and fossil-fuelled and nuclear plants create emissions in their construction and for a reliable comparison of the environmental impact a complete chain life-cycle analysis is needed (Norton 1999). Table 4.4 lists the life-cycle emissions for a variety of power generation options. As technologies advance, life-cycle emissions can reduce. For instance amorphous silicon PV systems are expected to emit only 8 grams CO_2/kWh and the new generation nuclear power stations 3 grams CO_2/kWh. It should be noted that the table lists the emissions only and does not address other impacts and risks associated with the various power generation options.
Kozloff (1998) states that renewables and small-scale non-renewable generators are likely to play a significant role in decentralised power generation systems in developing countries for the following reasons:

- To cope with the low power density and uncertain demand in rural areas.
- To avoid high transmission and distribution costs and system losses.
- To avoid the poor local service quality often found with long rural line

Table 4.4. *Comparison of life-cycle emissions of various power generation options.*

Option	CO_2 emission (g/kWh)	SO_2 emission (g/kWh)	NO_x emission (g/kWh)
Energy crops (current)	30 - 40	0.08 - 0.16	1.1 - 2.6
Energy crops (future)	30 - 33	0.06 - 0.08	0.40 - 0.55
Hydro	5 - 9	0.02 - 0.03	0.06 - 0.07
PV	98 - 167	0.20 - 0.34	0.18 - 0.30
PV(future amorphous)	8 (?)		
Solar thermal	20 - 30	0,50	0.23
Wind	6.5 - 30	0.02 - 0.09	0.02 - 0.36
Coal (hard); power plant eff. 36,5%	1050		
Coal (best practice)	954	11.82	4.34
Coal (flue gas desulphur, low NO_x)	986	1.49	2.93
Oil (best practice)	818	14.16	3.99
Gas combined cycle	430	-	0.49
Diesel embedded	772	1.55	12.3
Nuclear (current)	6	0.02 - 0.03	0.06 - 0.07
Nuclear (future)	3		

Sources: Norton 1999 (figures valid for the United Kingdom) and Caddet 1995.

Renewables will also increasingly be used in the industrialised world. In some industrialised countries customers can already buy “source tagged electricity” offered as “green electricity”, “natural electricity” and similar designations.
In Switzerland many utilities offer their clients “solar electricity” or “eco-electricity” against a price which covers the costs. Linder (1998) states that, on average, 1.5% of the customers take the opportunity to cover part of their consumption with this “labelled” electricity. The utilities have two possibilities in delivering this labelled electricity: they can either invest in their own renewable generation facilities or they can purchase electricity from others.
In the Netherlands, utilities offer consumers the opportunity to buy electricity generated with renewables against an additional payment of 3 to 4 USct per kWh. Ecotax, introduced in the Netherlands in 1996, is not applied to green electricity and reduces the price differential with “conventional” electricity. All distribution utilities are required to generate (or purchase) part of their supply using renewables. Utilities that fail to sell their allocation, are penalised by an amount per kWh above the market rate. Utilities can purchase green electricity, and 10,000 kWh is equivalent to one green certificate. These certificates can be purchased and sold on the market.
There is no reason to expect a separate market for “green” electricity in the rural and remote areas of developing countries. In these countries the emphasis should be on the provision of affordable and clean electricity.

4.3. Technological advances

For many years large-scale power stations have been used, often remote from electricity consumers, requiring long-distance, high-voltage transmission lines to bring the electricity to the load centres. This is commonly known as a centralised system.
Current technology developments make efficient decentralised power generation systems possible using, for instance, reciprocating engines, gasturbines, fuel cells and PV (Figure 4.1). These distributed, or embedded, systems can produce electricity near to the consumers, or even in their own premises. Basically, such systems can be as small as a few tens of watts or as large as 500 MW. Power electronics have enabled the construction of more effective high and medium voltage transmission lines and appliances.
These developments, together with the advances in telecommunications and information technology, have changed the scene on both the supply and the demand side and offer many opportunities for the deployment of renewables.
In the industrialised world, with a mature electricity infrastructure, the emphasis of utility activities will be on the reinforcement and updating of existing installations rather than on the construction of a new infrastructure. This implies that new technologies will have to be geared to integration into existing installations.

Figure 4.1. *Cheese farm "Zettenalp".*
In operation since 1992 and an example of the successful deployment of a hybrid system consisting of a photovoltaic installation (3.8 kWp), a diesel generator (2.5 kW) and a wood fired low pressure steam boiler for heat production. Grid connection was not economically feasible. Engineering requirements included a high availability, spare parts delivery within 24 hours and the use of available wood resources. The standard voltage of 220/380 V was selected mainly because of trouble shooting ease and the availability of spare parts. Stored energy 50 kWh/day, effective available energy 30 kWh, energy required 15 kWh/day. Milk quantity processed 600 kg/day, cheese produced 60 kg, butter 4 - 5 kg/day. The concept for this subsidised project was developed by the energy service department of the utility BKW.
(photo: Courtesy Bernische Kraftwerke AG (BKW), Switzerland)

The non-electrified rural areas of developing countries however feature a "green field" and this allows energy supply to be organised differently including the deployment of sophisticated technology on both the supply and the demand sides. The following sections looks at these options in more detail.

4.3.1. Supply side

In the past, supply and demand forecasts were generally based on historical data and economic growth expectations. The design and realisation of the electrical infrastructure were based on these forecasts, reliability and availability criteria, and the most cost-effective technology. As a result, the focus was, in general, on centralised power systems with the associated institutional and management structures.

CIGRE (1995a) concludes in relation to the activities of its Study Committee 37 (Power System Planning and Development): "…. difficulties and complexities became prominent year by year in seeing the future tendency of changing environments. This tendency indicates such keywords as energy conservation policies, demand side management, power quality requirements, co-generation, dispersed generation from renewable sources, electric storage techniques. All these are factors which may have large effects on electrical demand and therefore on expenditure for power system expansion in the future".

Fission based nuclear power generation now appears in a bad light, not least as a consequence of the Chernobyl disaster. Fossil fuels are still the dominant energy resources but their use involves emission of exhaust gases that are held to be responsible for at least some global warming. It seems that fossil fuels, and particularly coal and natural gas, will remain the most important primary resource over the next few decades. The efforts of the manufacturers of power generation equipment are therefore directed at a further increase in fuel efficiency and a reduction of emissions from fossil-fuelled power stations. Over recent years considerable achievements have been achieved. Coal gasification systems, combined heat and power units, combined-cycle units and even solar-thermal power stations[30] are in the demonstration stage or in commercial operation.

For decentralised applications intelligent and reliable power systems have become available in the last few years. Decentralised systems have the advantage of very short lead times when compared with centralised power supply and the associated power lines. Because of the difficulty of accurately forecasting demand in developing areas this is a great advantage.

Depending on local resources, these systems use diesel generator sets, wind turbines, phase shifters, photovoltaic arrays, battery storage and advanced supervisory and control equipment (SMA/Powercorp, 1995). Some systems combine diesel generator sets with wind turbines and a desalination plant (Danvest 1998), and wind turbines with an anaerobic digester and a gasifier producing gas from coppiced wood (Parker 1999). Local circumstances could further allow the use of geothermal, tidal and wave energy.

The last few years have seen a remarkable progress in the field of fuel cells. A number of types have been field tested and show acceptable reliability. Compared with traditional energy conversion technologies, fuel cells have some attractive features for electricity generation including an efficiency of 40% (for

30 See for instance Brakmann (1998).

low temperature types) to 50% (for high temperature types) and modest emissions of NO_x, CO and CH_x. A wide range of fuels can be used such as hydrogen, natural gas, biogas, methane and methanol.

Distribution systems

Developments in electricity transmission and distribution equipment have continued as well and sophisticated options have already been applied in supplying rural and remote areas such as:

- The use of the shield wires of high voltage overhead transmission lines together with the earth to form a small medium voltage system that is able to supply communities living along the line (system Prof.Iliceto)
- The use of capacitive coupling systems to tap power from a high voltage overhead transmission line to supply a small distribution system (Cegelec/BG Checo 1995 and IREC 1995). Typical capacities: from a few watts to 2000 kW.
- The use of a long distance single phase high voltage overhead line (Manitoba HVDC 1994). Typical capacity: 8000 kW, distance 170 km. Converted to a three-phase supply at the receiving end.
- The use of medium voltage direct current (ABB 1997). Typical capacity: from a few MW upwards at approximately 10 kV upwards.

Traditional distribution lines are expensive and during the 1997 Round Table on Rural Energy and Development organised by the World Bank (ESMAP), a number of speakers addressed the issue of lowering the cost of rural electricity services (World Bank 1997). The deployment of non-grid options was emphasised and careful project design on a case by case has the potential to reduce costs of distribution grids.

Munasinghe (1990) had already concluded on the basis of several studies that overall costs of rural electricity supply could be reduced by up to 30% through measures such as:

- selection of higher and more appropriate primary system voltages;
- improved design of lines and distribution substations;
- more effective operation and maintenance;
- advanced metering and billing systems;
- revised service quality criteria including voltage variation standards.

The all-in cost for a three-phase medium voltage overhead line for grid extension in a developing country, including materials and labour but excluding way leave, vary from 2,500 US$/kilometre to 21,000 US$ (1998 figures), depending on such variables as the voltage (11 to 34 kV), the configuration, the type of insulators, the pole length, the conductor size and the country (NRECA 1998). The lowest costs typically reflect a very light line with extremely low construction and installation costs. The typical range is from 8,000 US$ to 10,000 US$/kilometre, but in industrialised countries the cost is often much higher because of the required capacity, the way leave costs and the higher installation costs.

Although the grounding system is more expensive, the single phase line and particularly the single-wire earth return (SWER) line are significantly cheaper (single phase from 20 to 30% and SWER even higher).

NRECA (1998) reported that medium and low voltage grid extension could be less costly. At the lower end of the scale, the cost could be less than US$ 150 per connection, as efforts by NRECA in Nepal have suggested (Inversin 1995). Their project addressed new approaches by which the cost of some low power rural distribution systems could be lowered. The approach in Nepal included an experiment with a 1 kV/0.23 kV distribution system but it appeared that the cost advantages were not significant when compared with the standard 11 kV/0.4 kV system. Other activities included the use of insulated bundled cables[31] on simple poles, wiring harnesses, power-based tariffs and current cutouts and users' organisations for fee collection and servicing. Including service connection and housewiring, the distribution system (for 170 connections) cost US$ 180 per connection (1994 figure). NRECA state that the average worldwide cost per connection is US$ 600, but as has been explained in Section 2.7.1 the average would seem to be twice that figure. In this section, average capital cost of US$ 1200 has been determined using data of a variety of projects.

The studies of both Munasinghe and NRECA suggest that the cost of grid-based rural electricity distribution could be lowered through technical and organisational measures. However, as discussed in Chapter 2, one should not be too optimistic about the potential gains.

Renewables

Although the various renewable energy technologies are at different stages of development and associated costs, most of them can now be deployed successfully. Ahmed (1994) reviewed the status and costs of selected renewable technologies for electricity generation namely biomass-based, solar-thermal and photovoltaics. On the basis of the findings, the review recommended to expand the use of:

- photovoltaic systems for small-scale applications in high-insolation areas;
- grid-connected photovoltaic systems to support supply under peak load conditions;
- pilot thermal-solar power generation schemes;
- biomass for electricity generation.

31 Compared with bare lines, covered conductors have benefits: increased reliability of supply and safety, lower operation costs and less environmental impact. In industrialised countries, all-in costs are nearly the same as for a bare conductor line (Lines & Cables, June/July 1995).

Since Ahmed's comprehensive review, which was based on over 50 studies, technical developments have continued and the prospect for the deployment of renewables is even brighter, as appears from the following sections.

Photovoltaic (PV) systems

Photovoltaic technology is developing rapidly and will almost certainly become an increasingly important source of electricity in both the industrialised and the developing world. At the moment the market is mainly supply driven with the aim of increasing production to bring costs down. The main problem in the rural areas of many developing countries with the introduction of these systems is that most people cannot afford to purchase these systems without a credit facility. Moreover, these areas often lack appropriate distribution and service organisations. Relevant external support is therefore primarily directed at institutional development and the implementation of credit lines. Research (World Bank 1996a, ECN 2000) revealed that none of the institutional models used for the implementation of Solar Home Systems (SHS)[32] in rural areas failed. There are however indications that the involvement of existing institutional structures eases the implementation.

Hankins (1993) is of the opinion that it is not poverty that prevents rural people from accessing PV systems. Based on the situations in Kenya, Zimbabwe, The Dominican Republic and Sri Lanka, he argues that "the lack of cash income, the low earnings for their products, and the near worthlessness of many Third World currencies make it hard to buy PV systems…..". He continues in saying "their sustainable subsistence economies nonetheless generate enough cash for millions of 'poor' farmers to purchase radios, bicycles, and even battery powered television".

With solar home systems, people in the rural areas of developing countries, "leapfrog" into modernity (Figure 4.2). This could be one of the reasons why user maintenance is seldom successful as the research revealed. Another important "lesson learned" is that the success of the programme very much depends on the availability of a local service organisation with the relevant expertise and attitude. This is confirmed by Lorenzo (2000) and ESMAP 2000A. The latter report argues that technical assistance and appropriate maintenance for SHSs proved indispensable. Lorenzo list technical shortcomings with solar home systems identified by the Instituto de Energia Solar (Spain) in 12 countries during the last 15 years. These deficiencies do not refer to the photovoltaic technology as such, but to system and installation aspects and include poor siting of the equipment, inadequate wiring and low initial battery charge. Proper quality control is another important factor to avoid on site problems.

32 Energy Service Companies (ESCOs), utilities, co-operatives, leasing or hire-purchase arrangements, cash or credit sales to consumers.

Although in Kenya and Sri Lanka the PV market perforce developed without much assistance from the Government (Guaratne 1999), there are no indications that socially oriented objectives of rural electrification using Solar Home Systems are compatible with commercial aims (ECN 2000).

Figure 4.2. *Photovoltaic electricity supply (Islas Flotantes, Peru).*
(photo: Trudy Coenen)

PV generated electricity costs, under Swiss conditions between 0.45 and 1 US$/kWh (Roth 1999). The power generated by grid connected PV units is variable and has many similar features to the demand of a consumer, albeit in the opposite direction (sometimes called "negative demand"). The reserve margin of the other plant connected to the grid should therefore be sufficient to compensate for the variations in power supplied by the PV units. This is the reason why PV, if not linked to storage facilities, can only marginally substitute hydro and fossil-fuelled generating units.

Presently, external costs are not assigned to their cause and under this approach the economic value of PV generated power is merely the avoided costs of alternative generation which is of the order of 2 USct/kWh. For residential customers with a PV unit, the value is much higher (10 USct) because of the structure of the tariff system (Roth 1999).

The battery used in stand-alone PV systems is the most expensive component because of its relatively short lifetime. There is no doubt that the availability of high capacity and long-lasting storage facilities would substantially enhance the attractiveness and functionality of PV systems.
In a number of countries central PV systems have been installed. These power systems are used to support a local grid or to supply local communities (see Section 4.2.2). Kristof (1992) argues that the capacity of a central PV system must be about 16% higher than the combined capacity of decentralised PV systems due to line losses and power station consumption. Other additional costs are due the siting: decentralised systems are suitable for roof mounting while centralised systems need special sites and also routings for distribution lines. Central PV systems need some kind of metering, and are essentially prone to theft of electricity. The advantages of central systems include the use of existing infrastructure and backup diesel facilities, economies-of-scale and lower cost/kWh for equipment other than the modules.

Wind generated electricity

In recent decades, wind turbine technology has developed rapidly and turbines with a capacity of over 1 MW are in use. Many grid-connected wind farms are in operation or planned. In areas with a favourable wind regime, grid-connected wind turbines are now a commercial reality.
The windiest sites are found in remote areas and here the limited existing power systems, if at all available, often form a major obstacle. These grids are generally weak in terms of X/R ratio, fault level and rating. The capacity of wind farms is often too low and the distance to the load too great to justify the construction of a high voltage line. Variable speed wind energy conversion systems with asynchronous generators and thyristor-based AC/DC/AC converters for grid connection have already been developed. These systems allow power to be fed into a grid with constant voltage and frequency under a wide range of windspeeds (Çadirci 1998).
Under favourable circumstances wind energy is economically competitive with conventional electricity generation. This is due to the increasing unit size and the more effective and efficient production of the turbines. Current problems are mainly the unavailability of suitable and acceptable sites, the visual impact, and linked to grid connection. The intermittent nature of the wind remains a major drawback of wind energy and consequently a windturbine’s ability to substitute for firm conventional capacity on a grid is rather low. Sontow et al (1999) quantified this substitution for Germany and found a value of 10 to 25% of rated power depending on such factors as the wind regime, the demand profile, the network configuration and the features of the conventional power plants.

Electricity from biomass and biogas

From biomass, heat, electricity and also liquid fuels can be produced. Today, 900 million tonne of coal equivalent biomass is used annually. This equals to over 10% of total global energy production, most of it on a non-commercial basis. Although the available quantities of biomass are never likely to be sufficient to satisfy the world's energy needs, their contribution to satisfying the power needs of rural areas can be substantial.

The costs of large scale biomass conversion systems depend heavily on local circumstances, but often compare favourably with the costs of fossil-fuelled generation and sometimes even with hydro.

Gasifier/gas turbine technology could offer a reliable and cost-effective option for electricity generation.

During the 1990s, the amount of energy supplied from landfill and sewage sites has grown steadily. The equipment used in waste-to-energy systems is fairly traditional but minimum quantities of waste are needed to make these systems economically feasible. For this reason waste-to-energy systems are not unlikely to have a substantial potential in rural areas.

Case 4.1: Biomass fuelled co-generation

Typical sugar mills have a capacity of 6000 tonnes of cane per day and both bagasse and cane trash are available for power generation. From an agricultural viewpoint, 50% of the latter could be used to generate power. Utilising both bagasse and cane trash approximately 5 GJ per tonne of cane would be available.

However power generation at most sugar mills is designed to supply electricity and process steam to the mill only, and such a bagasse-fired sugarmill with a 5 month crushing campaign produces on average 20 kWh/tonne cane.

Studies in Tanzania (Gabra 1995) revealed that with advanced co-generation 300 to 400 kWh electricity per tonne of cane could be generated. With an electricity sales price of 6 USct, the pay-back time would be 6 to 7 years.

Valdes (2000) argues that Cuba's current electricity demand could be satisfied if all sugar mills in that country would be provided with biomass gasifier combined cycle systems producing 400 - 800 kWh of electricity per tonne of cane.

Solar thermal

The most widespread application of solar thermal is for water heating and this technology has undergone enormous development in both the industrialised and developing world over the last decade.

Experimental, large-scale, solar thermal electric power stations of different types have been built in a number of countries and the results are promising, albeit the costs are still high. The scale of these plants is such that large areas can be supplied with electricity.

Small-scale hydro

Small-scale hydro power stations have been used since the very beginning of electrification[33].

The technology is well developed and operation and maintenance not complicated. Over the world many hydro schemes have been developed but the potential for small-scale run-of-river types and storage types is still large. Micro and mini hydro-installations have attractive features for rural and remote areas: their capital costs are low and the electro-mechanical parts are not very demanding. In many developing countries however the deployment of these hydro schemes is frustrated by a number of barriers. These barriers often include an inconsistent government policy, no appropriate institutions available for quality and performance control and for operation and maintenance support, lack of competent human resources for identification, operation and management of the installations, limited awareness of the potential, lack of support for local initiatives and, most importantly, a limited ability to pay by the local population (SEM 1996, personnel communication)[34].

Power quality

Maintaining acceptable power quality is more difficult in rural power systems. These grids typically have a high source impedance and are therefore prone to voltage flicker and voltage distortion. In this respect, grid connected decentralised power generation can improve distribution grid behaviour (Jenkins, 1999).

Conversely, mature distribution infrastructures have showed problems when relatively small decentralised units were integrated into the grid. Dispersed generators have their own dynamics and cannot simply be treated as a negative load. Many utilities in industrialised countries are now developing network renewal/renovation programmes. One of the major problems is that 10 or 11 kV systems are not very appropriate for dispersed generation because of the rather small range of voltage within which the system is operated. Programmes therefore often include an upgrading from 10 kV to 20 kV through reconductoring overhead lines. To reduce the effects of any decentralised plant to a level acceptable for both the demand and the supply sides, close communication and co-operation between both sides is increasingly necessary. This is particularly true for rural and remote areas.

33 Examples are given in Section 3.6.

34 ESMAP 2000b provides information on best practices for microhydro power in developing countries.

4.3.2. Demand side

CIGRE (1995a) notes “the rational use of electricity will be an essential keyword in the future. This implies better use of facilities (kW) as well as energy saving (kWh). The potential for energy conservation by efficiency improvements of appliances is huge. Using Denmark as an example, power consumption of systems for cooling, heating, cooking, ventilation and lighting (based on the 1989 situation) can be reduced by 70% (Nørgård 1989). Such a reduction however is only possible if advanced efficient technology is developed and deployed. Nørgård argues that the cost of this technology would correspond to an average 2.5 USct per kWh electricity conserved, lower than the average fuel cost per kWh generated”.

During the last decade many new technologies have been applied on the demand side. New appliances with sophisticated (power) electronic components have appeared in the residential, industrial and commercial sectors.

Technological advances and stricter environmental requirements have induced market gardeners in the Netherlands to install small natural gas fired combined heat and power units and farmers to embark on wind farming using subsidised wind turbines. Byrne et al (1996) argue, on the basis of five case studies in the United States, that “dispatchable” peak shaving rooftop photovoltaic demand side management systems can offer substantial benefits for both utilities and customers. Demand side management programmes that reduce a utility’s peak demand tend to have a higher value to utilities than other utility DSM programmes with the result that such photovoltaic systems are closer to cost effectiveness than previously thought. It is noted that in the cases concerned, airconditioning caused summer peak loads.

In urban and rural areas alike, the future will include an increase in the deployment on the demand side of various new devices such as advanced process control and computer systems, heat pumps, new lamp types, electric storage, fuel cells, photovoltaic systems, mini-and micro co-generation systems, variable speed drives. The CIGRE Working group 37.17 (CIGRE 1999a) argues that with larger penetration, these new demand side technologies may have both positive and adverse effects on the power system, and in this respect, they identified four key areas of influence on system planning: energy demand, load curve, load dynamics and power quality. To avoid unacceptably low quality as a result of demand side equipment inadequacies, close co-operation between demand and supply sides is increasingly necessary.

With the emergence of photovoltaic systems and advanced electronic household appliances, the question arises whether AC or DC would be the best option for domestic use. Pellis et al (1998) argue that for grid connected houses with rooftop photovoltaic systems, given current options, that there are no energy conservation advantages associated with low voltage direct current. A house solely supplied by a solar home system could benefit from a low voltage DC system, but only for some of its appliances.

4.3.3. Renaissance of decentralised power supply

In the early days of electrification, small local power stations were used to satisfy the growing demand for electricity. The higher efficiency and lower cost per kW of larger generating units together with the ability of sharing spare generating capacity and spinning reserve via transmission lines, are some of the reasons that induced the electricity supply industry to move to central power stations, transmission lines and extensive distribution systems.

Kaijser (1995) analysed the transition some fifty years ago from local decentralised systems to regional electricity systems in Scandinavia and distinguished “economies of substitution” and “economies of scale” as supply side incentives. The underlying causes were the substitution of fossil fuel-based power with hydro power and the technical developments that made more efficient large scale power generation possible.

One of the salient features of grid-based systems is the general uniformity compared with decentralised technologies. This is one of the reasons why the centralised system has always been favoured, both politically and institutionally. In the last decade, however, decentralised electricity generation is again becoming an important option in many countries. The development of cost-effective and reliable natural gas engines, combined heat and power units, and the deployment of wind turbines substantially contribute to this trend. Modern decentralised fossil-fuelled units generally produce both heat and power with an energy efficiency that is hard to match[35]. It would seem that the “economies of substitution” is again an incentive to enhance decentralised power systems.

Kristof (1992) analysed various features of the prevailing centralised power system in Germany and the opportunities offered by renewable energy technologies, with an emphasis on photovoltaic systems. She also studied the optimal combination of centralised and decentralised photovoltaic power supply systems addressing four criteria: the feasibility (both economically and technically), the responsibility (in terms of current and future generations), the implementation (legislative and institutional aspects) and the environmental impact (including social and political aspects).

Based on a qualitative and quantitative assessment she concluded that, in the short term, medium-sized grid-connected PV systems installed on public buildings and dwelling roofs in an industrialised country are a meaningful option. She also concluded that a more widespread deployment of renewable energy sources must be accompanied by a number of measures including:

35 Wärtsila (1999) claims that the total cost per kWh at the terminals of a large natural gas fired decentralised power station (with gas engines) can be as low as 3.3 USct of which fuel costs are 58%. Typical high voltage and medium voltage distribution costs per kWh are 0.42 USct and 1.05 USct respectively.

- extensive demand side energy efficiency improvements;
- the widespread application of decentralised systems that take advantage of regional resources and opportunities;
- the tuning of the supply and demand profiles;
- the removal of legislative and institutional barriers.

In essence, decentralised power generation allows a step-by step increase in capacity, greater consumer control, and combined heat and power generation. Although no extensive electrical transmission system is needed, fuel must be brought in if local resources are not available. Decentralised power systems can feature better consideration of local resources and conditions, and improved co-ordination of other local systems and services. On the other hand, a major advantage of centralised systems is that the consumer does not need to do anything other than flick a switch.

In the past the function of the distribution system was limited to the distribution of electricity. Electricity was delivered to the local distribution system at substations from the transmission grid. It was in fact very straightforward and passive.

Past:
Fossil fuelled and
small hydro power generation ⇒ distribution ⇒ customers

Present: in some countries: emerging decentralised generators
Fossil fuelled, nuclear and ⇑⇓ ⇑⇓
large hydro power generation ⇒ transmission systems ⇒ distribution system ⇒ customers

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Future:
Storage facilities
⇑⇓
Fossil fuelled, nuclear and
large hydro power generation ⇒ transmission systems ⇔ multi-purpose power system ⇔ customers

⇓⇑ ⇓⇑
wind turbines | industrial and
small hydro | mini/micro CHP
PV systems | PV systems
biomass plants | wind turbines
small natural gas field generators

Figure 4.3. *Evolution of rural electricity supply systems.*

With the emergence of embedded generation in distribution grids, the function of the system changes from a passive into an active one. Active in the sense that power flows and system voltages are determined by both generators and loads, and not only by the latter. Figure 4.3 shows the evolution of some rural supply systems. It is noted that future systems could start as a decentralised system and then evolve into a multi-purpose system. The possible connection to a central grid depends on local circumstances and could be implemented at a later stage. Active systems increasingly require innovative solutions and thus a more sophisticated approach, technically, financially and organisationally, compared with traditional distribution systems.

4.4. Trends in power sector performance

The report “Electricity system performance: options and opportunities for developing countries” (EUR 1992) states that social, environmental, economic, technical and financial indicators must be addressed to assess the performance of the electricity supply industry in developing countries, and not only the latter as is usually the case. The same report also emphasises that the technical performance is “the basis upon which all other performance is built”.

“Benchmarking” is a management tool for performance improvements. Leven et al. (2000) argue that this tool is used to quantitatively and qualitatively assess the performance with an excellent performing organisation as reference. However, benchmarking does not necessarily provide adequate data to assess the actual performance of utilities. This activity does not reveal the weaknesses and strengths of an organisation because it is simply a “planned and structured method of learning from outside the company ….. “ (CIGRE 1999). The use of performance indicators makes sense if, for a utility, the figures of one year are compared with those of another year. The absolute value of the figures is of less importance because they strongly depend on local circumstances such as the institutional structure of the sector, tariff and accounting policies and the features of the supply area. When assessing the performance of utilities one should thus not draw generalised conclusions ignoring local circumstances. If performance is assessed against the background of the existing business environment in the developing country, the conclusion could be that the results are not as bad as first thought.

It is well known that there are well-performing utilities in the developing world, even in terms of the electrification of rural areas. Some of these countries, with support from the World Bank and other donors, have been successful in providing a sustainable electricity supply to rural communities[36]. But there are

36 For instance: in Thailand over 80% of the rural communities are served. In Costa Rica the co-operatives and the national electricity utility provide electricity to some 90% of

many other developing countries where efforts to provide electricity to rural areas have only had limited success.

Booth (1991) notes that the experience in countries with government sponsored rural electrification schemes has been very mixed and that results are modest. He argues that one of the major problems is that the programmes are not sustainable once external assistance is stopped. This is mainly due to substandard operation and maintenance of technical facilities, the failure of governments to encourage the private sector, and the lack of strategic plans tailored to each area. He also notes that co-operatives and municipal electric utilities often face difficulties in accessing financial resources.

Mason (1990) suggested, on the basis of an evaluation of a large number of electrification projects, to:

- clarify the definition of rural electrification within each country in order to be able to distinguish rural components of electrification programmes;
- improve data collection for rural electrification projects;
- set more realistic objectives, demand build-up and selection criteria;
- improve estimation of demand forecasts;
- improve technical analysis of projects;
- include all costs and benefits in the economic analysis, especially the LRMC;
- estimate the financial losses over the life of projects;
- identify the economic use of renewable energy resources.

Ranganatan et al.(1992) performed a number of valuable studies on the electrification of rural areas in five African countries[37]. Although the study focused on the impact of rural electrification on development (and the reverse), it also resulted in observations concerning the organisation of rural electricity supply and the problems encountered with certain technologies. These observations largely correspond with the findings from others including those concerning the performance of the enterprises servicing the areas.

Berrie (1992) observed that the majority of the utilities in the developing world face a whole range of problems: weak planning, inefficient operation, inadequate maintenance, high technical and non-technical losses, low supply quality. There are also frequent blackouts, price freezes, changes of management, excessive staffing, low salaries, poor morale and performance, and undue government interference. Meter tampering, poor billing, uneconomically

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the rural population (WB Energy Strategy Note 15 December 1999). In Bangladesh the Rural Electrification Board together with the co-operative (PBSs) are successful in implementing the national rural electrification programme.

37 See case study in this section.

low tariffs and overoptimistic demand and connection rate forecasts add to a substandard utility operating performance.

Lovei and McKechnie (2000) argue that the energy sector "lends itself to corrupt practices". They continue with saying that these practices "differ in scale but contribute to the same results - weak operational and financial performance and, for the poor in particular, declining service quality…..".

Many studies (Maillard 1985, Munasinghe 1990 and others) have revealed that in developing countries the system losses in many networks approach or exceed 20%, and rural electric systems tend to have the highest losses. Generally speaking, transmission and distribution losses should be below 10% of gross generation. Economic loss levels may be as low as 5%. According to the World Development Report 1994 (World Bank, 1994), on average, 40% of the power-generating capacity in developing countries was unavailable for production, twice the rate of that in the best-performing power sectors in low-, middle-, and high- income countries. Average real tariffs in the electricity supply industry in developing countries have declined to 1/3 of the real costs of supply (World Bank, 1996).

Case 4.2: Rural electrification in Africa

In (Ranganatan 1992), Mwebe, Mariam, Ramasedi, Khalema and Ahmed presented the results of a number of (ex-post and ex-ante) studies on the electrification of rural areas in five different African countries.

One of the central questions of the studies was related to the impact of electrification on development, and the reverse. To help answer this question each country study included a survey of three different areas of which two were electrified and one non-electrified.

From these studies and the policy recommendations, the following can be summarised.

- Electricity supply to rural areas improves the quality of life through better lighting, heating and cooking. As a result, the circumstances for the education of children are improved and also the possibilities for women to generate income. It is however noted that the degree of improvement heavily depends on the socio-economic circumstances in the areas. It appeared from one study that the use of electricity for cooking was limited to the wealthier areas (electrification rate 80%) and concerned only 4% of the households.
- The policies with regard to the electrification of rural areas were different in the five countries. In one country electricity rates were twice the actual costs and for supply by isolated diesel power stations twice as high as for grid connections. Although this situation would financially enable the utility to extend the supply of electricity to the more remote areas, electrification was

limited to the areas near existing load centres. For the more remote areas, the country sought to arrange funding by donors and lending organisations. In the other countries, grid extension would lead to large deficits if financing could be achieved at all. The long distances involved would cause the transmission costs per kWh to be extremely high given the rather low consumption (for one area a 1990 figure of US$ 8.73 per kWh was mentioned). In one of the countries there was a surplus capacity of hydro-electricity but this was beyond the reach of the remote areas. It was suggested in the study that small-scale hydro-electric power stations would be a solution or, if there is no such potential, one could extend the grid incrementally and resort to intensive electrification. It was argued that the most appropriate solution for rural electrification is grid extension provided that the distance to an existing grid is less some 30 kilometres, with mini-hydro based power systems as a second choice.

- Although the study did not address the issue of the impact of foreign assistance, Ranganathan stated: “ it can be broadly observed that the greater the foreign dependence, the greater the role of diesel power and the greater the neglect of domestic energy potential in general and hydro potential in particular. Also, it can be generalised that hydro development has fostered self-reliance in technology ...., whereas diesel power has enhanced foreign dependence not only for the diesel and spares but even for operation of the plants. In other words, foreign financial assistance has failed to promote technology transfer”.
- In one of the studies, diesel-based electricity supply appeared to lead to losses for the utility in spite of higher tariffs, whereas mini hydro and grid-based systems were both financially and economically viable provided that, for the latter, the main grid was nearby. One factor which could have influenced this outcome is that, in this particular case, less than 20% of the total installed diesel capacity was available. Maximum demand in the areas surveyed was between some tens and hundreds of kW. Ranganatha concluded that small isolated diesel-based systems need an appropriate organisational approach as the experience would seem to indicate that the utility is insensitive to local needs and has considerable overhead costs. In this respect, two models were mentioned: municipalities or co-operatives could be made responsible for the electricity supply, or a local industry could be asked to sell its surplus power to the surrounding area. For the latter model he also suggested having the tariff decided through discussion between the supplier and the user. In some cases rural electrification is considered to complement the other activities of a utility. Mwebe suggests as a practical approach, a separate rural electrification agency which could be a self-supporting division of the utility.
- If a utility is required to electrify rural areas without any government subsidy, the result can be long waiting lists and a very limited number of operating hours and capacity of the rural systems. Another result can be that

electricity is only available for lighting purposes and that the use of electricity for productive applications is not possible.

- In many African countries, rural electrification is not financially viable on the basis of the current tariff structure and level, and the high costs associated with the realisation of the supply systems. As no specific long term financing methods exist, users are often required to pay high connection costs and contributions towards the required power system extension. This tends to result in a rather limited degree of electrification with the associated low load factor and disappointing revenues.
- A number of cases where electricity supply supported agro-processing activities, appeared to be economically viable. In spite of this finding, and given that the application of electricity in other rural industries is less obvious, it is argued that, in general, the opportunities for the productive use of electricity in rural areas in, at least, these African countries seem to be very limited. Thus it is concluded that in many African countries, it is mainly the social and educational aspects that underlie the electrification of rural areas: electricity for lighting, health care and water supply improvements. Electricity will only support rural development where other favourable circumstances exist. It is argued that the electrification of rural areas should be part of rural development programmes. Also, in most of the countries, there is sufficient scope for reducing costs of rural electrification schemes. The local population should be involved, domestic resources more extensively used and the transfer of relevant technological expertise improved. Better transport facilities to markets, adequate communication and credit facilities, and other relevant improvements could lead to a faster growth in electricity consumption and thus to economically more viable investments in the electricity infrastructure.
- Social and political pressures can have a significant influence on rural electrification plans. The impacts can vary from the allocation of government funding to certain areas, to a request to the utility for rural electrification schemes. It should however be noted that in many countries political power is mainly concentrated in urban centres.

Already in 1990, Teplitz-Sembitzky (World Bank 1990) had concluded “a great deal of performance failures suffered by the power sector in developing countries seem to result from over-regulation. On second thoughts, however, poor performance can more plausibly be ascribed to unfettered political interference and the lack of efficient regulatory systems rather than to market failures. What calls for regulatory reforms are institutional shortcomings”.

This is supported by the results of the Electric Power Utility Efficiency Improvement Study (EPUES 1991)[38]. This comprehensive study revealed that many electricity utilities in developing countries supplying rural areas using diesel-based installations, had little chance of success. One of the findings of the study was that, in general, it was not the technical installations but rather such factors as management and institutional dimensions, that caused the substandard performance of these enterprises. In this respect Dutkiewicz (1991) notes that "a strong central government interventionist attitude in a number of developing countries has led to utilities frequently characterised by insufficient autonomy, poor accountability, and a lack of market orientation".

A key report (World Bank 1994) supports these observations (table 4.5) and notes "excessive government interference in organisational and operational matters has been a major problem in many parts of the developing world. This has adversely affected least-cost procurement and investment decisions, hampered attempts to raise prices to efficient level and promoted excessive staffing and inadequate management".

Bacon (1995) concludes: "the poor performance of many state companies in developing countries is more likely to be attributable to the nature of the ownership rather than their structure".

Table 4.5. *Common management problems in public electric utilities in developing countries (World Bank 1994).*

Management problems (based on a survey of 40 countries; percentage of loans.)

Number of loans	Unclear goals	Lack of management autonomy and accountability	Financial problems	Wages and labour problems
48	27,1	33,3	72,9	31,3

Source: World Bank database (ALCID).

In many developing countries, the potential for supply side improvements is substantial and current measures include an increased involvement of the private sector and the building of relevant institutions and human capacity. Previously investments were basically directed at capacity increase in the infrastructure, but there is now an increasing awareness of the cost effectiveness of demand side management and decentralised renewable power systems. Although in developing and newly industrialised countries, supply side efficiency (in terms

38 See case "Major problems in diesel-based power supply systems" in this section.

of technical losses and theft) is an important issue**,** recent experience by the World Bank (World Bank 1998) have revealed that many loss reduction programmes did not result in the projected loss reduction. These poor results are partly attributed to a lack of commitment by the players and due to over optimistic targets.

Case 4.3: Major problems in diesel-based power supply systems

In many developing countries, governments are committed to electrifying rural and remote areas despite this being usually uneconomic. The distance of communities from the existing grid and the limited demand for electricity often results in rural electrification through grid connection being uneconomic. Under these circumstances, isolated diesel generation with local distribution grids have often been considered as the next best solution.

In recent decades, many diesel-based rural electrification projects have been completed and in a substantial number of cases their performance has given rise to concerns. Despite foreign assistance many publicly owned power utilities have continued to perform both technically and financially far below acceptable standards.

The objective of the Electric Power Utility Efficiency Improvement Study (EPUES) was to identify common causes of poor performance and to prepare recommendations for future projects. Under this multi-donor study, which was conducted by the World Bank, the performance of a large number of diesel power plants in seventeen developing countries has been analysed. Twenty-five locations were visited and data from nearly 200 others analysed. The installed capacity of the diesel power stations varied between 640 kW and 72 MW with a typical value of 16 MW.

The study addressed both quantitative and qualitative factors. Initial capital utilisation, depreciation, labour, fuel and lube oil consumption and costs, and maintenance expenditure were used to calculate diesel plant operation costs per MWh of net power plant production.

The assessment of human related factors such as management, training and, consumers' attitudes, relied on the judgement of the assessment team using anecdotal information.

Diesel power plants are generally smaller than other thermal power stations and less complex from both the technical and managerial point of view. Moreover the technology and operating procedures of diesel plants are widely known so that the interpretation of performance figures is relatively straightforward. Although diesel power stations were the subject of study, the recommendations are, in general, considered applicable to many other power systems in the developing world.

Problems and common causes

Substandard production, low revenues, high costs and short diesel engine lifetimes ranked among the major problems. In some countries, power plants required rehabilitation after only a few years. Many unscheduled outages occurred and voltage fluctuations were common. Local pollution was caused by waste oil and contaminated cooling water spillage/dumping.

Only a few plants were financially viable. Electricity tariffs were generally too low and revenue collection poor. Even the operating costs of generation could not be covered by revenues (fuel costs were typically 70% of these operating costs).

The number of labour hours per unit of production was typically 10 to 15 hours per MWh (in the US and UK this would be 0.5 to 4 hours per MWh. The number of unskilled workers was high.

Typical plant production costs including capital costs were USct 14.7: 49.7% fuel costs, 3.7% lube oil, labour 6.3%, materials 5.4% and capital costs 35%.

Very few problems with the technology were encountered and therefore the emphasis was placed on functions and policies controlled by the government and utility staff. The study revealed that the major causes of substandard decentralised utility performance in many developing countries were: "poor governance and inadequate institutional and management structures and arrangements, usually combined with inadequate revenue flows and lack of timely access to foreign exchange".

It is therefore not surprising that, since then, the emphasis with technical assistance is placed on institutional and sector policy reform.

Recommendations

The recommendations derived from the EPUES study address the following issues:

- Power sector development: power sector planning and policy should be straightforward and the objectives clear; projects should not be undertaken unless costs are covered by budgets.
- Government-utility interactions: objectives and the target rate of return of the utility should be clear and consistent; there should be no interference by the government in utility operations; and adequate tariffs should be established.
- Utility management: managerial autonomy and accountability should be adequate; corporate objectives should be clear and corporate planning should include technical, financial and human resource planning; budget and management information systems must be in place; human resource development and training programmes are essential;
- Utility organisation: operating units such as isolated diesel plants should be reasonably autonomous in daily operation and have their own budgets; the

organisation structure and communication channels should be clear and appropriate, and adequate human resources available.

- Financing agencies' policies and procedures: where the relevant initial emphasis should be on remedial actions and technical/managerial assistance; power sector projects should be appraised realistically; policies of financing agencies should be appropriate; standardisation of equipment is important; donor co-ordination necessary.

Sources: "Core report of the electric power utility efficiency improvement study", World Bank IEN Energy series paper 46, September 1991(EPUES 1991) and "Improving electric power utility efficiency", World Bank technical paper 243, May 1994 (EPUES 1994).

The existence of many of the problems listed in this section has been confirmed by many investigations and has led to the reluctance of development banks and donor agencies to continue support to the power sector after some remedial actions were not very successful. This situation provides strong incentives for doing things differently.

Governments and utilities in the developing world now face the challenge of coping with institutional reform of the power sector and the increasing demand for electricity, improving technical and managerial performance, and striving towards cost effectiveness and long term marginal costing.

Essentially, prices should reflect the true costs of the power and give adequate signals to the consumers to encourage efficient energy use and demand side management. A tariff system based on the long run marginal costs enables the power company to generate the financial resources required for an efficient operation and extension of the power system.

Such tariff reforms are extremely difficult, and governments have to find solutions for the social and other consequences in ways that do not conflict with commercial operations of the utility. In this respect it is noted that the removal of general subsidies on electricity tariffs would release government funds that could be used to relieve the distress of targeted groups. If the political environment is stable and an acceptable return on investments can be realised through appropriate tariffs, there is reason to believe that developing countries can obtain sufficient private capital for large-scale power generation projects.

4.5. Societal trends

As seen in Chapter 3 most rural electrification schemes needed and received investment support and cross-subsidies. National and/or regional solidarity is thus often at the basis of rural electricity supply.

The transition to a more capitalist society bears the risk that the economic rationalism will lead to an ever decreasing solidarity. While we know that both classical capitalism and centrally planned economies have met with obstacles, Gorter (1995) perceived a certain disorientation in the reasoning about the desired economic order: an ideological vacuum in the economic theory seems to exist. Regardless, the general trend is that governments are withdrawing from public services and selling utilities to the highest bidder. This implies a shift of the centre of power in the direction of large companies whose priorities and control differ from those of the government. This could have repercussions for rural energy supply.

The siting and design of power stations and transmission lines is not just a technical-economic problem. Social, aesthetical and environmental factors play an increasingly important role in the decision making and design process. There have already been occasions where utilities considered the considerably higher costs of underground cables justified in view of public opinion against overhead lines which can lead to delay in obtaining permission. In the United States of America, the renewal of concessions for some large hydropower stations is subject to discussion.

The willingness of rural communities to accept transmission lines through their living areas will increasingly depend on the benefits for their own areas. These could include electrification of their areas and this could involve novel power supply concepts[39]. The growing influence of other than technical and economic factors is illustrated by these examples and there is sufficient evidence that this influence usually results in a more expensive electricity infrastructure.

4.6. Institutional developments

For nearly one hundred years most electricity has been generated in large central power stations to take advantage of economies of scale. In most countries vertically integrated utilities have dominated the scene. This system enabled the industrialised world, and some developing countries, to satisfy electricity demand and to achieve nearly full area coverage with an excellent supply reliability at an affordable price.

Despite this excellent achievement, recent institutional developments include a reform of the electricity sector. Kaijser and Hedin (1995) argue that the legal and institutional changes in the power sector have been introduced in order “to increase the system’s overall operating efficiency”. An important question is: were the utilities all over the world so inefficient that reform of the sector was needed? The answer is no, but there are a few other aspects.

39 See Section 4.3.1.

Lönnroth (1989) argues that "the attack on the societal organisation of the electric utility industry is partly driven by technological changes and partly by the notion that regulation and efficiency are incompatible". Patterson (2000) is probably right in arguing "the remarkable success of the traditional centralised electricity system confirmed and reinforced the underlying tacit view of electricity as a commodity. This in turn enabled free-market theorists to launch the process of liberalisation of electricity".

In most industrialised countries demand growth is reducing from some 7% to 2% or even lower, and such a reduced growth will have an impact on the organisation of the utilities. The existence in some countries of rigid regulations preventing or hampering independent power producers (including combined heat and power units and wind-turbines) in selling excess electricity to the grid, has been criticised. In other countries the impact of political interference on efficient utility operations was unjustified.
There is also reason to believe that traditional electricity utilities, for a number of reasons, have been rather conservative. A striking demonstration of this, at least in some countries, is the conservative attitude towards new entrants such as independent power producers, both small and large. Lönnroth continues by noting that the expression "dynamic conservatism" is sometimes used to describe how organisations, or rather people within organisations, respond to new technologies and that there is considerable literature on this subject. Some argue that a "disruptive" measure is needed to change the conservative attitude of the power sector. The separation of large-scale electricity generation from distribution has indeed had an enormous effect and the trend in most countries is towards this option. The current availability of natural gas fired small-scale power generation technologies supports this change.

A salient feature of the changes in the power sector is the introduction of market forces. In general, market forces can be effective in improving the performance of certain sectors but it is unclear to what extent these forces are able to do this in the electricity sector (EUR 1992).
Market forces alone cannot guarantee a stable and efficient situation in the long run. After some time, certain groups will achieve sufficient power to control part of the market and thus disturb competition (NEI 1996).
Some form of regulation is essential but it is also noted that regulation can be misused to achieve advantages for specific groups. Regulation is also needed to protect the environment. As long as externalities, including environmental impacts, are not fully internalised within the product or service delivered by the power sector, the effects of market forces should be critically judged.
However there is also reason to believe that reform of the utility sector is not the answer to all of society's questions. Do the reforms and the associated institutional changes really contribute, directly or indirectly, to the most pressing problems such as environmental pollution, poverty, and the prosperity of the

global village at large and rural areas in particular? To address this question, the reform of the electricity sector in specific countries will be reviewed.

4.6.1. Background to power sector reform

United Kingdom

In 1927, the government owned Central Electricity Board (CEB) was established in the United Kingdom, an organisation responsible for the planning, construction and operation of power stations and the national transmission grids. Until 1946, the electricity supply industry was a mix of some 600 private and public enterprises with rather varying performances. Roughly one-third of these enterprises were privately owned (Flavin 1994).

In 1946 the power system was nationalised and the state owned generation and transmission company the Central Electricity Generating Board (CEGB) established, together with twelve regional distribution companies. Following this nationalisation a number of technical efficiency improvements could be achieved, but it also appeared that the limited guidelines gave scope for sub-standard performance (EUR 1992). Over the years, a number of mechanisms were introduced to improve both performance and government control. Generally speaking, the performance of the British electricity supply industry since nationalisation has been considered satisfactory, apart from investment appraisal and government pressures on such issues as procurement of both equipment and fuels, and power plant capacity (EUR 1992).

In 1989, the Thatcher government of the United Kingdom started a process leading to a liberal, competitive and privatised power market. Littlechild (1999) argues that the reasons why the United Kingdom decided to privatise electricity supply included:

- a desire for a reduction of the role of the government in industry;
- the pursuit of a more demand driven electricity supply;
- an increase of the efficiency of the electricity supply industry;
- floatation of power supply companies involved revenues for the government.

Patterson (2000) argues that "in the United Kingdom the policy of privatisation was prompted in part by an ideological hostility to government involvement in economic activities, and the conviction that free markets were always preferable to government intervention in business. Selling off government assets was also, of course, a convenient way to raise large sums for government coffers". But the power sector reform in this country was also a response to the problems in the British coal industry. In the United Kingdom, and also in Germany, the power sector had been forced by the government to use expensive domestic coal.

As part of the privatisation of the Central Electricity Generating Board, the sector was completely re-structured and competition introduced in both the

production and the distribution of electricity. The introduction of competition was partly prompted by the negative experience with the privatisation (without competition) of British Gas regarding customer orientation.
The re-structuring included an unbundling of transmission and generation, and the establishment of a number of competing power generation companies. The 12 distribution companies were maintained and an independent grid operator and consumers' committees were established along with a power pool and a regulator (OFFER). Price controls on transmission and distribution activities were introduced and minimum quality of supply standards and incentives to increase efficiency developed. The promotion of renewables was secured by a non-fossil-fuel-obligation (NFFO) requiring power suppliers to purchase a certain percentage of their electricity from renewable sources. Several alterations to the initial reforms were necessary and changes in the regulatory regime were made to offer more scope to non-utility generators.
In 1998 the United Kingdom government declared a moratorium on further gas-fired power stations. The market mechanism had promoted the construction of these cheap and efficient plants causing existing plants to close.
Although the privatisation of the British power sector was not primarily a response to poor performance, it was believed that, with the introduction of competition, the efficiency would be improved. Littlechild[40] is of the opinion (ESMAP 2000) that "the principles of private ownership, competitive markets and independent regulation have worked well, and the British electricity industry is now more efficient and innovative. All groups of customers have benefited significantly in terms of lower prices and better quality of service". It is beyond the scope of this work to prove whether this statement is justified and whether the results could also have been achieved with a state owned utility.

United States of America

In the United States of America, the reform process was mainly triggered by the financial losses made by some utilities as a result of a substantial excess generating capacity, cancelled coal and nuclear power stations and large cost overruns (World Bank 1990a). The federal law has been changed to introduce more competition into the electricity supply sector. This has prompted some municipalities to create their own electricity utilities and to bypass the local or regional utility (Bush 1996). Large electricity bills, particularly as a result of the use of air conditioning, induced consumers in Palm Springs to stand up to the existing utility. Local rates (in summer residential customers are charged 12.4 to 14.6 UScts reflecting the high costs of meeting the stringent environmental regulations in California) are some of the highest in the country. The utility did not believe that the establishment of another electricity distribution company would be a good solution for Palm Springs and they focussed on issues such as

40 Former UK Electricity Sector Regulator.

energy conservation and demand side management. It is noted that the structure of the electricity supply sector in the United States has always been different from that in Europe. As is elaborated in Section 3.3 the sector is very diverse and investor-owned, co-operatives and semi-autonomous government-owned utilities exist. The role of regulators has always been very important.

Power sector liberalisation in the European Union

To establish a single competitive electricity market within the Union, the European Union (EU) decided to liberalise the electricity sector and to require member countries to gradually open up their electricity markets to competition. Kindermann (1993) states that the background of the European Commission's proposal to reform the power sector in the members states was:

- There was no cost transparency.
- There were obstructions to new entrants in the market.
- There was no competition between vertically integrated utilities.
- The discrimination of captive consumers by monopolistic producers.
- The absence of a level playing field.

To enable competition in generation, independent transmission operation and third party access to the networks, more transparency in the financial structure, and prevention of internal cross-subsidisation to avoid unfair competition were all required. The way in which this liberalisation is implemented is largely left to the member states which, in turn, gives rise to politically different solutions.

Case 4.4: Deregulation and combined heat and power generation

In the Netherlands, the electricity sector is not privatised but utilities operate as limited liability companies at an arm's length from the provinces and municipalities who are the shareholders. Over ten years ago, new electricity legislation was adopted in the country that created a separation between large-scale electricity generation and the electricity distribution sector.

The distribution sector was allowed to build and operate combined heat and power units up to 25 MW and thus a form of competition between the generation and distribution sectors developed.

The implementation of a National Environmental Policy Plan, and the corresponding energy conservation action plans for the energy sector, led to a significant growth in decentralised combined heat and power schemes.

Interest in these CHP schemes was boosted by subsidies, the availability of natural gas throughout the country, the increased fuel-efficiency, and also by their potential peak lopping capabilities.

Initially, the generators charged the distribution companies on the basis of a pricing structure that included the quantity of electricity supplied and the actual

value of the peak-load in four defined periods during the year. The peak-lopping capabilities of CHP schemes enabled the distribution companies to influence peak-load and thus their corresponding charges.
Since 1987 some 5000MWe of new industrial and commercial sector CHP schemes have been developed by the distribution companies, some of them in collaboration with industries and other organisations. This amounts to one third of the current total installed generating capacity in the Netherlands. To avoid a further increase in excess central generating capacity, it was necessary to agree on a moratorium on combined heat and power units with a capacity above 2 MW.
This case shows that in the energy supply sector not only is a national capacity planning required but also sufficient regulation is needed to avoid unnecessary investment and corresponding demands on the capital market. Market forces alone appear to provide insufficient self-regulation in this respect.
The experience in the Netherlands shows the enormous potential of combined heat and power schemes in the industrial and commercial sectors. To unlock this potential for the sake of energy efficiency and public electricity supply, the institutional conditions have to be suitable. Relevant regulations should exist and an appropriate utility organisation and culture which is willing to expand this market in collaboration with the private sector needs to be in place.

Italy

In Italy, the electricity industry was nationalised in 1962 resulting in ENEL, a monopoly for generation, transmission and distribution of electricity. Other players included municipal utilities and industries who had their own generation plant. Following the directives of the European Commission, ENEL recently has had to reduce its generation market share to enable competition and internally unbundle its transmission and distribution assets from the remaining generation ones. These activities have resulted in five separate enterprises covering generation, transmission, distribution, sales on the open market, and disassembly of nuclear plants.

The Netherlands

The organisation of the electricity sector in the Netherlands has been the subject of many discussions since the mid sixties (EZH 1996). These discussions addressed the organisation of the sector rather than the performance which was generally considered satisfactory. Tariffs were acceptable and the service reliability was, with an average annual “down-time” per connection of some 30 minutes, excellent. In accordance with the national custom, various committees studied the subject and prepared reports and even bills. A new electricity act was constituted in 1989 forcing the utility sector in the Netherlands to unbundle large-scale production from transmission and distribution and also to concentrate distribution activities. This act stipulated a minimum number of connections per distribution company albeit that there are no indications that smaller companies are less efficient than the bigger ones (Huygen 1999). One of the ideas behind the separation between production and “the grid” was that it would stimulate the use of electricity produced by small (<25 MW) independent power producers such as industrial combined heat and power units. It appears from the case study included in this section, that the outcome of this measure was a substantial growth in both combined heat and power schemes and excess central generating capacity. Huygen is right in arguing that the 1989 electricity act did not result in a stable environment.

These developments triggered more discussion on the organisation of the sector and, in 1999, a new electricity act was passed based on earlier discussions and on the neo-liberal directives from the European Commission. This new act is intended to improve efficiency of the sector and turn the sector from a perceived supply-driven industry into a demand-driven industry. Following the implementation of this act, the following changes will occur in the Dutch electricity sector:

- Electricity generation will be completely liberalised.
- A gradual transition to an electricity market where all consumers can freely choose their electricity supplier.
- The government will temporarily determine the tariffs for the consumers who cannot yet freely choose their supplier. This implies that for the time being the rates for small consumers are the subject of political forces (see also Section 4.7, footnote 14).
- Introduction of third party access to the power grid on a regulated basis with rules set by the government.
- A separation between the distribution system (“the grid”) and the sale of electricity by independent companies.

In the Netherlands, the provincial and municipality governments have always been the shareholders of the utilities and there is no evidence that the electricity supply sector in the Netherlands has misused its monopoly position. Politicians are entirely accountable for the withdrawal by municipalities and provinces of financial resources from Dutch utilities (Bakker 1997).

Norway and Sweden

Unlike the United Kingdom, Norway and Sweden did not privatise but only liberalise the power sector. Midttun (1995) described in his essay “(Mis) understanding change” the liberalisation of the electricity sector in Norway and Sweden. He argues “for both countries the reform implied a dramatic departure from previous regulatory regimes with serious consequences for vested interests within the electricity industry and its largely political owners, for industry, and for households”. In spite of the revolutionary changes induced by the new law, only limited opposition was experienced on the political level. Midttun argues that the reforms in both Norway and Sweden are clearly part of a broad political and professional re-orientation. However, in Sweden the basis was more ideological and part of “a more explicit liberalist policy”.

In both countries, the reform was mainly driven by the state administration, and in Norway it was partly triggered by dissatisfaction with the investment and pricing policy of the existing electricity sector. At the time, the electricity sector in Norway consisted of over 300 electricity companies with policies based on local conditions, both political and other. Earlier attempts to centralise the sector were not successful. To achieve sufficient support from local organisations involved in regional utilities, and to avoid controversy between rural and central actors, the vertically integrated regional utilities were left intact and only a separation of accounts for monopolistic and competitive functions was required.

In Sweden the development of more politically independent state electricity utilities was one element of the reform, but realisation of third party access to the national transmission grid was another important issue. Studies have revealed that a separation between the potentially competitive generation, and the monopolistic transmission function, was a prerequisite for competition.

Midttun also noted that the pressure from economists to embark on a market-based approach was a conducive factor. Despite the parliaments of both countries being somewhat sceptic about liberalisation, the reforms were accepted partly because of a lack of suitable alternatives and the expectations that stakeholders had about the benefits. Kaijser and Hedin (1995) concluded, on the basis of Midttun’s research, that at least in Norway, the actual outcome of the liberalisation has been disappointing to a number of stakeholders. They argue that “the reforms were, in a sense, ‘misunderstood’ by actors in the electricity market”. They probably allude to the stimulation of economic growth, industrial electricity pricing, and greater centralisation.

Discussion

It appears from this section that the backgrounds of deregulation efforts in the power sector are different for various countries and the same applies for the institutional modelling. In some countries reform, and the associated de-regulation, is a response to dissatisfaction with a sub-optimal performance of the utilities, in others the need to attract private capital for investments, and for some belief that only true market forces, and thus the introduction of competition, will lead to an efficient power sector.

Patterson (1999) states that one common strand emerges from the developments in all the countries involved: “government rhetoric always insists that liberalisation .... will make electricity easier to use – cheaper, more accessible, more reliable. Whether these statements are confirmed in practice is to be seen. Another common thread is that governments in industrialised countries started all these initiatives and – given the limited time horizon of politicians – it must be feared that they did not look very far ahead”.

Patterson's fear seems justified. In May 2000 the WRR[41] in the Netherlands issued the report "De borging van publiek belang (Ensuring public interest)". In this document the privatisation of Dutch public entities over the last decade was assessed and recommendations made. On the basis of the perceived results for the public, the Council identified a number of ill-considered and unrehearsed privatisation actions and recommended addressing the public interests well in advance of any privatisation decisions. Public interest and the responsibility the government wants to retain should be at the centre during all discussions about the institutional form of public services such as the railways, the utilities and health service. The report concludes that the belief of the government in market forces appears to be very strong and public interest has sometimes been ignored. The authors warned that privatisation should not become an ideology and that the notion that "the market" is always more efficient should not become a dogma.

Advocates of power sector reform claim that private ownership and competitive markets work well and strongly support improvements in the efficiency and innovative capability of the sector.

Some opponents argue that most of the achievements attributed to power sector reform, could have been realised with government-owned companies, if these were allowed to operate at more than an arm's length from the politicians. Burns and Weyman-Jones (1994)[42] concluded that, in the case of the near monopolistic distribution companies in England and Wales, no increase occurred in the rate of productivity in the period after privatisation relative to that before privatisation. The same tendency has been found by Galal (1994) in Chili.

The ongoing debates on the appropriate structure for the power sector, and the electricity supply industry in particular, are driven by various assumptions including those of an ideological nature. Sometimes it seems that reform is an objective in itself instead of being a vehicle for performance improvements.

According to Hunt (1996) four institutional models can be distinguished:

- monopoly (generation, transmission and distribution regulated);
- purchasing agency (in which the transmission grid obtains electricity from independent power producers, through an agency that purchases power);
- wholesale competition (individual distribution companies purchase from electricity utilities and competing independent power producers with power delivered through the transmission grid);
- retail competition (customers purchase from electric utilities, independent power producers, companies with power delivered through transmission and distributions systems).

41 Wetenschappelijke Raad voor het Regeringsbeleid (Scientific Advisory Council of Government Policy).

42 Cited in Bacon 1995.

The purchasing agent model could be appropriate for countries with substantial growth. The wholesale competition model is used in the United States of America although some utilities are moving toward the retail model, and the retail model is used in the United Kingdom.
Based on information from Bacon (1999) and Albouy (1999) Box 4.1 lists the various steps that lead to a fully privatised and restructured electricity sector. It is emphasised that power sector reform can take many forms, from a corporatisation of government-owned utilities to a completely privatised sector.

Box 4.1: Power sector reform steps

1. Corporatisation and commercialisation of government owned utility
2. Introduction of legislation permitting power sector restructuring/ privatisation
3. Establishment of power sector regulation
4. Unbundling of generation, transmission, distribution and supply
5. Concessions for private investments allowed
6. Privatisation of existing assets

Source: Bacon (1999) and Albouy (1999)

Vertically integrated utilities have been successful because of “economies of scope” and “economies of scale”, the latter particularly with regard to top management and support staff (Bacon 1995). The model of reform applied in most cases is one where generation is separated from transmission and distribution (vertical separation) and the latter two are sometimes separated as well. In this case all the new entities are corporatised and commercialised, competition is allowed in generation, and service delivery and the monopolistic grid regulated. This model may be appropriate for large and mature power systems, but it is doubtful whether this applies for immature and small systems such as in developing countries. Bacon (1995) argues that for these smaller systems “the balance of advantages and disadvantages may be quite different from those in larger economies” and that unbundling of small systems would “fragment the industry into a series of very small individual units and would risk losing economies of scale and increasing the overhead costs associated with establishing separate companies”. The vertical separation could also result in the loss of “economies of co-ordination” and stronger regulation would be needed to avoid high prices. Vertical separation has the additional drawback of the costs of contracts needed between the separated entities.
Bacon is right in saying that “the need to separate transmission from generation is strongly linked to the desire to obtain competition between generators”. In the

case of a single generating company (as with small systems) it seems more efficient not to separate generation and transmission.
An argument used in favour of vertical disintegration is the better transparency obtained, particularly with regard to costs. However, this transparency could also be achieved with an appropriate budget and accounting system.
As can be seen from Table 4.6 the restructuring of the power sector fragments the original vertically integrated utilities and makes them weaker. In both situations regulation is needed but whether the grip of the government on the sector is stronger or weaker depends on how the regulator was set up. In either case the regulator can hold a key position and be politically influenced.

Vertically integrated power sector

Utility 1	Utility n
Generation	Generation
+	+
Transmission	Transmission
+	+
Distribution incl. sales	Distribution incl. sales

'Ideal" reformed power sector

Generator company 1 Generator company 2 Generator company n
One or more transmission companies ("the wires")
Distribution companies ("the wires")
Electricity sales companies ("the service")

Table 4.6. *Vertically integrated and reformed power sector.*

4.6.2. Emergence of energy service companies and multi-utilities

In the power sector of the United States of America the fastest growing markets are electricity and gas trading and the delivery of energy services (Weinberger 1996). Energy Service Companies (ESCO's) cover the latter market and at least 40 power companies own or participate in an ESCO. Weinberger argues that the aim is not to convert a power company into an ESCO but to create new markets. The ESCOs are generally independent entities under a holding company. The drawback of delivering energy management services through a department of a utility is that the focus would probably be on the utility's supply area and not on exploring markets beyond its "borders".

Since energy management could lead to a reduction in the turnover of other departments, there is also an inherent conflict of interests.
ESCOs identify and realise power cost reduction opportunities for clients, particularly department stores, universities, large schools, offices and supermarkets. Weinberger mentions as critical success-factors: technical expertise, customer focus, good reputation and position in the market, and entrepreneurship. For the implementation an effective scheme, financial engineering and project-management is needed, together with access to working capital.

In many developing countries, the improvement of end-use efficiency is still in its infancy despite of its large potential. The results of a limited number of projects have been mixed and the barriers have included disinterested consumers, financing problems and a low commitment by local players (World Bank 1998). To overcome some of the barriers, the establishment of ESCOs has been proposed in some developing and newly industrialised countries in recent years. The main problems for these companies, and the same applies for utility based DSM departments, concern a lack of human and financial resources.
It is noted that commercial energy efficiency services such as ESCOs might also concentrate on industrial and large commercial customers rather than on households since both the expected savings and the business opportunities tend to be larger. Because of a low ability to pay by the local communities and small enterprises, there is no reason to expect a market for ESCOs in the rural areas of developing countries.

The restructuring of the power sector in the industrialised world has led to an increased interest in multi-utilities. The establishment of these utilities is boosted by the break-up of the electricity value chain into large scale generation, wholesale marketing and trading, transmission and distribution (“the grid”), and retail marketing/services. Electricity services can be bundled with products and added value services that meet customer needs with the aim of building customer loyalty.
Multi-utility companies deliver end users a range of services including electricity, gas, heat, water and even waste disposal, home and business security systems, telecommunication and/or cable TV systems. Research in the United States of America (PEI 2000) revealed that many electricity customers are likely to purchase additional services from the utility: 45% would prefer TV service, 42% telecommunication service, and 39% home appliances service.
In the Netherlands some of the electricity distribution companies acquired, as part of the process to establish a multi-utility, water supply companies. In 1999, this process was frustrated by the recently formulated political belief that water, apparently unlike energy, is socially so important that it should not be left to

market forces[43]. Hoffer (1995) argues that “privatised water supply is possible under strict control of standards….without significant danger for public health”. The main advantages of the multiple utility services approach are claimed to be better customer service, economies of scale, improved and cheaper marketing. Combined meter readings with an associated lower cost is possible, and the overhead costs such as for customer information and billing systems are lower.
Multi-utilities can proactively offer customised solutions provided that the organisation and corporate culture is aligned with client care. This would suggest that the multi-utility approach is a favourable option given the decentralisation of facilities that is currently taking place.

4.7. Comments and conclusions

Evolution in decision making

As a result of recent developments the electricity supply sector in many industrialised and developing countries faces unprecedented changes which affect both the sector itself and its customers.
Current developments often refer to environmental, technological, societal and institutional issues and there is a growing consensus that the notion of “sustainability” should be at the centre of all our activities. One of the most important developments is the way in which decisions are supposed to be made. In the field of power supply projects, four main criteria for decision making can be identified:

- the need: what is necessary;
- the environment: what is acceptable;
- the economy: what is affordable;
- the technology: what is feasible.

In this respect “environment” covers the ecological, the societal and the human aspects. Although the criteria for decision making has remained the same, the order of priority of these criteria has changed over the last decade as is illustrated in Figure 4.4.
This evolution in decision making is largely induced by growing environmental concerns and also by the negative implications of some power projects on the local population and the associated inadequate compensation. In the past the

43 Some politicians argued that the provision of adequate safe water is so important to society that its supply, unlike electricity and gas, should remain in public hands. This viewpoint seems to underestimate society’s dependence on energy. Current dependence is such that long electricity and/or gas outages cause enormous problems including the risk that people freeze to death, the disruption of health and transportation services and robbery. In terms of institutional aspects, there is thus no reason to distinguish between energy and water.

technological possibilities dominated, immediately followed by the economic aspects of power projects. This was because electricity demand grew so fast that advanced technical solutions had to be developed. Concerns about the ecological effects of energy production and use have promoted the relatively recent development of advanced wind turbines, combined heat and power and combined cycle units, photovoltaic systems, energy efficient appliances and other sophisticated equipment.

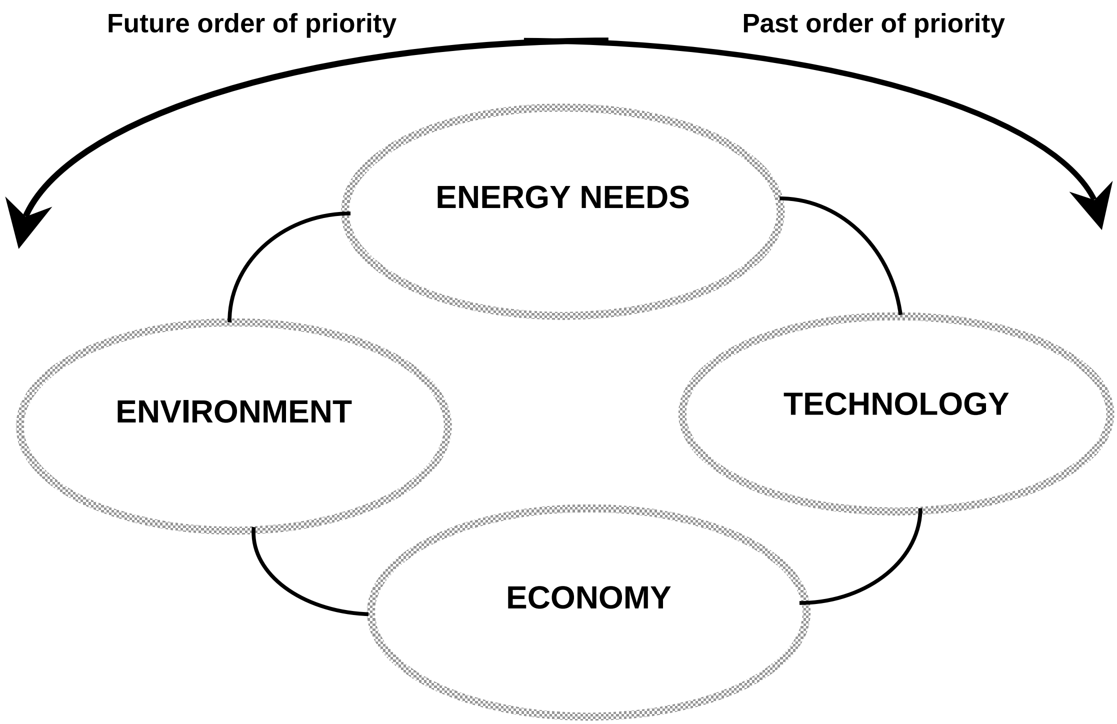

Figure 4.4. *Decision making criteria and shift in emphasis.*

Power sector reform

History shows that, in most countries, electrification has been seen as a national effort to create an appropriate and stable environment for technical development, economic growth and the improvement of living standards. The generation and supply of electricity have always been considered so important that they should not be left entirely to market forces. This is the main reason why national, provincial and even municipal governments often took responsibility for the delivery of this public service and to that end established power supply utilities as part of their organisations. As a result, nationalised, or semi-government, organisations with a monopolistic nature have emerged in many countries over the years. In some countries monopolistic investor-owned utilities emerged alongside government regulations.

State-owned utilities can operate at high standards of performance and management provided they are governed by sound business principles. Provided the utilities have sufficient authority, the "government-ruled" structure is appropriate when the electricity supply infrastructure is expanding and efforts have to be directed at making electricity available to the whole population. In industrialised countries, the more expensive to electrify rural and remote places were not left out because the power supply entities were enabled, sometimes even forced, to electrify their supply area on the basis of more or less complete area coverage. Most of these utilities were vertically integrated and as a result the indispensable co-ordination between generation, transmission and distribution of electricity was ensured. When demand is growing, an adequate planning relationship between the generation and distribution of electricity is extremely important because electricity must be produced as demanded. There have been many occasions when a poor tuning of these functions has ended in sub-optimal and uneconomic use of technical facilities and operational losses.

Power sector reform often results in the unbundling of generation, transmission and distribution. Kasper (1993) is right in fearing that moving away from the joint planning and operation of these functions will increase bureaucracy and, together with competition, will inversely affect economic viability and the optimisation of power generation and grid use. He argues that planning and grid operation will become problematic. Casazza et al.(1996)express concerns that fragmentation of the traditional utilities may affect the economies of scale achieved over many years. Forecasts will become more uncertain and the long term will be reduced from the previous 15 to some 5 years or so (WEC 1995).

Avoidance of political interference

However direct and strong government control can also have drawbacks. There have been cases where governments took advantage of the monopolistic nature of the organisations for the realisation of general policy objectives. Moreover changing political ideas and priorities can affect the policy and even daily operations of a utility in such a way that its management can not model the organisation to best suit the business or be held responsible for its performance. Within a utility, such a situation often leads to a conservative and bureaucratic approach with reliability of supply at the centre rather than the development of innovative solutions and customer care.

There is a general consensus that excessive government interference in financial and managerial operations of power utilities in many developing countries has adversely affected the performance of these organisations. As a response to the growing dissatisfaction with the poor performance of these utilities, alternative solutions based on deregulation and privatisation have been proposed. Albouy (1999) states "the goal of institutional reform of the energy sector in developing countries is to organise energy policy, legislation, regulatory framework, and market structure, in the way that best enables the energy sector to fulfil its role in development". The problem of making sufficient funds available for the expansion of the power system is another reason why many developing countries are pushed towards liberalisation and the creation of Independent Power Producers (IPPs).

It is however emphasised that increased effectiveness is not realised through reform as such, but rather through the avoidance of political interference, and the existence of appropriate and consistent government policy and good management. The utility should work on more than an arm's length from the political world and should be free to design and implement its own organisation and approach. Possibly the most important prerequisite for the effectiveness of an electricity company is a high degree of autonomy.

The neo-liberal wave of the last decade has dictated, on a worldwide scale, reform of the power sector. Deregulation and privatisation were the mission, and competition in the electricity sector was introduced because of the expected greater efficiency benefits compared with government regulation. Burns and Weyman-Jones (1994)[44] concluded that for the case of the nearly monopolistic distribution companies in England and Wales, no increase occurred in the rate of productivity in the period after privatisation relative to that before privatisation. The same tendency has been found by Galal (1994) in Chile. Bogt (1997) found, on the basis of several cases, that a substantial increase in autonomy of Dutch government administrative agencies did not result in improved efficiency.

One of the arguments used in favour of privatisation is the better management of the private sector[45]. However there is insufficient evidence to prove this argument and, moreover, the transition from a publicly owned to a private utility does not in itself lead to benefits. Removing most of the direct governmental/ political interference in utility operations and increasing autonomy appear to be the most successful steps towards performance improvement. In the World Development Report 1994 "Infrastructure for development" (World Bank 1994), three basic characteristics of successful providers of infrastructure services were given:

- The organisations are run on commercial principles and have clear and coherent goals focused on delivering services.
- Their management is autonomous.
- They enjoy financial independence.

44 Cited in Bacon 1995.

45 For a definition and meaning of privatisation, main forms of privatisation and arguments in favour and against, see for example Boorsma (1994).

Corruption

The widespread corruption in some developing countries is one of the most difficult impediments to an adequate performance of parastatal organisations. Practice shows that these ingrained institutional practices are not easily redressed by technical assistance. Alternative structural changes such as corporatisation and privatisation of the organisations are now accepted as an effective remedy for such situations.

Power sector restructuring in developing countries

Littlechild (ESMAP 2000) argues “with appropriate modifications for the circumstances of each case, the policy of privatisation, competition and independent regulation seems the right policy for developing countries too”. This opinion seems debatable particularly with regard to rural electrification.

In the industrialised world, liberalisation and the introduction of competition in the electricity sector is aimed at creating an environment in which generators and service suppliers have to compete for existing consumers. In developing countries, and particularly in their rural areas, the situation is very different: there are no suppliers and only a few customers who can afford to pay the full costs of electrification. Privatisation and the introduction of competition, together with the associated unbundling, while the infrastructure is still in its infancy would seem “a bridge to far”. In this respect it should also be noted that industrialised countries had a mature infrastructure prior to the current liberalisation process.

With regard to the privatisation of public utilities in developing countries, the author agrees with Teplitz-Sembitzky (World Bank 1990) that “a dose of healthy scepticism is in order” and the role that the private sector and market forces can play in the power sector of the developing world must not be overestimated, not least because of the small size of the market. Another, even more important, reason for scepticism is that, with a growing infrastructure, most of the investments are only recoverable in the long term and thus unattractive to private investors.

One cannot apply all the institutional and organisational principles advocated today in industrialised countries to developing countries. To an extent, because of the totally different stages of development of the utilities in developing and developed countries.

Unlike in industrialised countries, power sector reform in developing countries requires much more than just an adjustment of the regulatory framework. Developing countries’ governments face the problem that an appropriate relationship between the private and public sectors is still lacking and the same applies for the business attitudes. Adequate financial and human resources are critical success factors for the effectiveness of government regulation (World Bank, 1997a) and in most developing countries these are missing. Measures to mitigate the lack of institutional and human capacity must be developed and implemented.

Countries with a relatively small power sector may find that restructuring would fragment the industry into a series of very small individual units and would risk losing the economies of scale and increasing the overheads. Bacon (1999, 1995) is right in arguing that bidding systems for the supply of electricity are too complex for most small systems and for economies at low levels of development, so a contract system is often used instead for selling power from the generators. He concludes that not only a country-specific but also a size-specific element needs to be taken into account when considering restructuring.

Some 10 years ago there was a consensus among stakeholders that the performance of government owned and managed electricity utilities in some Latin American countries was considerably below standard. The levels of both investments and supply security were no longer acceptable[46].

It was accepted that a restructuring of the energy sector was needed to reduce political influence and to achieve the necessary improvements in utility operations. By mid-1999 half of the countries concerned had taken concrete steps towards power sector reform. In some of these countries, capital from private investors became available to help meet the increasing energy demand. There is evidence[47] that the power sector reform has had little impact on the rural population and it is unlikely that private capital will be made available to provide electricity and other modern forms of energy to rural areas.

Bacon (1999) found that only 12 of the 115 developing and newly industrialised countries have taken all the steps (see Box 4.1 in Section 4.6.1) that lead to the privatisation of existing government-owned enterprises while in 42 no reforms have been made at all.

Girod et al. (1998) argue that most sub-Saharan countries are willing to reform their power companies but that the scope for restructuring is unclear. This particularly concerns “the viability of an economic system for which competition would be the only regulator and on the capacity of the private sector to truly work for national development”. They conclude, on the basis of a study of sub-Saharan power industries, that the extent of power sector reform should be adapted to the specific situation. Generally speaking, compromises are needed and if full privatisation has been adopted, this would not be possible. They also argue that most African power companies, even when fully privatised, are likely to remain heavily dependent on external subsidies for financing new installations because of the extremely low internal financing rate of these utilities.

It is generally accepted that utilities must be enabled to perform as enterprises and not simply as instruments for pursuing political aims. However, this does not generally require a complete restructuring of the sector. While industrialised

46 WB Energy Strategy Note, 15 December 1999.

47 Personal communications with utility staff and development agencies.

countries ask themselves the question what is the *maximum extent of* power sector reform that is desirable, the question for the developing world could be which *minimum* reform would be appropriate for stopping political interference and government intrusiveness and that would enable utilities to buy power from, and co-operate with independent generators and industries.

Move towards decentralised generation

Most existing power systems are operated centrally and the design of the distribution system is, in general, based on a one-way electricity supply. Because of its limited significance, decentralised generation has not received much attention in the past but, as the result of recent technological developments and the emphasis on measures to protect the environment, its importance is rapidly growing. The impact of these dispersed generators on existing power systems, and the value of the electricity supplied to the grid, have already attracted substantial attention.

Decentralised generation and advanced storage systems could avoid expensive transmission and distribution system upgrades. There are a number of places where utilities have already installed photovoltaic systems, fuel cells and electricity storage facilities in their distribution substations. As has been outlined in Section 4.3.3, the renaissance of decentralised power generation has important implications for the power sector, both technically and institutionally.[48]

A significant move towards decentralised generation demands a different power system design and operation philosophy. Morgan and Talukdar (1996) are right in arguing that centralised power system control has its limits and that there is a need for long-term research on power system issues and, in particular, small-scale distributed technologies and a possible transition from central control to co-operating autonomous power agents.

Electricity infrastructure typically has a technical service life of 40 years and many utilities in industrialised countries will soon have to undertake major replacements. It is thus a good opportunity to reconsider the principles underlying the electricity supply system. In this respect the World Development Report 1992 (World Bank, 1992) states: 'technological advances have put developing countries in a better position to reduce all forms of pollution from electric power generation than the industrial countries were in as recently as twenty years ago. In industrial countries the capital stock takes about thirty years to turn over, and retrofitting is costly. Because developing countries are making new investments, they have the opportunity to install less-polluting plant right away'.

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48 Devine (1987, cited in Kristof 1992) alleges that the implications refer to the technological and the institutional structure of the industry".

Proponents and opponents of centralised and decentralised systems should realise that both systems will be needed to satisfy the growing electricity demand within the existing environmental and economic constraints. National grids, decentralised generators and Solar Home Systems have one aim in common: serving customers with electricity.

Energy conservation, renewables and power sector liberalisation

There is considerable concern that power sector liberalisation and the introduction of competition will affect energy efficiency, the deployment of renewables and environmental protection. Hvelplund (1995) concluded, on the basis of experiences in Denmark, that liberalisation must be accompanied by government influence and appropriate regulation in order to enhance energy conservation. This is confirmed by Hard and Olsson (1995) in their paper based on a study into the implementation of combined heat and power district heating units throughout Europe. They also express the view that the difficulties in combining the production of heat and power were partly caused by the "differences in perceived status, cultural values and attitudes among actors".

COGEN Europe[49] fears that electricity liberalisation threatens the deployment of combined heat and power plants and green sources of electricity. After liberalisation many utilities reduced their wholesale unit prices in an attempt to win market shares. Many combined heat and power installations could not compete with these prices and were closed. There is also reason to believe that fluctuating energy prices will cause investors in CHP units to be reluctant.

Conversely, Slingerland (1999) argues, on the basis of case studies into the effects on energy conservation of electricity sector liberalisation in four West European countries, that the development of industrial and small-scale combined heat and power units is stimulated by advanced power sector liberalisation and functional separation between entities in the electricity sector. This is mainly attributed to a reduced thwarting power of the former utilities, and improved access to the grid and the power market. It is however noted that this conclusion is probably only applicable for natural gas-fuelled units.

In a liberalised power sector, demand side management and the deployment of wind energy and other renewables will need continued regulatory and financial government support. Voluntary support from end users through "green electricity programmes" cannot replace government support. Slingerland states that the more integrated an electricity company is, for example horizontally integrated with gas distribution, the more options that are available for optimisation of resources. This would suggest that particularly for the electrification of "green field" rural areas a multi-utility approach would be appropriate.

49 "Electricity liberalisation- a disaster for clean energy", Cogeneration and on-site power production, March/April 2000.

One of the greatest threats to the deployment of renewables is the subsidisation of fossil fuels. Kozloff (1998) is right in arguing that power sector reform in developing countries provides threats to renewables but also offers opportunities, provided that fossil fuel and tariff subsidies are eliminated. If governments remove the barriers to a more widespread deployment of renewables, including the elimination of fossil fuel specific subsidies and the internalisation of environmental impacts, renewables would have comparative advantages and thus better prospects. For a variety of reasons, however, only a few government-owned monopoly utilities in developing countries have taken the initiative to deploy other renewables than hydro power and, under a business-as-usual scenario, they seem unlikely to do so.

Who is benefiting from deregulation and competition?

The advantages of competition in the power sector are not absolute but relative. An important question is: who pays for, and who is benefiting from, deregulation and competition? There is a fear that in the liberalised market bulk consumers will be favoured. Flavin (1994) is right in arguing that most of the short-term price reductions would come from reallocating existing costs away from larger industrial customers and that someone else will have to pay. Small industrial and commercial enterprises in rural areas could be the victims and have to pay more for their electricity. This could have a negative effect on rural employment because most new jobs are created in these sectors and not in large industries. There are indications that the poor have suffered from the effects of deregulation because a social “safety net” was not available (ESMAP 1999).

It is questionable whether power sector reform and the introduction of competition benefits society at large. After liberalisation and the introduction of competition, organisations are “downsized”, “right-sized” or “re-engineered”. The effects included manpower reduction, reduced maintenance costs, and large-scale re-organisations. In the United Kingdom, unemployment in the power production sector increased substantially (with consequences for society at large) while the share price rose sharply[50]. Basically this involves a shift of costs from the shareholder to society.

Role of the government and the regulator

It would seem that in industrialised countries deregulation and the introduction of competition in the power sector does not imply a more limited role for the government. Huygen (1999) found that in the Netherlands the intensity of regulation increased instead of decreased. Post-liberalisation experiences in the United Kingdom and the Netherlands reveal that a strong government (or regulator) is needed to control and supervise a free electricity market.

50 Employment was reduced by 44% (according to CFO 1997).

In this respect, Berrie (1992) argues that governments in developing countries should address:

- The support utilities need to obtain or guarantee loans for capital from aid agencies and commercial sources.
- Supply standards, environmental aspects and fuels.
- A national energy policy; having such a policy means that right signals should be given to consumers (because of the limitations of market forces).
- A consistency in all projects across utilities in the country.

Regulation is also required to protect the interests of consumer groups, to control the use of primary energy resources and the access to the transmission and distribution grids, to monitor the electricity trade and to deal with emerging conflicts. In particular the interests of residential customers and the environment must be proactively secured. However, most governments do not behave proactively and this would suggest that the next few years will see a growing dissatisfaction among small consumers and the need to form organised interest groups.

An independent regulator with the right and the power to set limits on electricity tariffs and on transmission and distribution charges is needed. Regulation means controlling the performance of the utility by the setting of specific targets or through exerting direct influence on decision making. This means that the regulator effectively determines the rate of return on investments by the utility.

A regulator is in a very strong position, and control of the actions and decisions of this authority is extremely important. The factors which are given special attention during the control process in the United Kingdom include “whether the actions are acceptable to the public”. This might seem appropriate but it should be noted that the limited political power of rural dwellers in most developing countries does not guarantee sufficient influence to that end.

The power of the regulator to set prices (and thus the rate of return) and the quality of service, and even to confiscate assets, involves a risk unless there is sufficient control. The control system applied in the United Kingdom (in which three government institutions are involved) includes a focus on the procedure followed by the regulator, the substance of the decisions, and the acceptability of the decisions to the public. But how impartial and non-political can these institutions really be?

There are cases known where the power of the regulator has been misused, for example in countries where corruption is common and judicial governance is dysfunctional. Albouy (1999) suggests that in these cases the setting out of precise tariff-setting rules in both legislation and contracts with individual service companies is a better way. Green (1999) concludes that increased openness and public consultation is the best way of gaining the confidence of the people in the regulatory system.

Price reduction through liberalisation?

Basically power sector reform results in market-style power generation and power supply, with the grid (including all technical facilities) in between as a regulated natural monopoly. Assuming that the costs of access to the transmission and distribution grid are the same for all competitors, three factors are important in determining the actual end-user price: power generation costs, the quality of the service, and the efficiency with which it is delivered.

Because generation costs represent on average 50 to 75% of the costs of a kWh, it is particularly in this area that greater competition can encourage productivity gains and lead to lower prices. Low-cost generation facilities with short lead times will probably be the rule for producers. This could adversely affect fuel diversity and hydro power schemes could, in this context, be unattractive.

In some countries, a substantial and still increasing part of the consumer tariff is determined by the government through energy tax, eco tax and value added tax[51]. Because energy prices are increasingly dominated by these government surcharges, the price reduction induced by the liberalisation of the sector and the introduction of competition will be limited.

Role of renewables

In an advanced society, electricity is essential and without it the communities could no longer function. With growing development, rural areas in developing countries will also increasingly rely on electricity. In many of these areas, batteries are already used to power lights, radios and TV sets. Currently available stand-alone technologies such as Solar Home Systems can offer electrical service. However, in order to satisfy an increasing demand for electrical services such as refrigerators, freezers, advanced medical and industrial facilities, more powerful supply equipment, able to secure electricity "round the clock", will be needed.

In some cases renewables are the most economic (but still expensive) option, and the only practical way, for supplying the energy necessary to lift rural economies up to and beyond the subsistence level. This, and the fact that financial support is needed, has been recognised by the major aid and financing institutions and many of them have created special policies and funds to stimulate the development of renewables such as the World Bank and Global Environmental Facility's Solar Initiative (Bevan, 1995). There is no doubt that

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51 As an example: in the Netherlands the consumer price of petrol (in a competitive market) includes 65% excise and taxes. The actual costs including production, distribution and profits are NLG 0.95. The total surcharges are NLG 1.72 or 280% (source NRC 27/05/2000).

Per 01/01/01 the sum of the environmental surcharge/energy tax and BTW (VAT) amounts to 18.75 NLct per kWh electricity for residential consumers. With average nett unit costs of 18.15 NLct the surcharge amounts to some 103% on the basic price.

generating electricity from renewable energy sources has an important role to play in the internationally agreed objective of reducing CO_2 emissions.

The delivery of the services and the management of a multi-purpose power system (see Figure 4.3) will be one of the most challenging activities in the near future, in both a technical and a commercial sense. Power demand and supply diversity in rural areas could be large and local private generators, including small-scale industries, should be encouraged to supply power to the grid. It should be noted that these future, non-conventional, activities in rural areas are much more complicated and time consuming than those related to grid connections. The number of smaller stakeholders is rather large and there are interrelationships with other sectors, for instance water supply.

Teplitz-Sembitzky (World Bank 1990) emphasises that, provided small-scale power producers prove to be a viable option, a proper regulatory framework (rather than deregulation) will be required to manage the relationships (for instance risk sharing) between the participants. This is confirmed in (EUR 1992) and this also notes that new actors will only participate if a “fair place” is offered. The regulatory framework for rural electrification hat to be properly defined and should enable private participation, co-operative initiatives and innovative technical and financial solutions, including sophisticated credit schemes. National guidelines should help in setting tariffs and maintain the return on investments at an acceptable level.

Service-oriented organisation

With an increasing number of dispersed generators the need for integrated resource planning (IRP) becomes more important. In this respect the multi-utility concept could offer a good opportunity for identifying and delivering the most appropriate services to customers in rural areas. A separation between the “grid” in rural areas and the delivery of the service should be avoided, as this would be at odds with integrated resource planning. Moreover, co-operation with small independent power producers will require an overview of the limitations of the grid in relation to power demand, consumption and power production opportunities. For the utility, a service-oriented organisation will be needed and an approach should be adopted that also takes the environmental and reliability aspects into account.

Rural areas and the impact of liberalisation

At present the wholesome effects of market forces are preached and competition is introduced into the power sector and other public services. However rural areas have seldom benefited from market forces and, to prevent neglect, governments have always needed to take rectifying measures (LC 1995b). Wilke (1996) argues that the logic of the market leads entrepreneurs to cut uneconomic activities. This suggests that the current strong belief in market forces involves a threat to the delivery and cost of services in rural areas.

In this respect the recent attempts should be mentioned of a German electricity company to subdivide its supply region into areas with “rural” or “urban” features with the aim of bringing the charges for the customers more in line with the actual costs of power supply (Baur 1996). The company argued that the subdivision had a sound business reason and was required from the point of view of competition. Although the proposal was not approved by the authorities, it is an indication that in a more competitive environment rural areas could be faced with higher costs for electricity services[52].

Another example relates to the Dutch Railway Company (NS). One of the first actions, after the privatisation of this company, was the disposal of the unprofitable lines in the more rural areas of the country. For strategic reasons, and under certain conditions, the regional bus companies have agreed with the government to take over these lines but future developments are uncertain. There is also sufficient reason to fear that rural bus services will adversely be adjusted to accommodate to the budget allocated for the public transport tender procedure.

These examples support the fear that the change from state-owned utilities to competing private companies will lead to a reduction in the “social face” and this could result in rural areas in developing countries remaining deprived of electricity. A private company will search only for attractive customers and these do not include the poor rural dweller with a consumption of only a few tens of kWh per month. In general, rural communities do not have sufficient political power to bring about the electrification of their areas.

Rural electrification: external support needed

In Chapter 3 the conclusion was drawn that the electrification of rural areas in most countries needed financial support and government initiatives. The experiences of the United States of America in the thirties for instance showed that private utilities do not electrify rural areas. Only after a special Rural Electrification Organisation (REA) was established, did some of these utilities extend their grids to the least loss-giving rural areas thus frustrating REA’s distribution infrastructure planning.

There is thus considerable evidence in both industrialised and developing countries that rural electrification should not be seen as a “commercial” activity and that utilities need targeted external support from the government or others (World Bank 1993).

There is no sound reason to expect private interest in rural electrification after reforms take place in the absence of subsidy and/or special sponsored programmes. Kozloff (1998) even argues that privatised utilities will have a

52 It should be noted that in the year 1968/1969, rural prices in Ireland were lower by over 29% and urban prices higher by almost 9% than they would have been in the absence of cross-subsidisation at the then consumption levels (see Section 3.1.5).

decreased interest in serving non-electrified areas. On the other hand, he notes, that tariff reform will likely promote off-grid and demand side applications. According to a World Bank paper (1996), private investors have so far been mainly interested in large scale generation and not in distribution and this supports the above statement.

The conclusion can be drawn that neither the privatisation of utilities nor competition are solutions for the electrification of rural areas. It would be very difficult to find private enterprises that would be prepared to electrify rural areas, accept a very low rate of return and charge affordable tariffs, even monopoly-based ones let alone those with competition[53].

The most likely source of financial support is from donors, and institutions such as the World Bank, and perhaps from local stakeholders who themselves have an interest in the electrification of their areas. These organisations will only be prepared to support electrification schemes if there is sufficient confidence that the electrification process is properly organised and managed, contributes to the alleviation of energy poverty, and is sustainable.

Particularly in the developing world, rural industries increasingly contribute to the GDP[54]. To enable these industries to supply products with a substantial added value, modern and reliable forms of energy, particularly electricity, must be made available. In this respect it is noted that the potential role of technological improvements, and the associated introduction of modern forms of energy, in income generating activities is often underestimated. One of the major problems is the lack of a institutional infrastructure for technological support (DGIS 1992).

Energy supply to rural areas should preferably be part of a rural development programme and not an isolated activity. An integrated development approach could lead to well defined programmes that fit in with flexible instruments such as the Clean Development Mechanism and provide ample opportunities for donor funding and multidisciplinary technical assistance.

53 Independent power producers seek to gain a return on their investments of around 17% (GEC/Alstom 1997). Such a return cannot easily be obtained in rural areas (10% would be the rule).

54 In this respect it should be noted that there is a lot of existing activity (particularly by women) in the informal sector that is yet plain ignored.

Chapter 5

Implications for the Rural Electricity Supply Sector

5.1. Introduction

The first two chapters of this thesis provided relevant background information and stressed the growing importance of an adequate energy supply and particularly of an electricity supply, for achieving an acceptable quality of life for the global village. In the third chapter the historical aspects of rural electrification were analysed and conclusions drawn, while Chapter 4 summarised and discussed the nature and scope of current developments and trends in the electricity supply sector.

The first part of the present chapter summarises the conclusions drawn from the previous chapters and the implications of the research to the approach for electricity supply to rural areas in developing countries. A number of case studies are included, some of them serve as examples of advanced co-operation and others illustrate the difficulties that can be encountered and the lessons to be learned. In this part of the chapter the main research question, and the question that forms part of the title of this thesis, are also answered.

The second part of the chapter addresses the management challenges and summarises the critical success factors for the organisation of rural electricity supply. To identify and successfully implement appropriate solutions for organisational and managerial problems, the manager should not only have a proper understanding of the nature of the problems and success factors, but also of the environment in which they occur. This is the reason why, in this section, attention has also been paid to the various aspects of the business environment of contemporary utilities.

Although the internal organisational structure and the management approach contribute to an appropriate performance of electricity supply companies, these factors are not addressed in detail in this chapter. However, relevant principles are discussed and their application recommended. For further details managers can consult the many books devoted to the structuring and management of organisations[55].

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55 Stoner (1992) is recommended as a classical book for the practising and prospective manager. It addresses all aspects of organisation and management including organisation theories, organisational development, human resource management, communication, the identification of key performance areas and control. Kuipers (1992) addresses modern sociotechnology and is recommended for supporting concrete organisation system design based on increased flexibility and reliance on selfregulating teams.

Drucker (1962, 1974, 1985, 1990 cited in Beatty 1998) has had a pivotal effect on corporate management theory and practice.

Clegg (1996) is a more theoretical and verbose book that addresses organisation studies within the context of the changes that took place in organisation theories and practice, as does Keuning (1991). The emphasis of Schieman (1980) is on governance and control of business processes. For literature on more specific topics see the bibiliography.

Although the focus is on electricity supply to the rural areas of the developing world, some of the information contained in this chapter has relevance to industrialised countries.

5.2. Research findings

5.2.1. Conclusions from previous chapters

Conclusions and comments on general electrification aspects, rural electrification history, and developments and trends have received detailed treatment in the relevant sections of the previous chapters. The conclusions and comments in this section are listed insofar as they are needed to answer the general research question and define the management challenge.
To that end they are divided into three groupings: the rural market, rural electrification technology, and the institutional aspects. Insight into the features of the rural market is necessary to identify the needs and potential and, to some extent, the approach. The conclusions regarding the available technologies could help answer the question of how to satisfy the needs. The group of the institutional aspects provides “dos and don’ts” and insight into various aspects of the institutional embedding of organisations. For easy reading each group is divided into sections in which the key aspects of the subjects are summarised.

The rural market

1. *Large potential*
   Rural areas in developing countries are large markets but they need to be developed. Because modern manufacturing, processing, and information facilities rely almost entirely on electricity, the availability and service reliability of this form of energy increasingly determine the productive potential of rural and remote areas. If the rural and remote areas in the developing world are to rise significantly above the level of subsistence, electricity is essential and therefore warrants increased attention by the international community. Over two billion people do not have access to electricity and there is evidence that yet un-serviced rural communities are willing to spend a significant share of their incomes on this form of energy. There is sufficient reason to justify that the question is no longer whether rural areas will be electrified, but only when and how.

2. *Gender issues*
   The role of electricity in contemporary society differs from that during the early days of electrification. In those days electricity was mainly seen as the

"new light" but currently societies all over the world desire electricity to power computers, medical instruments and storage facilities, industrial processes, TV sets and telecommunication equipment. Still, there are many poor rural communities happy with electricity that only brings light to the darkness. The growing importance of electricity for mankind, including poor rural communities, leaves unimpaired the significance of having access to safe water, affordable traditional fuels and economic development. Despite the increasing penetration of electricity, there is no doubt that traditional energy resources such as wood, crop residue and coal will continue to satisfy cooking and heating needs of households in rural areas of developing countries. It is recognised that in most developing countries, traditional energy has a great influence on the daily lives of women. This suggests that the electrification of rural areas will, as yet, not significantly help to free up women's time. In energy programmes, the role of women has been underestimated but awareness is growing that gender issues need to be addressed in the energy planning process. Albeit that this conclusion is mainly based on the gender aspects of traditional energy, the need to include gender issues in electricity planning including renewables is recognised (Cecelski, 1995). There are various motivations to include gender: to increase the efficiency and efficacy of programmes, to better achieve sustainability, and to reach welfare goals as regards women (Skutsch, 1998).

3. *Appropriate financing*

In developing countries electricity is the fastest growing source of energy, but in most poor rural areas only some of the commercial and industrial enterprises and just a few residential dwellers can afford to pay the full costs of service connections or to buy individual electricity systems such as a Solar Home System (SHS). In many developing countries, NGOs have introduced SHSs and it appeared that appropriate end-user financing is the most pressing problem. There is sufficient evidence that consumer financing is needed to develop the market and that the challenge is to find micro-financing institutions and to involve the community in the process[56]. The greater part of the rural population belongs to a market for which subsidies and/or special credit schemes are needed. Electricity consumption of this group is very low but, with grid connection, many consumers could afford to pay for the energy used. The affordability problem relates to the costs of the service connection itself or, in the case of solar home systems, to the initial costs. Smith (1995) suggests a number of solutions that could specifically help low income households to obtain an electricity connection to the grid such as load limited supply, prepayment meters, pre-fabricated house-wiring systems and credit schemes for both connection fees and house-wiring. By

56 Confirmed by research in Sri Lanka (Gunaratne 1999).

using load limiters "lifeline" rates could be limited to just the low income households. These devices are about half the price of meters and have the advantage of reduced administration efforts and the avoidance of meter reading costs. Prepayment meters, with their relatively high initial and operating costs, are less suitable for households with low consumption levels (up to 100kWh/month). Prepayment meters make consumers more aware of their electricity consumption and most prepayment electricity user groups show some reduction in energy usage (Youngleson, cited in Smith 1995).

4. *Affordability*
   If the economic principle of "the customer pays the real costs" were to be generally applied, particularly the poorest of the rural population in developing countries would be unable to use electricity despite the fact that they generally consume very little electricity. Though there may be convincing social and political reasons for electrification, extensive rural electrification projects can have a negative impact on the economy of a country, a province or a utility. Funding the electrification of rural and remote areas therefore needs a special approach. In this respect it is noted that there is a salient difference between presently developing countries and the industrialised world as it was around 1900. The latter already had sufficiently developed economies and rural infrastructures and they could afford to invest in electrification. The economies of most developing countries are weak and do not allow major investments in infrastructure. This leaves the international community to support rural electrification activities in developing countries.

5. *Integrated rural development*
   As has been argued in Chapter 2, some argue that rural electrification should only be undertaken if it contributes to economic growth by supporting industrial, semi-industrial, commercial, and agricultural activities. From a purely economic point of view this statement might be valid, but the reality is that the provision of electricity is perceived as a substantial improvement to the quality of life of the rural population. History shows that electrification of rural areas has always been considered to be more than an economic activity and it has been seen as socially important. The social benefits and political gains often outweighed the financial burden incurred by the electrification of uneconomic rural areas. In this context it is also noted that economic circumstances were not a decisive factor in the wide-scale electrification of rural areas in industrialised countries. The power of lobbies and pressure groups was probably more important. However, as elaborated in Sections 2.8 and 3.8.5 electrification must be considered as part of a rural development programme and not as an isolated initiative.

6. *Rural industries*
   Particularly in the developing world, rural industries increasingly contribute to the GDP and they provide much needed employment as well as commercial opportunities for the rural population. Many of the rural industries are small, seasonal and related to the agricultural sector and the building industry. The thermal energy required by these industries is mainly provided by biomass. The features of the industry, the need for application guidance, and the lack of an institutional infrastructure for technological support, have thwarted the application of modern technology in rural industry, and the associated benefits in terms of income generating activities. To enable these industries to supply products with a substantially added value, modern and reliable forms of energy, particularly electricity, must be made available. A substandard rural electricity supply will not only affect the quality of life and the productivity of rural industries but also, through their contribution to the GDP, the national economy. The above observations suggest that the organisation of rural electricity supply requires re-thinking and innovation, preferably in the context of rural development.

7. *Reliable service*
   In principle, electricity supply for productive uses in rural areas should be commercially viable because of the positive effect on turnover. But, in many developing countries, the productive use of electricity in rural areas appears to remain rather limited, certainly during the first few years following electrification. This is perhaps partly due to the limited priority that utilities attach to the small-scale industrial sector and hence the limited attention paid to the associated marketing. Another reason could be a substandard service reliability. For rural industries that do not have a heat demand, an unreliable electricity service would seem a decisive reason for switching to another power source rather than a high tariff. The deployment by industries of their own (stand-alone) power production units could have serious consequences for the economic feasibility of traditional public power supply systems. If a service is to be delivered, is has to be sufficiently reliable. The technical facilities and the organisation of the utility should be such that such a service can be guaranteed.

8. *Community involvement*
   Though there is concern about the practicalities of organising and implementing rural community involvement successfully, utilities in developing countries have begun to see advantages in terms of savings on investment and possible maintenance and collection costs. Labour costs for distribution, service connections and house-wiring could perhaps be reduced by approximately 10%, and the costs of revenue collection and maintenance by approximately 50% for remote communities (Smith 1995). The rural

population in developing countries often seems to have limited affinity with electricity and hence education concerning energy efficiency and technological innovations is needed. This also implies a stronger relationship between the utility and the customer base. An analogous trend, but here as a result of the introduction of competition, can be observed in industrialised countries where utilities have rediscovered the client and adapted their organisations accordingly.

Rural electrification technology

1. *Costs*

   In the past, most rural electrification programmes relied on the extension of a centralised grid. The grid-based electrification of rural areas is expensive, and without a technological and associated cost breakthrough, a connection will continue to need an average investment of approximately US$ 1900[57]. This includes investment in generating capacity, the transmission and distribution system, and the service connection, but excludes house wiring. This estimate takes into account an average area coverage, recent efforts to reduce distribution and connection costs, and the fact that prospective rural areas are progressively more expensive to electrify because of their remoteness.

2. *Solar Home Systems*

   Together with energy efficient appliances, Solar Home Systems can offer attractive services but have a limited capacity. An installed Solar Home System of 50 Wp offers, under tropical conditions, about 100 kWh per annum[58] and would just be sufficient to power some fluorescent lamps, a radio, and a black-and-white television set for a few hours per day. Such a system might cost US$ 750 corresponding with an investment of US$ 7.5 per kWh/annum produced[59]. Though the costs are high, photovoltaic systems would seem the most attractive renewable option and the potential is large. Although area coverage is not an issue for solar home systems no issue compared to grid based electricity supply, a minimum quantity per area is important from the point of view of marketing, and an efficient maintenance service. Provided that the costs can be reduced substantially and institutional barriers are removed, the deployment of customer based

57 See Box 2.1.

58 Many life-line tariffs, as found in developing countries, allow a larger consumption: for example 240 kWh per annum (Nepal, Gerger 1997) and 360 kWh per annum (Costa Rica, Foley 1997).

59 Technically, a light grid connection would allow a consumption of some 1000 kWh/annum, corresponding with US$ 1.9 per kWh.

photovoltaic systems will substantially expand: in countries with a mature distribution grid as grid connected systems, and in areas without such a grid as stand-alone devices.

3. *Electrification process*

The deployment of Solar Home Systems (SHS) has sometimes been considered as “pre-electrification”. Central-grid based electrification has also shown a pattern of starting from a limited supply: house wiring and service connections were initially designed for just a few lights, and the initial limited single phase distribution systems have been modified into more powerful three phase systems to allow heavier loads. Many utilities have reinforced existing distribution grids more than once since their original implementation. The implementation of Solar Home Systems could be seen as another step in the electrification process. These stand-alone systems will increasingly be deployed but it is fair to conclude that, in a more advanced stage of rural electrification, a connection to a grid will also be needed[60]. The latter could be a mini grid, a local grid or a national grid, depending on the particular situation. If the deployment of SHSs is considered as pre-electrification, after some time to be replaced by or operated in parallel with a more powerful electricity supply, the conditions under which organisations other than the local utility might be allowed to implement these systems, needs to be carefully determined. Proponents and opponents of the centralised and decentralised options should realise that both systems, possibly in combination, are needed to satisfy growing electricity demand within the existing environmental and economic constraints.

4. *Service diversity*

A major advantage of Solar Home Systems is that users can purchase equipment that suits their financial situation and still have the possibility of extending the installation in the future. Electrification through offering small Solar Home Systems only might cause difficulties in an area with mixed prosperity. The wealthier residents could afford to buy irons, colour television sets, refrigerators and freezers and might not be satisfied with the capability of such a SHS. Diversity in the services offered and associated marketing efforts are needed to satisfy the entire customer base. In this respect, Barnes (1988) concluded that the extent to which electricity is used in a community is extremely important in evaluating its impact on long term socio-economic development, and that this may be limited by the technology

60 To allow more energy demanding services, to shave peak demands, and to improve service reliability. This statement is supported by experiences in Tunisia with a large solar electrification programme (AME/GTZ, 1999).

used to produce electricity. He also argues that the present and future development of electricity use can be affected by limitations on service, no matter what the generation source.

5. *Advanced electrification strategy*

Central grid based utility planning has always been rather pragmatic and featured an extrapolation of historical data and the construction of grid extensions and standard service connections to consumer premises. Such an approach, and business as usual scenarios, are no longer suitable or acceptable under the present dynamic and often interdependent circumstances. To mitigate unacceptable pollution of our environment, and to achieve sustainable development, the use of fossil fuel based energy must be reduced, the efficiency of the conversion and use of energy increased, and the deployment of renewables promoted. These observations suggest the development of a rural electrification strategy that takes dispersed power plants, both traditional and renewable, into account. In this respect the World Development Report 1994 (World Bank, 1994) states: “technological advances have put developing countries in a better position ….. than the industrial countries were in as recently as twenty years ago. In industrial countries the capital stock takes about thirty years to turn over, and retrofitting is costly. Because developing countries are making new investments, they have the opportunity to install less-polluting plant right away”. Flavin et al (1994) are of the opinion that developing countries have the opportunity to “leapfrog” to a more efficient and reliable decentralised power system.

6. *Role of renewables*

Because of hostile institutional conditions, its relative complexity and high costs, decentralised renewable generation has not received much attention in the past (see Case 5.1). But many rural and remote areas have substantial renewable resources and offer opportunities for the deployment of modern decentralised renewable energy technologies. Renewables can be the most economic option and the only practical way of supplying the energy necessary to lift rural economies to and beyond the subsistence level. This has also been recognised by the major aid and financing institutions and many of them have created special policies and funds to stimulate the development of renewables such as the World Bank and the Global Environmental Facility's Solar Initiative (Bevan, 1995). There is no doubt that generating electricity from renewable resources has an important role to play in the internationally agreed objective of reducing CO_2 emissions.

Case 5.1: Sustainable energy project Dearsum: lessons learned

Dearsum is a small rural village in the northern part of the Netherlands with 150 inhabitants living and working in some 50 houses and 10 farms. The village is connected to the electricity supply grid and is also supplied with natural gas, the latter mainly used for heating of premises.
In 1988, the community consumed 331,000 kWh electricity and the maximum demand varied between 70 and 102 kW depending on the season. In 1994, consumption reached 385,587 kWh and peak load varied between 83 kW and 128 kW.
The reliability of the electricity supply to the village was, as in most other areas of the Netherlands, high: an average of over 99.99%. Thus it was not the unreliability or the price of the electricity supply that induced the village to develop a sustainable energy plan. Rather it was the search by a regional manufacturer for an attractive site for a pilot biomass digester plant. In addition, the impact of two successive oil crises and the increasing awareness that sustainable energy sources needed to be developed, advanced the discussion among many villagers on becoming self-supporting with regard to energy.
In the early eighties, the mayor, councillors and a number of the villagers grew convinced that local resources such as dung and wind, could be used for the production of biogas and electricity and enable the village to largely satisfy its own electricity needs. Moreover, a small-scale sustainable energy project could act as a catalyst for a more widespread use of renewable energy resources.
To advance the project, the foundation “Stichting Energievoorziening Dearsum” was established by the municipality, the province of Friesland, the regional gas supply utility and a representative of the village. A feasibility study was completed and in 1987/1988, heavily subsidised by the European Community, the Dutch government and the province of Friesland, a dung digester and a wind turbine generator were installed. The main objective of the project was to demonstrate the technical and economic feasibility of the combination of a dung digester and a wind turbine unit for electricity generation in rural communities.

Project data

- Investment cost: US$ 650,000, excluding US$ 200,000 for site-selection, engineering and evaluation.
- Wind turbine: nominal capacity 160 kW, expected average on-site production 200,000 kWh/year.
- Digester: 210 m^3, 100 m^3 gas storage capacity, CHP gas engine unit 15 kWe.
- Expected input: 3800 m^3 cow dung/year from six farmers.
- Expected output: 15 m^3 biogas/m^3 dung and 1 kWh electricity/m^3 biogas.
- Residues from digester to be used as fertiliser.
- Total output is expected to meet 62% of the annual electricity consumption

of the village, the remainder to be supplied by the grid.

- The management of the digester is contracted to one of the farmers, and maintenance is executed on contract basis by the suppliers.

Lessons learned

- Initially, it was suggested meeting the village electricity needs in full (islanded) by the conversion of wind energy and bio-energy into electricity. This idea was discarded because of the high costs associated with maintaining the reliability of the electricity supply to the village. An electricity grid was also considered necessary to absorb excess electricity.
- In the first year (1988), the wind turbine produced 222,000 kWh and the digester and gas engine 33,000 kWh of electricity. The specific electricity production in this year appeared to be 1.14 kWh/m³ biogas and the specific biogas production (with dung) 16 m³ biogas/m³ dung.
  The average production costs were US$ 0.20 per kWh (1988 figures). However a cost of US$ 0.11 (US$ 0.9 and US$ 0.18 for the wind turbine and the digester respectively) was considered feasible given a high price for excess electricity sold to the grid, a cheaper location, increased dung flow to the digester and a higher price for the fertiliser by-product.
  In these calculations, the positive environmental effects were ignored.
- The first year confirmed the technical feasibility of these energy projects. It is fair to conclude that the combination of bio-energy and wind-energy could reduce grid supplied electricity by at least 50%, in the right conditions.
  It should however be noted that in 1996 about three-quarters of the electricity for the village had to be supplied by the regional electricity board because of technical problems with both the digester (ageing/leakage) and the wind turbine generator (gale induced damage).
- Unlike the digester, the wind turbine appeared to be cost-effective in the given circumstances. The cost-effectiveness of the wind turbine mainly depends on the tariff for excess electricity sold to the grid.
  After ten years of operation, the digester needed to be renovated or replaced. The conclusion was drawn that the digester can only be made cost-effective by a reduction of the investment costs, increased biogas production, a price attached to the collection of dung and an attractive price for the fertiliser.
  On-site investigation showed that both the cost-effectiveness and the biogas production from the digester could be improved considerably by using cow dung together with garden and kitchen waste[61]. Further investigations revealed that a digester with a daily processing capacity of 240 m³ dung together with 60 m³ of garden and kitchen waste, would produce some 10,000 m³ biogass/day. Cost effective operation is possible given a

61 Cow dung is not the best producer of biogas. There might have been a different result with pig and human waste.

minimum remuneration of US$ 30 per m^3 biomass and US$ 0.12 per m^3 biogas.

In 1995, another digester was planned which would process both dung and garden waste and produce high quality biogass and a valuable fertiliser. The digester appeared to be economically feasible if 10,000 tons of dung and 15,000 tons of garden and kitchen waste were available annually. Because these quantities were well in excess of the dung and waste production of the village, additional supplies of dung and particularly garden and kitchen waste would have to be found.

This appeared to be impossible because existing contracts with waste processing organisations were held by the potential sources. In the Netherlands the processing of garden and kitchen waste is based on composting and has been centralised.

This situation meant that there were no cost-effective opportunities for small-scale digesters. Without a new dung and garden waste based digester however, there is considerable doubt as to whether the project can survive in the near future.

- Most of the problems experienced during the initial phase of the project, have been of an institutional nature, including the protection of vested interests.
- There is some evidence that the project has induced the villagers to become more energy-conscious, as the average increase in electricity consumption in the village was lower, over the years, than in the province as a whole.
- Involvement of the villagers is extremely important as was the provision of regular information about energy conservation measures and equipment choices.

  No difficulties have been experienced in the logistical co-operation between the farmers regarding the dung and fertiliser.
- Peak load management is an important issue, not only to reduce the purchase costs of grid supplied electricity, but also for an effective utilisation of the generating equipment. At times a peak load reduction of some 15% was achievable.

  On average, the gas engine linked to the digester was used for 4 hours per day during periods of maximum load. Consumers were visually informed about the loading capability of the system by means of an “on-line” maximum load indicator.

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7. *Power system evolution*

As a result of recent technological developments and the emphasis on measures to protect the environment, the importance of decentralised renewable energy sources is rapidly growing. The impact of these dispersed generators on existing power systems and the monetary value of the electricity supplied to the grid, have already attracted substantial attention. In many industrialised countries the deployment of decentralised power systems such as wind turbines, solar home systems and small combined heat and power units have already changed the function of the existing rural grid into a more dynamic one. In these situations, grid adaptations were needed to maintain system integrity and service quality. Moreover, decentralised generation and advanced storage systems could avoid expensive transmission and distribution system upgrades. Adequate storage systems are vital for the development of a more sustainable electricity supply. These systems have the potential to completely change the electrical infrastructure, give demand side management another dimension and meet increasing service reliability requirements. There are already a number of places in the world where utilities have installed central photovoltaic systems, fuel cells and electricity storage facilities in their distribution substations[62]. Electricity infrastructure typically has a technical service life of 40 years and many utilities in industrialised countries will soon have to undertake major replacements. It is thus an opportune time to reconsider the principles underlying the electricity supply system.

8. *Design and operation philosophy*

As a result of dispersed generation, future rural power systems will increasingly have a dynamic character. Basically the distribution system will change from a passive one into an active one with technical requirements and a sophistication that are very different from the past. Maintaining adequate voltage levels, managing spinning reserves, reactive power and quality of supply are associated factors with the change towards active

62 As an example: Tokyo Electric Power Company operates 6 MW (48 MWh) sodium sulphur battery demonstration installations at the Tsunashima substation and Ohito substation for load levelling purposes.

systems. A strong move towards decentralised generation also forces another power system design strategy and operation philosophy. Research is needed into relevant power system issues and, in particular, small-scale distributed technologies and a possible transition from central to a more decentralised control.

9. *Integrated demand and supply approach*
More dynamic rural electricity systems require a different organisational and commercial approach to that with the former central grid-based electricity supply. Both the sale and purchase of electricity at various quality levels will occur. The technical implications of these activities are such that an integrated approach of grid planning, grid operation, marketing departments, and the clients will be needed to avoid inefficiency, lost opportunities and power system management problems. This requirement contradicts the currently fashionable principle of liberalisation where grid operation (as a natural monopoly) and the supply function (as a market place) should be separated to stimulate competition. In such a situation appropriate co-operation is more difficult to achieve.

10. *Advanced business approach*
Customer-based decentralised power supply facilities offer business opportunities for both utilities and local industries. With such facilities, there is no need to pre-invest in large grids for which an acceptable customer base is needed to cover the costs. The deployment of decentralised power devices offers a utility the opportunity, on a case by case basis, to acquire customers[63]. In non-electrified rural areas, utilities could sell or lease power units to local industries or enter into a joint venture with them. The potential for these business activities will heavily depend on the features of the economic activities in the supply areas, and is also closely related to ongoing development programmes. Schemes such as BOOT (Build, Own, Operate and Transfer) and BOO (Build, Own and Operate) are inappropriate for such small projects because of their complexity and the costs associated with these arrangements.

11. *Technical options*
For the electrification of rural areas, a whole range of technical options is presently available: from stand-alone solar home systems to fuel cells and sophisticated grids. Variable speed wind turbines with a capacity of several

63 The "true" value of an electricity customer in the UK for example is estimated at US$ 60. The value could be higher if these customers purchased other utility services from the same utility. In a competitive environment energy companies have invested up to US$ 600/customer to acquire multi-service customers (Harrison 2000). In the USA a figure of US$ 100 is mentioned for the marketing costs to capture a customer (PEI 2000).

MWs are already available and are suitable for offshore use and adaptable to various grid conditions. The advances in generation, transmission, distribution, power electronics and appliance technology pave the way to a more decentralised and also more energy-efficient power system. From the point of view of emission control, a life-cycle emission approach is needed to select the appropriate electricity supply systems and appliances. The justification for this statement is that “green electricity” should be really green and without hidden emissions, since the differences in the life-cycle emissions from the various options can be rather large[64]. The conclusion is drawn that the design and implementation of future electricity supply systems is much more complicated than those previously used and that utilities need to adapt themselves technically and organisationally to this new reality.

Institutional aspects

1. *National electrification plan*

When electrification started at the beginning of the previous century, many technically different electricity supply systems were offered by entrepreneurs and applied. Standardisation and region-wide power system planning were needed to avoid proliferation. In the decades that followed most of the currently industrialised countries developed and adopted national electrification plans prior to the implementation of electrification schemes. A plan in which the institutional, financial and technical aspects are covered, is a precondition for successful and sustainable rural electrification activity. Without such a plan, rural electrification will result in a patchwork of various technical and organisational systems. In the absence of a nationwide electrification plan, the numerous isolated and different (but otherwise well-intended) rural electrification initiatives by donors, NGOs and other institutes may undermine the potential for a well-planned and organised electrification of the rural areas in the developing world.

2. *Subsidies*

History shows that in most countries, electrification has been seen as a national effort to create an appropriate and stable environment for technical development, economic growth and improvement of living standards. Rural electrification was supported either by special national programmes or by a legislative and organisational approach. Rural electricity supply, both centralised and decentralised, has always been considerably more expensive than the supply to urban and industrialised areas, and none of the

64 Table 4.3 illustrates the life-cycle emissions of various generating options.

investigated rural electrification programmes could have been implemented without subsidies. Subsidies were in the form of grants on the initial investments (up to 50%), low-interest or interest-free long-term loans and cross-subsidies. Despite subsidies, the rates of return were as low as 5% and rarely above 12%. In most countries funding has also been a major problem. These observations suggest that organisations based on the “not-for-profit” principle are most appropriate for the electrification of rural areas. Private enterprises have the drawback that subsidies would be used to achieve an acceptable shareholder return.

3. *Proactive approach*
In general, the political strength of rural populations is low and politicians have often been far from proactive. In many countries the rural population has had to rise up against neglect before any actions on electrification of their areas were taken. There is also historic evidence that rural populations will only seldom organise electricity supply to their areas themselves. These observations suggest that the current reliance on private initiatives and market forces is unlikely to work for the non-electrified rural areas of the world. This underlines the importance of a proactive and worldwide approach to the problems that rural populations experience, certainly now we are moving towards a global village.

4. *Integrated development planning*
Though the promotion of rural development appears to be the most common objective of electrification, many rural electrification programmes have been planned and implemented as independent technical activities isolated from the economic and social development of the areas. This has often led to underutilisation of the power system because the population could not afford to purchase appliances. This observation underlines the need to consider rural electrification as a fully fledged component in the development process. Electrification will improve the living conditions of the rural communities but is, in itself, not the key to rural development. Rural electrification is only one component of rural energy development. Any improvement to the living conditions in rural areas through development schemes that include electrification, will likely promote the development of a middle class in rural society. This middle class is important from the point of view of commercial initiatives, employment development and similar issues. The idea that electricity should be seen as something only for a more advanced stage of rural development, is no longer supportable. Electrification must be approached as an integral part of rural development

programmes[65]. The integration of electrification into development schemes would also enable a better determination of the time dependent affordability and willingness to pay for the energy services provided. In this respect it is noted that the opportunities to economically utilise local resources for electricity production such as wind energy, hydro power, solar energy, biomass and fossil fuels will heavily depend on present and future needs. The transition to a more sustainable and modern energy economy of the rural areas of the developing world, including the use of locally available energy resources, often implies the introduction of electricity. In many of these areas the potential for the deployment of renewable resources, such as solar energy and biomass, for electricity generation in the residential and commercial sectors and in small-scale industries appears rather large. Most of these renewable energy systems are small-scale, and offer manageable opportunities to contribute to technological development and to enhance local employment. The use of locally available resources for rural electricity supply could also be attractive from the point of view of reducing dependence on foreign assistance. Diesel power stations often lead to a substantial foreign dependence, for fuel, spare parts, expertise and even operation. Small-scale hydro and photovoltaic systems have this problem to a lesser extent. To deploy small-scale traditional and renewable power systems it is desirable to seek new concepts for the development of industrial infrastructures; structures which integrate the nature of the industries, the location and the locally available energy resources.

5. *Autonomy*

As found in the previous chapters, the most important causes of the substandard performance by utilities in some developing countries are of an institutional nature: a lack of autonomy and accountability, serious political interference and/or social and political instability. The most important single cause of substandard performance of a number of publicly owned power utilities in developing countries, is the lack of autonomy, both financial and institutional. Other important causes include uneconomically low tariffs as the consequence of political interference, poorly organised and supervised revenue collection, lack of access to foreign exchange, and an inadequate corporate culture. Most of these observations are similar to those found by Hoffer (1995) when investigating urban water companies. He emphasises that the lack of autonomy is “the main constraint and at the same time the main opportunity for the improvement of urban water supply”. Hoffer does not mention the organisational structure *itself* and the associated human resource management as major causes of substandard effectiveness.

65 See Section 2.3.1; Pearce et al. (1987) and Ranganathan (1992) came to the same conclusion.

North (1990) holds the view that organisations arise as a consequence of the institutional framework while Bacon (1995) concludes that “the poor performance of many state companies in developing countries is more likely to be attributable to the nature of the ownership rather than their structure”. All these observations support the view that an appropriate institutional framework is a critical factor for the success of a proper operation of electricity utilities.

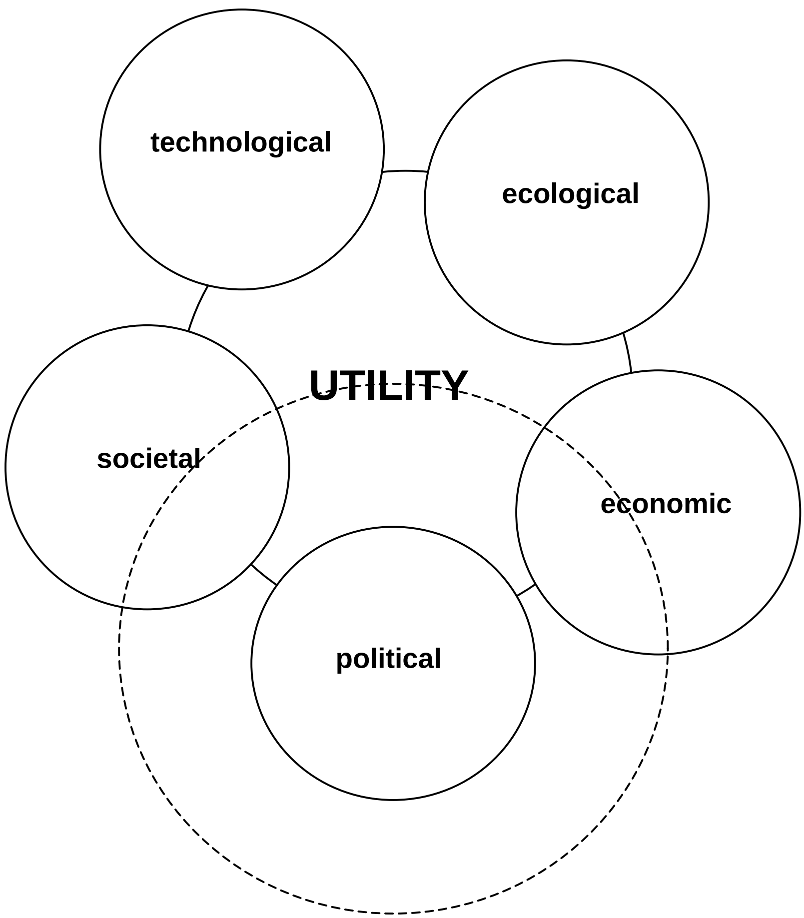

Figure 5.1. *Simplified displacement model with five influence domains.*

6. Influence domains

It is generally accepted that excessive government interference in the financial and managerial operation of power utilities in many developing countries has adversely affected the performance of these organisations. The possible negative impact of the political elite on utility operation is illustrated in Figure 5.1 which depicts a simplified displacement model. Generally, four domains of influence are distinguished when an impact on utility operation is discussed: the technological, the ecological, the economic and the societal domains. These domains reflect the diverse interests and the final category should include political interests. While, in many developing countries, the majority of the population do not have any influence on the nomination of politicians, the Western world is facing a steadily increasing and alarming distance between society and the political elite. For this reason separate societal and political domains have been distinguished in the environment of utilities. The societal one refers to the interests of society at large while the other one serves political interests. Specific national cultural aspects are seen as part of the societal element and the sometimes observed “donor domain” reflecting specific interests of donors is omitted. The message of Figure 5.1 is clear: as exemplified by the dotted circle, an excessive increase in political influence on the utility causes the other domains to move away from the utility function and to become subordinate. The end result could be an entirely political “business” without a sufficient relationship with the societal, technological, economic and ecological interests and, of course, the actual utility function. This illustrates the need for utilities to operate at more than an arm’s length from the political world. With regard to the role of politicians in relation to the planning and implementation of rural electrification programmes a certain ambivalence may be recognised: on the one hand the utility should be managed on an arm’s length, on the other local politicians could play a functional role.

7. *Neo-liberalistic ideology*

In most countries, industrialised and developing alike, the electricity supply sector is experiencing a period of unrivalled institutional change. The emergence of new and efficient technologies is often seen as a catalyst for institutional change (Thue 1995), but this is not the background to the current worldwide liberalisation process. Although the substandard performance of some utilities in the developing world may have induced institutional reform, it is by no means so that the entire global power sector has performed unsatisfactorily. The background to the widespread changes in the power sector is more of an ideological nature: neo-liberalistic ideas with their strong reliance on market forces. Privatisation became the mission and competition is being introduced in the electricity sector because of the expected benefits of greater efficiency relative to monopolies under government regulation. However, Burns and Weyman-Jones (1994)[66]

66 Cited in Bacon 1995.

concluded that with the nearly monopolistic distribution companies in England and Wales, no increase occurred in the rate of productivity in the period after privatisation relative to that before privatisation. The same tendency has been found by Galal (1994) in Chile. More recent information on the financial performance improvements of the power sector in industrialised countries has shown a more favourable picture. One of the arguments in favour of privatisation is said to be the better management of the private sector. However there is insufficient evidence to defend this argument and, moreover, the transition from a publicly owned to a private utility does not in itself cause management benefits. Removing direct political interference in utility operation, increasing autonomy and appropriate legislation appear to be the most successful steps towards performance improvement. Another significant obstacle in some countries has been the rigid legislation that has prevented industrial and independent power producers from supporting public electricity generation, and utilities from establishing joint ventures with these organisations. The legal and administrative systems that have been adopted to suit large-scale centralised electricity supply, need modification to allow the integration of small-scale generating units in a distribution infrastructure, and the involvement of the private sector in power generation. Deregulation paves the way for solutions that can effectively contribute to rural electricity supply as illustrated in Cases 5.2 and 5.3[67].

Case 5.2: Independent Rural Power Producers

India has mainly relied on grid-based electricity supply and this system will continue to be the backbone of India's power supply for large urban and industrial centres. To provide grid-based access to reliable electricity for the other half of the population, in the more remote areas, would require massive investments in transmission and distribution equipment.

This is the reason why the opportunities for decentralised rural electricity generation systems have been assessed, and a concept based on a biomass gasification plant developed. A pilot plant performed well and provided valuable lessons. It also showed that the electricity service could be reliable and affordable for both industries and the public. As with traditional power systems, low cost investment capital, reasonably priced fuel and acceptable plant load factor are decisive factors.

Particular attention has to be paid to site selection, biomass management and the opportunities to use the waste heat for heating and cooling purposes. One of the

67 See also ESMAP 2000b.

main obstacles to the wide-scale implementation of this technology in rural areas is the lack of human resources.
The potential of small independent power producers to supply rural power has often been underestimated. Sufficient rural entrepreneurs are willing and able to invest but they often lack the appropriate type of funds and so that form of support is needed.
Following the results of the pilot plant, DESI Power developed an Independent Rural Power Producers Programme aimed at establishing joint ventures with local communities, small-scale industries and entrepreneurs. DESI Power provides 25% of the financial resources in the form of equity, local partners provide another 25% and the remaining 50% is market funded, if possible from green funds or from donors. In order to demonstrate the commercial viability of decentralised village-scale biomass-based power generation and distribution, and to support the electrification of rural areas, six IRPPs are being established with financial support from the Dutch Ministry of Development Co-operation
These 100 kW power plants will be fed with a locally available local weed and will be operated and maintained by local staff (in some cases from the local power utility). Technical and management training is part of the project. These projects offer local employment, development and social advantages and, since based on renewable energy resources, environmental benefits as well.

Sources: H.Sharan from DESI Power (Joint ESMAP/ASTAE/RPTES/AFRREI donor meeting, Washington, April 2000), J.F.M.de Castro (personal communication), A.Khosia, ("Independent Rural Power Producers and Sustainable Development in India", Renewable Energy for Development, September 1999, vol. 12, No.2/3).

8. *Approach of electricity distribution*

In their publication "Reshaping the electric power industry", Flavin and Lenssen (1994) provide a blueprint for the future of electricity supply. They advocate "a competitive market for wholesale electricity generation, an open access transmission system, incentives for reliance on diverse power sources, and development of a service rather than a commodity oriented local distribution system committed to integrated resource planning and demand side management". This concept is, essentially, the basis of the restructuring efforts in most countries with a mature electric infrastructure. Flavin and Lenssen are right in arguing that power distribution is potentially the most dynamic component of the entire electricity business as a result of the range of innovations now under way in decentralised electricity technologies. They recommend legally separating the distribution business from power generation and transmission, "so as to ensure that local distributors maximise economic and environmental opportunities ….. These distributors would periodically prepare integrated resource plans, selecting an appropriate mix of power service options, including demand side management and locally based power generators”. They argue that “the distribution utility’s profits should be de-coupled from its sales, linking profits instead to the ability to provide energy services at the least economic and environmental costs – known as ‘performance-based’ rate making”. This approach implies that the distribution company is made responsible for the entire regional energy business and that the performance assessment criteria include both economic and environmental aspects. Such an approach is attractive but seems at odds with the competitive thrust. Though not the most obvious solution for immature infrastructures, large-scale generation and transmission on the one hand, and distribution on the other, could be operated independently and under different regimes in terms of private and public involvement, and financial support. Proper co-ordination between central generation, transmission and distribution would have to be provided. But, for the electrification of rural areas in developing countries, a separation of the “grid” from the delivery of services should be avoided. In an unbundled situation there is basically no central generation planning, generators invest only where they expect sufficient profitability, and a system operator is responsible for balancing generation and load[68]. This might be appropriate for large-scale mature systems but it is not for the multi-functional distribution systems with a variety of dispersed generators of the future.

Case 5.3: Windfarm Hiddum-Houw: an example of advanced co-operation

In the coastal area of the province of Friesland in the Netherlands, a 5 MW wind farm has been erected as a result of a co-operation agreement between the regional electricity company NUON and a private farm (see Figure 5.2).
The site offers favourable opportunities for electricity generation with a mean wind speed of over 7.5 m/sec. Since 1995, ten windturbines of 500 kW each supply electricity to the grid. The annual production of the wind farm was estimated to be 13,000 MWh. Although wind speeds were below average during 1996, the windfarm still produced 12,159 MWh in that year. Of the ten wind turbines, seven are owned by the utility and three by the farm.

68 Cigre session 2000 (group meeting 37/38/39): concerns were expressed that in Norway available generation capacity would, in a severe winter, not be sufficient to satisfy peak demand because power station owners do not offer capacity because of low prices. The system operator is not responsible for matching future generating capacity to future demand.

The windfarm site is primarily the property of one farmer but two of the utility owned wind turbines have been erected on the land of a neighbouring farmer.
Originally, the farmer and the utility had different intentions. The farmer, supported by a regional wind energy consultancy, had developed a plan to invest in a limited number of wind turbines for electricity generation and thus needed a connection to the local grid. The utility was in search of a suitable site for a windfarm somewhere in its supply area.
The first consultations between the parties involved, revealed that the local grid was unsuitable for transmitting the power generated, even with a small number of wind turbines. To maintain acceptable load- and voltage conditions, a new medium voltage connection between the location and the nearest 110/10 kV substation was necessary. Such a connection appeared to be cost-effective only if the capacity of the windfarm was increased to at least 5 MW.
The solution was a windfarm in which the farmer owned three and the utility seven wind turbines of the same type and capacity.
The agreement between the utility and the farm addresses the co-operation between both parties, and the purchase of electricity and the land use by the utility. In more detail, the agreement between the utility and farm covers the following issues:

- The right of way, the wind rights and other rights for a minimum of 15 years with the possibility of five-year extensions.
- Co-operation regarding planning, project-management etc.
- Access roads have been constructed at the expense of the utility and subsequently ownership has been transferred to the farm. Maintenance is carried out by the latter.
- Compensation for land use: the utility will pay compensation to the landowners which is a function (5%) of the electricity produced by the wind turbines and the tariff applicable for wind based electricity supplied to the grid by private generators (*). A minimum compensation per year, based on a fixed amount per kW of installed capacity, has also been agreed.
- Site supervision: the farm carries out limited supervision of the windfarm. Compensation is based on a fixed amount per kW of installed capacity.
- Maintenance of turbines and other equipment: the utility has contracted the supplier for maintenance and the farm had the opportunity of joining the agreement. The costs are divided on the basis of the capacity owned by the participants.
- Electricity supplied to the grid by the farm: the tariff is based on the quantity of electricity produced (kWh) and not on the power in kW. Obviously, an allowance based on both kWh and kW is possible but because of the high costs associated with the measurements this is not feasible for this type of installation.

The project involved a co-operative municipality and the local population. The procedure for the environmental impact assessment appeared to be the most time

consuming activity, mainly due to a discussion on the arrangement of the wind turbines.
Both the utility and the farm were granted a subsidy of approximately one-third of the investment costs of the wind turbines. Operational costs are not subsidised (*).
Obviously projects of this nature will only emerge where private individuals and utilities show enterprise and if appropriate stimulating conditions, including subsidy schemes, exist.
Other private individuals in the supply area of the utility have also expressed the desire to invest in wind energy. In most of these cases, preference is given to the establishment of private limited companies with a number of shareholders, including the utility, commercial banks and equipment suppliers.

(*) The tariff is based on the avoided cost. In April 1995 a minimum of US$ 0.081 was applicable. This amount included a government subsidy of US$ 0.033 per kWh supplied to the grid.

Source: Personal communications (U. Bouwman and P. Wiersma of NUON, The Netherlands dd. 27/02/1997)

9. *Power sector reform*

As has been suggested in Section 4.7, the widespread corruption in some developing countries is one of the most difficult impediments to an adequate performance of parastatal organisations. It is now accepted that structural changes such as corporatisation and privatisation of the organisations are needed to effectively remedy these ingrained institutional practices. As a response to the growing dissatisfaction with the poor performance of "politically infected" and other similarly performing utilities, also solutions based on deregulation and privatisation have been proposed.

On the other hand, a certain reserve with regard to the privatisation[69] of public utilities in developing make senses. The role that the private sector and market forces can play in the power sector of the developing world must not be overestimated. Other reasons for reserve include the fragmentation of the power sector as a result of restructuring and the fact that, with a growing infrastructure, most of the investments are only recoverable in the long term and thus unattractive for private investors. It should be noted that industrialised countries established a mature electricity infrastructure prior to the current liberalisation process. Privatisation and the introduction of competition, together with the associated unbundling of generation, grid

69 For a definition and meaning of privatisation, main forms of privatisation and arguments in favour and against, see for example Boorsma (1994).

management and the delivery of services, when the infrastructure is still in its infancy, would seem “a bridge to far”.

As has been elaborated in Section 4.7, the bidding systems for the supply of electricity, as applied in some industrialised countries, are too complex for smaller power systems and for economies at low levels of development. In these situations a contract system is a better option for generators to sell power.

As has been concluded in Section 4.7, industrialised countries could determine the maximum power sector reform that is desirable, while the question for the developing world could be what is the *minimum* reform that is appropriate to stop political interference and government intrusiveness and to enable utilities to buy power from, and co-operate with, independent generators, including industries.

Figure 5.2. *Combined cattle and windfarm.*
(photo: G. Martha Zomers)

10. *Government involvement*

The involvement of the state more-or-less guarantees the continuity of enterprises that are strongly influenced by government decisions, such as power companies. However, this involvement should not take the form that the civil service “rules” the company. It is generally accepted that utilities must be enabled to perform as enterprises, and not as instruments with which to pursue political aims. This however does not generally require a complete restructuring of the sector. As Hek (1994) suggests, a solution should be found in appropriate regulation and a market-oriented utility.

Generation and supply of electricity have always been considered too important to be left to market forces alone. This is one of the reasons why national, provincial and even municipal governments often took responsibility for the delivery of this public service and, to that end, established power supply utilities as part of their organisations. As a result, nationalised or semi-government organisations with a monopolistic nature have emerged in many countries over the years. In some countries monopolistic investor-owned utilities emerged alongside government regulation. There is evidence that publicly-owned utilities can be operated efficiently if an appropriate institutional framework and business environment exist which provides management with the authority and incentives to achieve an acceptable company performance. For these successful companies, the World Development Report 1994 “Infrastructure for Development” (World Bank 1994), lists three basic characteristics:

- The organisations are run on commercial principles and have clear and coherent goals focused on delivering services.
- Their management is autonomous.
- They enjoy financial independence.

Provided that the utilities have sufficient authority, “government ruled” structures are appropriate while the electric infrastructure is expanding and all efforts are directed at making electricity available to the whole population. In industrialised countries, the more expensive rural and remote places were not left behind because the power supply entities were enabled to electrify their supply area on the basis of a more-or-less complete area coverage. Most of these utilities were vertically integrated and, as a result, the indispensable co-ordination between generation, transmission and distribution of electricity was ensured. If demand is growing at 5% per annum or more, an adequate planning relationship between the generation and distribution of electricity is extremely important because electricity must be produced when it is demanded. There have been many occasions when a poor tuning of both functions has ended in sub-optimal and un-economic use of technical facilities and operational losses. The ongoing power sector reform, with the associated unbundling of generation, transmission, distribution and supply, and the introduction of competition demonstrates that strong regulation is needed to avoid such co-ordination problems.

11. *Privatisation nor competition a solution for rural electrification*

The neo-liberal wave in the power sector is claimed to offer opportunities, challenges and lower energy prices but the current economic rationalism could also lead to a decline in the efforts to electrify rural areas. Generally speaking, electricity supply to rural and remote areas is not very profitable, and in a more liberal environment, this is at odds with efforts to improve the financial performance of utilities. When electricity is treated as a commodity in a market place dominated by private companies, historical evidence suggests that tariff structures will be more attractive to large customers than to residential ones and little attention will be paid to rural electrification. Without appropriate regulation, the fear that rural consumers in the electrified areas of industrialised countries will be saddled with higher costs will become reality. Liberalisation and the introduction of competition in the electricity sector aims at creating an environment in which generators and service suppliers compete for existing consumers. In the rural areas of developing countries there is no electricity, there are no suppliers, and only a few customers who could afford to pay the full costs of electrification. There is no reason to expect the emergence of forces in this institutional market except, perhaps, for stand-alone equipment such as SHSs. It seems fair to conclude that neither the privatisation of utilities nor competition is a solution for the electrification of rural areas in developing countries. Moreover, it would seem impossible to find private enterprises prepared to electrify rural areas, charge affordable tariffs, and accept a very low rate of return[70] against the background of the risks including a low take-up of power consumption. The author agrees with Patterson (1999) that, without special regulations, the more than two billion people in the world without access to electricity are unlikely to benefit from the worldwide liberalisation process and the reliance on market forces.

12. *Energy conservation and renewables*

In a competitive environment, the efficient use of energy and the deployment of renewables are unlikely to receive substantial attention from the market place[71]. This was also the conclusion of a study in the Netherlands (CE 1994) and the main finding was that there is a need for government supported programmes to solve energy conservation bottle-necks. The industrial and the commercial sectors offer the most interesting opportunities for cost-effective energy services provided that the energy bill and the conservation potential is sufficiently high. The study concluded that those with a low energy consumption can only be served if the energy service is subsidised. An integrated approach of risk management, financial engineering and project management would best suit this market. Because of

70 Independent power producers seek to gain a return on their investments of around 17% (GEC/Alstom 1997). Such a return cannot easily be obtained in rural areas (10% would be more normal).

71 See Section 4.7.

the relatively limited number of energy functions, the commercial sector is the easiest to approach unlike the industrial sector with its various processes requiring specific expertise and short payback periods. Most energy efficiency measures in the residential sector are not cost-effective because of the needed labour intensity. The interest by entrepreneurs in the establishment of energy conservation project development organisations has been marginal, and government support in the form of working capital and subsidies appears necessary. The study suggested that energy distribution companies could establish these organisations. The experience with ESCOs reveal that their services focus on industrial and large commercial customers rather than on households. In this customer category both the expected savings and the business opportunities tend to be larger. Since local communities and small enterprises could not afford to pay for such services, there is no reason to expect a market for ESCOs in the rural areas of the developing world. This suggests that regional offices of a utility and/or local enterprise should address energy efficiency services for small-scale industries, commercial enterprises, and the domestic sector in these areas.

13. *Implementation of rural electrification programmes*

The substandard performance of national utilities in some developing countries, their centralised organisation and perceived bureaucratic attitude, has led to the question whether they are suitable organisations to manage the electrification of rural areas. Opinions also differ on the "appropriateness" of utilities as promotors of renewable energy technologies. The extent of centralisation in these utilities would make the implementation of small-scale projects in rural areas difficult, and operation and maintenance complicated and expensive to manage. These utilities give priority to generation, transmission and urban projects it is believed because of the larger size of the projects and their greater technical complexity (Mason 1990). Kaufman et al. (2000) are also negative about the ability of larger utilities to implement SHS based rural electrification programmes. They argue in their research report "Rural electrification with solar energy as a climate protection strategy" that these systems can be seen as a "disruptive technology", the deployment of which "can disrupt the traditional electricity business, which typically relies on a big power plant connected to customers through extensive wires". They argue that the involvement of small organisations is necessary for the distribution and maintenance of these SHS systems. However, other research (WB 1996a) has revealed that none of the institutional models recently used to implement SHS programmes have failed, some effective and sustainable schemes have made use of existing organisations including national utilities. Historic analysis[72] reveals that

72 See Chapter 3.

national and provincial utilities in the industrialised world, and in some developing countries, have been able to electrify rural areas with success and in a sustainable manner. In nearly all countries, dedicated entities were made responsible for the implementation of subsidised rural electrification programmes. Large power utilities that have been responsible for these programmes have generally adopted, for their rural electrification operations, a decentralised organisation on a geographical basis: the district structure. This structure, with more-or-less autonomous entities, has proved to be both efficient and effective, at least in the period during which the electricity infrastructure was developed and consumption stimulated. For a stable situation, as with a mature infrastructure and steady customer base, a centralised organisation structure may offer efficiency gains. Recent experience in various industrialised countries with mature electric infrastructures, reveals that power companies have had to adapt their internal organisations several times to meet changing circumstances, including a stabilisation of demand, more emphasis on demand side energy efficiency, growing importance of renewables, and the introduction of competition with an associated need for entrepreneurship.

14. *Implementation organisations*

The analysis in Chapter 3 revealed that dedicated, and more-or-less financially autonomous entities, have been an appropriate solution for "green field" rural electrification programmes. There is evidence[73] that for the institutional embedding of such entities no single model is likely to work well everywhere. In a review (World Bank 1996) some institutional alternatives are given:

- Public or joint public-private involvement in distribution together with regulations requiring companies to supply a service and allowing an acceptable financial rate of return.
- Private distribution company together with regulations requiring supply to the region and allowing an acceptable financial rate of return.
- Private distributors and a regulator monitoring the prices, efficiency, and quality of the service.
- Development of small power systems by electricity co-operatives or private companies.

It would seem that the basis for the institutional embedding must be found in the world of politics rather than from organisational experts. This is recognised by Nye (1990) who argues that the American system which is dominated by private companies, but which also has municipal, federal and

73 See Chapter 3, Flavin et al.(1994), Foley (1993) and Mason (1990).

co-operative utilities, “was hardly an inevitable result of the technology itself, but reflected the political and economic segmentation of the country”. History does not support one type of structure over another, both centralised organisations and co-operatives have successfully and sustainably implemented rural electrification programmes and also had failures. Small-scale private businesses have had mixed success (see Case 5.4).

Case 5.4: Small-scale private electricity supply

Although many rural electrification projects have been realised during recent decades by the Indonesian national utility Perusahaan Umum Listrik Negara (PLN), many villages will remain unconnected to the national grid for the years to come. These villages are located in very remote and isolated areas far beyond the transmission network.

Quite a few of these villages however do have some form of electricity supply provided either by small co-operatives or by private generators. In the latter case, typically by diesel generators of 3 - 5 kW owned by the village chief or a local shop owner, supplying single phase electricity to surrounding premises through a simple distribution system (Figure 2.2) for a limited number of hours. The electricity is mainly used for lighting purposes and for charging of batteries used for TV and radio equipment. Many of these small-scale private electricity supply systems have experienced difficulties in maintaining supply. Discussions with owners have revealed that there is a need for electricity and, in general, a willingness to pay. Howeve, it was also apparent that the management and the organisation of revenue collection and maintenance pose problems. In one case, the owner (the village chief) removed the connections to some 80 premises and lights because of repeated problems with the collection of the revenues. Obviously the relationships between the villagers and their fellow-villager/ electricity entrepreneur could be frustrated by such defaulting. These experiences would suggest that a more neutral agent, for instance a bank, is a desirable way of managing the collection of money.

Source: Hommes/Zomers, “Report mission electrification South Sumatra”, November 1987 (unpublished).

The advantages of co-operatives are said to include ownership of the community or groups of individuals, and the direct link with the beneficiaries. Ownership is extremely important and the likelihood of success is significantly increased if the initiative to establish a co-operative comes from the stakeholders and not from external promoters. There is also

evidence that the success of co-operative organisations, and possibly electricity utilities in particular, is culturally and situationally determined.
As appeared in Section 3.8.2 there are a number of quite successful co-operatives, but when the organisations became politicised and used for development activities other than electrification, the consequences were mis-management and deterioration of operational performance. Co-operatives, and this also applies for all small decentralised organisations, often show weak management structures and therefore need strong management, administrative and technical support (see Case 5.5). If utilities are to operate at more than an arm's length from the political world, municipality-based utilities are not the most appropriate method of institutional embedding. Another drawback with these municipal utilities is linked to the electrification of supra-municipal areas. In many countries a national or a provincial power utility was preferred in order to avoid municipal boundaries hampering the development of an economically sound electricity infrastructure, and to achieve an acceptable area coverage and sufficient uniformity in tariffs.

15. *Multi-utilities*
The restructuring of the power sector in the industrialised world has led to an increased interest in multi service utilities. These multi-utility companies deliver to the end users a range of services that can include electricity, gas, heat, water and even waste disposal, home and business security systems, telecommunications and/or cable TV systems[74]. The potential advantages of the multiple utility services approach are better customer service, economies of scale through combined meter reading and customer information and billing systems, and improved and cheaper marketing. The multi-utility concept could offer a good opportunity for identifying and effectively deploying local resources and delivering the most appropriate services to customers in rural areas. A separation between the "wires" in rural areas and the delivery of the service should however be avoided, as this would be at odds with an effective integrated resource planning. Moreover, co-operation with small independent power producers will require an overview of the limitations of the grid in relation to power demand, consumption and power production opportunities. For the multi-utility provider, a service oriented organisation is needed and an approach should be adopted that also takes environmental and reliability aspects into account.

74 A recent development is the interest of media companies (Cable TV) in un-electrified rural and urban areas in developing countries. The proposed contract includes the supply of media as well as electricity.

Case 5.5: Locally managed organisations

In many developing countries, private initiatives have been taken for the small-scale supply of electricity to rural and remote areas. In Tanzania, power sector reform and privatisation plans induced a renewed interest in the possibilities and associated problems of locally managed electricity supply organisations. Research conducted by Gerger and Gullberg, aimed at identifying the various aspects of local organisations and their management that could be useful in the implementation and assessment of pilot projects in the supply area of the Tanzania Electric Supply Company (Tanesco). Apart from a literature survey, the research included an investigation into eight rural power supply organisations in Bolivia, Nepal and India. These organisations included share-holder companies, co-operatives and associations of consumers. The smallest company investigated supplied power to 150 consumers and the largest to 165,000.

In all three countries locally managed power supply organisations emerged in response to problems with national rural electrification programmes and the inability of private power companies to expand the power system into rural and remote areas.

The research revealed that local organisations can be viable and successful in supplying power and that there is no distinct preference for the form of administration. Flexibility and sensitivity to local preferences and conditions, and the willingness of local people to support the development of their living areas are important. The following success factors emerged from the research:

- Appropriate long-term managerial, financial and technical assistance is essential.
- Clear and consistent national rural electrification plans are needed.
- The involvement of local people in the planning of the power supply system promotes the identification of solutions and productive use of power, and eases implementation.
- An indigenous and autonomous organisation should support local initiatives, guide external assistance and ensure that the rural electrification projects are properly designed.
- Many countries could benefit more from locally available energy resources.
- Tariffs should generally be set to cover all costs.

Source: Å. Gerger and M. Gullberg, “Rural power supply with local management”, Stockholm Environment Institute (SEI), Energy, environment and development series No.43, 1997.

5.2.2. The answer to the general research question

In Chapter 1 the general research question was formulated as follows:
"What is the impact of past experiences and current developments and trends in the electricity sector on the electricity supply to rural and remote areas, and which approach could lead to improvements?"

To answer this question, Chapters 2 and 3 addressed the features of rural electricity supply, analysed historical aspects of rural electrification, and listed the lessons learned. In Chapter 4, the nature and scope of the developments and trends in the electricity supply sector were identified and discussed. This chapter summarises the results of the previous chapters and draws conclusions regarding the appropriate approach for electricity supply to rural areas in developing countries. Based on these findings the answer to the general research question can be formulated as follows.

Affordable energy is necessary to lift rural economies in the developing world to and beyond the subsistence level. In an advanced society, electricity is essential and without it the communities could no longer function. Modern industrial processes, and commercial and information facilities need electricity. The introduction of modern technology will help rural industries to manufacture products with an added value and it is reasonable to conclude that, with growing development, rural areas in the developing world will increasingly rely on electricity.

In view of the relationship between social and economic development on one side, and electricity demand and affordability on the other, rural electrification should preferably be a fully-fledged component of rural development programmes. Further, there are other aspects of energy provision, and particularly electricity supply, to consider when planning the development of rural areas:

- Development efforts increasingly imply the introduction of electricity to rural areas, and an institutional infrastructure for education and technological support concerning its use is needed.
- In many rural areas of the developing world the potential to use locally available energy resources seems large, and current technological developments enable the deployment of small-scale traditional and renewable energy concepts.
- Transaction costs of small-scale energy concepts could be lower if the financing volume is larger.
- New power sector legislation can allow the utilisation of excess power generated by local industries to help satisfy residential and commercial demand.
- To take full advantage of these opportunities, an integrated approach to power system planning, locally available resources, industrial infrastructure planning, and the expected development of regional energy demand is needed.

A general conclusion is that electricity supply to rural and other remote areas has always been considerably more expensive than the supply to urban areas. All over the world, the majority of rural electrification programmes have needed public involvement and a special funding approach. These observations suggest that future rural electrification efforts will need some form of subsidy, unless a cost breakthrough regarding, for example, photovoltaics occurs. Unlike the industrialised world at the beginning of the twentieth century, the presently developing countries do not have reasonably well developed economies and rural infrastructures, and most of their economies are too weak to allow major investments in rural infrastructure. This leaves a need for the international community to support rural development activities.

In the past, the support of the international community for electrification was mainly directed towards national governments. In essence the ongoing restructuring of the power sector implies a decentralisation of responsibilities and authority, and this would suggest that, in terms of the development and electrification of rural areas, the next few years are likely to see a shift in the financial and technical assistance to regional and local institutions.

Historically, most countries preferred the central grid-based electrification of rural areas though for very remote places stand-alone diesel power stations were (and still are) used. However, it is generally accepted that the provision of electricity using central grid-based systems to remote areas with small populations is economically not justifiable. This feature now has increased significance because it is the more remote areas, where the poorest people live, that must be addressed. Though cost reductions still seem possible, the average investment needed per connection for central grid-based rural electricity supply is likely to remain of the order of US$ 1900[75].

There is evidence that currently available technologies pave the way for reliable and more economic small-scale on-site power generation and advanced sub-transmission systems. The deployment of these facilities, including advanced power electronics, will have an impact on existing rural grids and offer attractive alternatives for the electrification of yet un-serviced areas.

As a result of the move towards the deployment of dispersed generation facilities, existing distribution systems in both urban and rural areas will change from “one-way”systems into multi-purpose systems[76] and therefore their capabilities, including protection and control, will have to be enhanced. This development, together with the increasing demand, and the efforts to maintain service quality, will force utilities in industrialised countries to reconsider the configuration of existing rural distribution and sub-transmission systems.

75 See Box 2.1.

76 See Section 4.3 and Figure 4.3.

In developing countries, and depending on locally available resources, many future rural electrification schemes are likely to start with decentralised generation facilities, near the community that will benefit or even, as in the case of Solar Home Systems, as part of the dwellings themselves.
Compared to the relatively straightforward planning of passive central-grid based systems, future dynamic distribution systems will require a much more advanced planning and engineering approach. To achieve optimal solutions, the future rural multi-purpose system must be viewed as an integrated system of local energy production, distribution and consumption. This is why a separation of the grid from the marketing and delivery of services, purely for the sake of introducing competition, should be avoided.
Renewables can be the most economic option and the only realistic way of supplying energy to some rural and remote areas. Although their capability is relatively limited, Solar Home Systems are an excellent option for satisfying the initial electricity needs of some of the rural populations in developing countries. These systems can cost-effectively replace the automotive batteries that are currently used some of the rural areas of the developing world, to power lights, radios, and small TV sets. The cost of the electricity provided by the batteries is often several US dollars per kWh. However, the initial costs of currently available SHSs are still high and the majority of rural people in the developing world need subsidies and appropriate financing schemes.

In order to satisfy the increasing demand for electrical services such as for refrigerators and freezers, and advanced medical and industrial facilities; more powerful supply equipment able to provide electricity "around the clock" will be needed. The implementation of any electrification scheme should therefore be part of a well-founded long-term strategy and fit into other development plans.
In many less developed countries, the performance of electric power utilities in supplying remote and rural areas has decreased gradually in spite of the provision of external financial support. Moreover the benefits and progress of a considerable number of rural electrification projects has fallen short of expectations. These are some of the reasons given when lending and donor agencies exert pressure on developing country governments to embark on power sector reform and search for other organisational solutions to rural electricity supply than those using traditional utilities. There is, however, convincing evidence that the lack of financial and managerial autonomy, and the resulting political interference in utility operation, are key factors in the substandard performance of utilities. If the appropriate institutional conditions are in place, traditional utilities can meet high standards of performance and management, as has been shown in many countries. It is, therefore, generally accepted that legislation and power sector reform should lead to an appropriate business environment with a government that focuses on the establishment of appropriate preconditions and relevant regulations. It should remain the responsibility of the government to look after the interests of the poor and to ensure that such non-

profit making activities as electricity supply reaches rural and remote areas. There are good reasons to fear that under a more liberal regime, these rural interests will particularly suffer.

With immature electricity infrastructures, power sector reform does not necessarily lead to an unbundling of generation, transmission and distribution, or a complete withdrawal of the government from the sector. In many developing countries, a "government-ruled" structure is appropriate provided that the utilities are able to operate at more than an arm's length from the political world. Provided that proper co-ordination between central generation, transmission and distribution is ensured, large-scale generation and transmission on the one hand, and distribution on the other, could be operated independently and under different regimes in terms of private and public involvement, and financial support.

Even more so than in the past where central-grid based rural electrification was the norm, a decentralised organisational structure would seem more appropriate for future electricity supply to rural areas in developing countries. The justifications for this statement include:

- Rural electrification should preferably be a component of rural development programmes. The international funding community is likely to focus on regions, and this would benefit the design and implementation of appropriate customer financing schemes.
- Future rural electricity systems require an integrated approach to system planning, locally available resources, and industrial infrastructure planning.
- Decentralised organisations have benefits in terms of marketing, the identification of customer financing needs, and communication with all stakeholders.
- The tendency to decentralise responsibilities and authority within the framework of the ongoing reform process.
- Operation and maintenance management of multi-functional systems that include solar home systems, requires a region-oriented approach.

The research findings do not support one type of utility organisation over another. It is noted that the findings essentially refer to central-grid based electricity supply. However, if a utility is reasonably efficient and innovative, then it should be able to implement different forms of rural electrification programmes. The most important conditions for success are that there is a separate rural electrification entity with clearly allocated funding, a strong regional level organisation to identify customer needs and carry out implementation, operation and maintenance, and, most importantly, a commitment on the part of the utility to carry out these electrification programmes.

The transition of vertically integrated utilities into horizontal structures, the deployment of dispersed combined heat and power units, and the competition introduced in the power sector of industrialised countries, have been conducive to the establishment of multi-utilities. This concept has many proponents and it can give additional consumer and efficiency benefits. Multi-utilities can offer customised solutions provided that the organisation, the attitude of its staff and the corporate culture are aligned to client care. The multi-utility approach can also be a favourable option given the decentralisation of power generation that is currently taking place.

It is justified concluding that the design and implementation of future rural electricity supply systems is much more complicated than in the past. Demand forecast simply on the basis of extrapolating historical data is no longer appropriate. Nowadays, rural electricity infrastructures depend on the possibilities offered by locally available resources, and new demand and supply side technologies. Utilities need to adapt technically and organisationally to this new reality. Reform of the power sector in developing countries should pave the way to an appropriate business environment and to a more autonomous operation of utilities, more than an arm's length from the political world.

However, the support of the international community for the development and electrification of rural areas is needed. A well-performing electricity supply organisation is not only in the interests of the rural community, but also one of the prerequisites for receiving this support.

5.2.3 Rural electrification: utilities' chafe or challenge?

As was shown in Chapters 2 and 3, electrification of rural and remote areas has always been relatively expensive. Capital costs are relatively high and revenues frequently poor. Rural electrification has therefore often been regarded as a utility's chafe. This observation, and the perceived substandard performance of government-ruled utilities in several developing countries, made their suitability for future rural electrification efforts questionable.

Several utilities in the developing world have not been interested in the electrification of rural areas, the major obstacle being the negative impact of rural electricity supply on the financial performance of the company. There are however indications that this situation is changing[77] and there is reason to believe that this is connected with:

- The increased pressure from the outside world to develop rural areas and to alleviate poverty.
- The ongoing power sector reform and the creation of an appropriate business environment.
- The options offered by modern centralised and decentralised systems, using both traditional sources and renewables.

77 Personal communications with utility staff and development agencies.

- The opportunities offered by donors and recently established funding instruments such as Joint Implementation, Clean Development Mechanism and the Global Environment Facility.

There are indeed sufficient reasons for utilities in developing countries to start rethinking their strategies regarding electricity supply to rural and remote areas. First of all: the question is no longer whether these areas will be electrified, but when. As previous chapters have shown, progress in the field of energy technology, including renewables, has been significant and new opportunities present themselves through both demand-side and supply-side developments. Rural electricity supply also has new dimensions stemming from a better insight into the whys and wherefores, the environmental issues, and the sustainability of power resources. If utilities do not act proactively, they will lose the opportunity to contribute to the development of these areas and to have a role in the associated substantial future electricity market.

The question posed in the title of this thesis is whether rural electrification should be seen as utilities' chafe or challenge. From the analysis of the current circumstances, the answer is without doubt: a challenge. But, at the same time, it is argued that the electrification of rural areas in the developing world should not be considered as a challenge for utilities only, but also for the global society at large. It was also emphasised that the presence of an appropriate business environment is a prerequisite for taking up that challenge and promoting support from national governments and the international community.

As with their counterparts in many industrialised countries, utilities in the developing world can play an important role in the development and electrification of rural areas, but first of all they must break out from the corner where they have to defend and explain themselves all the time. They have to do this for themselves. When appropriate institutional conditions are in place, the solution lies in organisation and management.

5.3 The management challenge

In many developing countries there are social and political pressures to electrify rural areas and there is reason to believe that these pressures will grow more. In both industrialised and developing countries, the pressure on utilities to embark on renewable energy programmes and to further improve energy efficiency is also expected to grow.

Of all the energy options, electricity is expected to remain the fastest growing form of end-use energy worldwide and it is therefore of the utmost importance that the electricity sector meets the growing demand in an efficient, environmentally and socially acceptable way.

As was seen in the previous chapters, the most important grounds for a fresh look into the institutional embedding and approach of electricity supply utilities

supplying rural areas in developing countries, are found in institutional failures, a changing business environment and recent technological advances. Environmental concerns, and the need to conserve energy, add to the need for a more advanced approach. Many developing countries are now in the process of reforming their power sectors with the aim of establishing utilities which can be operated as autonomous businesses under an "arm's length" regulation.
The ongoing reform process will offer opportunities for utilities to organise themselves in a way more in line with current views and requirements. However, many factors such as legislation and regulation, new demand-side technologies, environmental concerns, and socio-economic conditions will determine future needs and the ability to pay of electricity customers, making it increasingly difficult to assess the evolution of the rural electricity market. In this era of volatile changes, utility management face a number of challenges:

- To develop an appropriate corporate strategy, culture, and management commitment which ensures that all stakeholders can be satisfied.
- To create a market-driven energy distribution company and to organise new business opportunities and utility services
- To implement advanced energy equipment, services, and customer-oriented information systems.
- To develop communication with stakeholders in order to identify needs and opportunities.

There is no simple design for the internal structure of an organisation but, as the research findings reveal, there are seemingly universal organisational and managerial preconditions for rural electricity supply enterprises to be successful. Apart from the nature of the organisational and managerial problems and the success factors, the management must also have a proper understanding of the environment in which they occur. To this end, various aspects of the environment of contemporary utilities are addressed in the next Section 5.3.1, and the critical success factors elaborated upon in Section 5.3.2. Both sections are confined to the *methodologies* for the approach of an organisation and the analysis of the situation.

5.3.1. Organisations in a changing business environment

It is generally accepted that the environment of utilities has changed over the last 15 years. Before this period, initiatives for adaptations to the strategy and organisation mainly came from within the organisations. These initiatives were triggered by the emergence of new organisational and management theories, efforts to increase efficiency, and sometimes by the need to achieve a better insight into the internal processes and the associated monetary and cost flows.
However, current pressures on the organisation and management of utilities are mainly driven by external developments. As was shown in the previous chapters

these developments include institutional, technological, ecological and societal aspects.
In both industrialised and developing countries, the trend is towards increasing and more insistent interference in utility operations by several groups from the national and international community. The ideas held by the various groups about criteria and values differ widely and change over time. It is likely that further stakeholders will appear and this trend can have repercussions for the communication strategy, the structure of an organisation and its management approach.
These observations highlight the need to pay considerable attention to the actual situation in which a utility has to operate when designing an organisational structure and management model. Kast (1976) argues that "the most appropriate organisation and management models are those which best fit the environment of modern organisations (an extension of Darwin's theme – survival of the fittest)".

Contingency approach

Classical organisational theories focus on internal events and try to identify universal, situation independent, rules on the basis that there is a single structure that is highly effective in organisations of all kinds (Donaldson[78]). But, despite what is often claimed, practice shows that organisational and management theories do not have a universal and systematic validity. It is generally accepted that the organisational structure and management approach are not invariables, and the application of their principles heavily depends on the real situation. The contingency approach provides a basis with which to address an organisation as a socio-technical system[79] interacting with its environment, and can be used as a tool for the design of organisational structures and the associated management concepts.
Staehle (1973) distinguishes between monistic and dualistic classical theories that contain one or two basic organisational principles respectively. However, both types of theories imply a single way of structuring and managing organisations and they do not take environmental conditions into account. With this view, Staehle argues, organisation and management are far too often approached with ill-founded theories, rules, principles and formulae instead of

78 Cited in Clegg 1996.

79 The socio-technical system assumes the presence of a technical and a social subsystem and emphasises the need to better gear them to each another. The notion of the socio-technical system was introduced by Trist and Bamforth in 1951 (cited in Staehle 1973) to express the interdependence of social and technological aspects of production systems. A.K.Rice (cited in Kast 1976) argues that, in a socio-technical system, the effectiveness and efficiency of the utilisation of the technology is largely determined by the social system. This observation emphasises the importance of proper human resource management.

thorough an analysis of the complicated, multi-dimensional problem. He is also of the opinion that most of the organisation theories presented during the eighties, do not satisfy the “classic scientific requirements attached to theories”. More specifically, he argues, these quasi-theories lack the impact of various time dependent environmental circumstances on the selection of organisational and managerial measures, despite claiming a universal validity. The circumstances very much depend on the current political, cultural and economic thinking. Staehle concludes that, in the eighties, such a geographically and time differentiated approach to organisational and managerial problems was rarely employed.

One should be cautious of using the work of Staehle since he based his study on pre-1972 literature. To overcome this concern, relevant literature published since then has been reviewed and it is concluded that only the contingency approach and a more advanced form of sociotechnology emerged after that year. Dutch researchers including De Sitter and In ‘t Veld, and Van Amelsvoort contributed to the development of sociotechnology. In practice, the socio-technology builds on the work of Trist and Bamforth (1951) and the systems theory (Kuipers 1992, Eijnatten 1989). In sociotechnology the focus is on labour quality and the relationships between human resources, job content, technology and advanced controllability through increased reliance on self control. A design methodology based on a modern approach to sociotechnical system design should certainly receive attention when organisational principles and labour divisions are worked out. The situational approach, basically a forerunner of the contingency approach and also based on system theory, emerged around 1970 and so must have been known to Staehle.

Organisation and management theories are continually evolving and the first theory which considered a number of relevant external aspects was the system theory in around 1965. This theory addressed an organisational phenomenon in which all subsystems were correlated and mutually influencing. Unlike the classical methods, the system approach addresses organisational and management problems in a multidisciplinary way including technical, social, and economic aspects, and also environmental influences.

Schieman (1980) argued that perceived problems with the academic level of system theory led to the establishment of two advanced approaches: the situational approach (1970) and the contingency approach (1976). Kramer (1978) states that the criticisms of system theory are often justified and he notes the lack of practical recommendations as an example. Both the situational and contingency approaches are based on the system theory in terms of organisational and management questions, and consider an organisation as a socio-technical system.

The situational approach aims to include all relevant aspects when identifying organisational structures and management models and is open to various solutions. Staehle argues that the situational approach to organisational and managerial problems, if founded on an analysis of concrete situations, leads to

the formulation of condition-based and situation-based propositions. The contingency approach is a more advanced and practical elaboration of the situational approach and produces recommendations as to how to construe the functional relationships in specific circumstances.
The contingency approach takes the situation and the environment in which a problem occurs as the starting point, followed by the selection, from existing theories, of the appropriate organisational and managerial principles. This approach assumes an open-system because such a system tends to experience interactions with its environment (see also Section 1.5.5).
Contingency theory states that there is no single organisational structure that is the most effective for all organisations, and that the optimal structure and internal processes are contingent upon such factors as the technology, environment and staff expectations, and their uncertainties. This approach is attractive because (based on Kramer 1978):

- It departs from a pluralistic[80] perception of organisational theories and fits in with the system theory.
- It leads to recommendations for decision making in terms of organisational and management questions in specific situations. The specific situation determines the solution.
- It is suitable for practical problems.

Because of the dynamics in the environmental conditions of contemporary utilities, classical organisation theories should be considered as inappropriate starting points for the identification of organisational and management models. Unlike classical theories, the contingency approach explicitly takes the features of the real situation into account and would therefore seem a good starting point from which to tackle current management questions.
Kast (1976) argues that the application of the contingency approach requires a considerable amount of conceptual skill on the part of the manager and also a pragmatic approach with a strong emphasis on situational analysis.

Situational analysis

The contingency approach should start with an analysis of the environmental situation of an organisation. A model can help in understanding the inter-relationships between the structure of the organisation, its management approach, and the major influence domains. The model illustrated in Figure 5.3 is based on the work of Staehle (1973), the results of a literature survey, and my own field experience.

80 Pluralism: none of the existing organisation theories are rejected in the identification of solutions for organisation and management questions but they are only valid in one single situation and in one single specific way.

Staehle based his work on a comprehensive study of literature on organisational, management and behavioural sciences and he discussed the results in his publication “Organization und Führung soziotechnischer Systeme”. He considered an organisation as a socio-technical system and gives the main question as which organisational structure and management model would, in terms of business objectives, lead to success under the given environmental conditions. Staehle does not claim his model to be ideal-typical, but aims to describe the situation using many influence parameters, and provide sufficient information to allow the identification of organisational and management options and their implications.

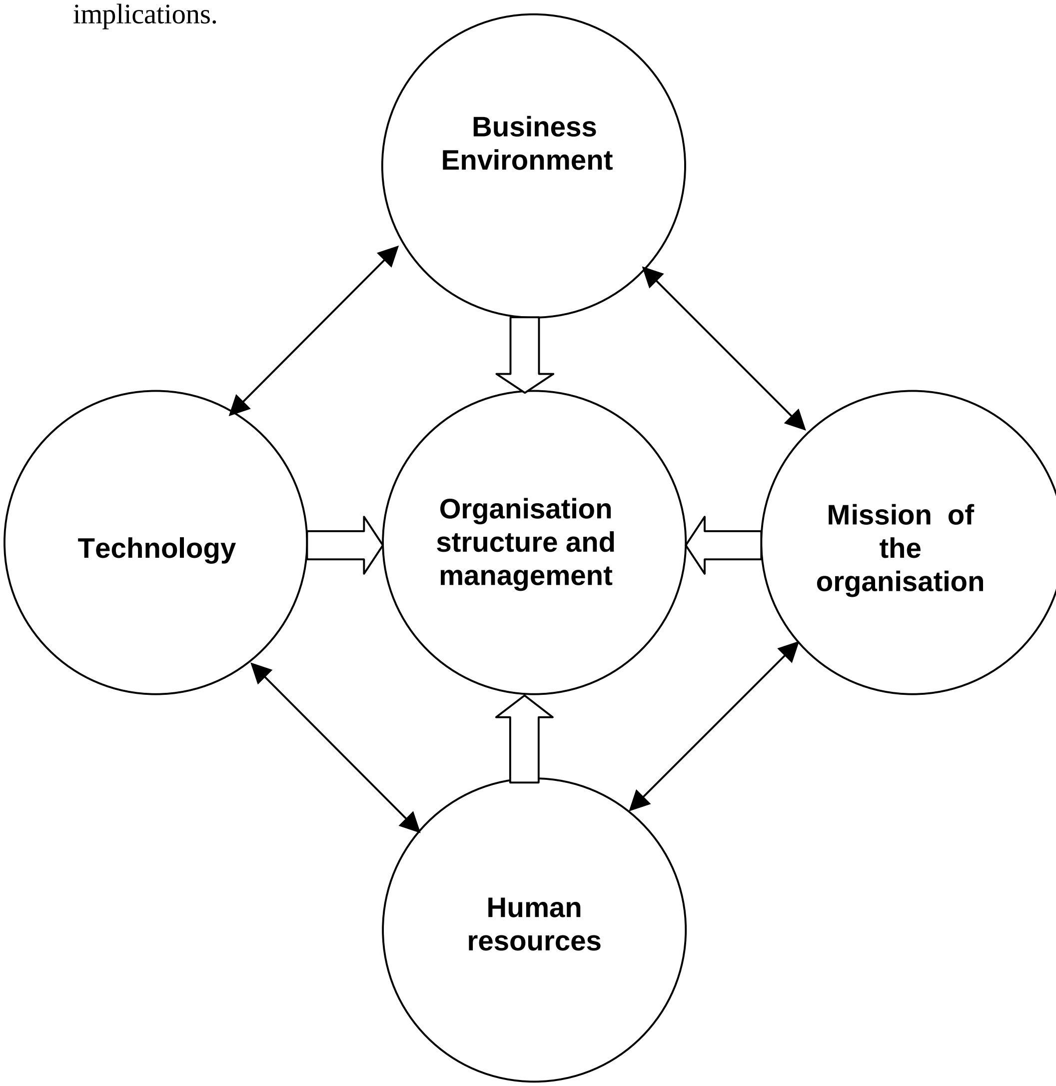

Figure 5.3. *Simplified situational model (based on Staehle 1973, see also Schieman 1980 and Kramer 1978).*

Staehle defined the variables of the model and their functional and causal relationships. He distinguished four domains of independent variables (Einfluß-größen) and one dependent variable (Struktur und Führungsverhalten). He argued that the four domains (business objectives, environment, technology and human resources) were not an exhaustive enumeration of all the influence parameters, but that this classification subsumed the majority of the independent variables.

Staehle emphasised that a very strong interdependence existed between the environment and the business objectives of an organisation. This is clearly true of contemporary power utilities because they interact and maintain a dynamic balance with the environment. This underlines the fact that management should continuously follow and analyse developments in the environment of the utility and take appropriate actions to update the organisation.

Kramer (1978) notes that the relationships between the independent variables (technology, environment, human resources and business objectives) and the dependent variable (organisation structure and management model) have been confirmed in earlier research[81]. Woodward (1965), for instance, found that "different technologies imposed different kinds of demands on individuals and organisations, and these demands had to be met through an appropriate organisation structure". It is fair to conclude that technological changes do not only affect the internal structure of an organisation but also the external relationships.

Staehle considers corporate culture and the relationship between management style and "organisational climate", but he does not address the "national" culture and the influence of the views and antecedents of the incumbent managers. Experience shows that both factors can have a major influence on the organisation and management model. For example, an objective analysis of the environmental situation is extremely difficult because managers will use their own interpretations of the findings.

The outcome of the situational analysis should determine the corporate strategy and the principles of the organisational structure and management approach. The analysis should first lead to the formulation of a strategy. Contingency theory concludes that strategy leads to structure and Chandler (1962) also argues that "Structure follows strategy". Schieman (1980) argues that the internal organisation is a response to the strategy which, in turn, is based on the results of the situational analysis. Although others argue the opposite, the view that corporate strategy must be known before a structure can be determined seems well founded.

81 Kramer refers to Woodward, Harvey, Perrow, Lawrence, Lorsch, Chandler and Fiedler.

Box 5.1 provides an example of a situational analysis for the electricity supply industry in Switzerland. The results suggest that marketing offer the greatest opportunities and should therefore be seen as a critical success factor[82].

Box 5.1: Impact of changing environment on utility strategy

To identify the most important impacts of the changing environment on utilities, Schlange (1996) emphasised the need for systems thinking (see Section 1.5.5) and, because of the interdependence of the variables, to apply the 'Cross-Impact-Analysis' methodology[83].

He argued that such a systematic approach would enable the identification of the main driving forces in the environment of utilities and, even more importantly, their priorities in terms of strategy development and actions. Schlange based his research on the Swiss Electricity Supply Industry but the results should be applicable to other countries. During his investigation, a system description was made and the impact of a set of relevant variables identified. On the basis of the results an impact matrix was developed.

Schlange's most important question was how the results of this analysis could be used for strategic planning and decision making, and for this purpose a strategy matrix was developed. Such a strategy matrix (a simplified matrix is given in Figure 5.4) enables the identification of the critical strategic success factors for future utility operations and those opportunities with maximum leverage in terms of utility success.

Schlange concludes that formerly important factors such as electricity demand, service quality and the capacity of the network, in terms of their impact on future utility operations, are now less relevant than other emerging factors. Technological innovations, the liberalisation of the energy market, the regulatory environment and the dynamic structure of the sector are, nowadays, the most important aspects to be considered when developing a utility strategy. He emphasises the need to influence the developments as early as possible and to use the available scope of action as effectively as possible. In this respect the competitive advantage of electricity, customer orientation, and service options offer the greatest opportunities. In the industrialised world utilities increasingly want to be "seen as green" and to that end no proven technologies, both renewables and non-renewables, should be overlooked.

82 Eurelectric (2000) provides scorecards to assist utilities in assessing their current performance with regard to customer relationships and retail marketing. These scorecards provide "best practice" figures on the four key quality drivers: call centres, complaint management, customer communications and staff development.

83 A discussion of this methodology is beyond the scope of this dissertation. See for instance Gordon, T.J. 'Initial Experiments with the Cross-Impact-Matrix Method of Forecasting' in Futures 1, December 1968, pp. 100-116.

Strategies for change

Over the last decade, developments and trends have led power utilities in industrialised countries to reconsider their internal organisations and to that end Business Process Re-engineering (BPR) has often been used. BPR was a response to the perceived compartmentalization of organisations that was a consequence of past functional and managerial specialisation.

Long-term leverage \ **Scope of action**	Limited	Large
Large	**Foresight** • Public opinion on/acceptability of nuclear power • Climate impacts • Political decisions • Aspects of overabundant society • Stable population and economy	**Promotion** • Technological innovations • Liberalisation • Regulation • Client orientation • Service options (e.g green electricity) • Dynamical structure of the sector • Competitive advantages
Limited	**No action**	• Credibility • Electricity demand • Energy efficiency demand side • Service quality • Network capacity • Environmental impact of electricity **Maintain results achieved**

Figure 5.4. *Simplified strategy matrix for utilities in developed countries (based on Schlange 1996).*

Many large utilities had evolved into compartmentalized organisations with similar features to those listed for the mechanistic system in Table 5.1. Burns and Stalker[84] distinguish, on the basis of empirical research, mechanistic and organic systems as shown in the table. Naturally these two ideal-typical systems will seldom occur in their purest form, most organisations will be hybrids.

Staehle concludes, on the basis of comprehensive literature research, that mechanistic systems are suitable with more-or-less stable circumstances and limited innovation efforts. It is generally accepted that the mechanistic organisational system cannot effectively respond to current developments in the power sector.

84 Cited in Staehle (1973).

The organic system is flexible and adaptive, and appropriate in a dynamic and innovative environment, and thus decentralised organisations have been an appropriate response to large-scale "green field" rural electrification programmes (see Section 5.2.1). Empirical research by Burns and Stalker, Thompson and others support this conclusion. Essentially, the organic system is comparable to team organisations as proposed by sociotechnical theory.

Table 5.1. *Features of ideal-typical mechanistic and organic organisation systems (based on Holt and Staehle 1973).*

Organisation	**Mechanistic system**	**Organic system**
Structure	Function-oriented	Task-oriented
Authority	Centralised	Decentralised
Co-ordination	In higher ranks	In lower ranks
Interactions between subsystems	Limited	Strong
Informal system	Negligible	Important
Management model		
Approach	Authoritative	Participative
Human relationships	Commanding	Supportive
Staff attitude	Conformative	Creative and entrepreneurial
Assignment instructions	Detailed and prescriptive	Broad outlines

Excessive functional specialisation has several drawbacks including increased co-ordination needs, limited decisiveness, a reduced overview and a loss of focus on the core process. Business Process Re-engineering (BPR) is a tool used to redesign an organisation on the basis of an integration of the constituent processes with the aim of more efficiently and effectively responding to requests and needs of internal and external clients. In this respect, Senge (1990) in his "The fifth discipline" and Hammer and Champy (1993) in their "Re-engineering the corporation" argue that the past is no longer appropriate for forecasting the future and that new approaches to change, such as BPR, are needed. Though this message seems correct, there are indications[85] that many change strategies have not resulted in the expected performance improvements. According to the Economist the American Management Association reports that "fewer than half

85 Research by A.T. Kearny and Bain&Co (cited in NRC 2000).

of the firms that have downsized since 1990 have seen long-term improvements in quality, profitability, or productivity"(cited in Beatty 1998). Re-engineering and downsizing seem to have left many utilities without sufficient human resources to engineer new facilities. Prakken (1995) argues that BPR lacks a sound scientific theory.

In view of the ongoing technological developments and market trends in the electricity supply sector, the capability of an organisation to innovate and learn is increasingly important in order to identify opportunities and improvements in both services and products. This calls for appropriate organisational structures, management approaches and attitudes and skills of the staff. Such an organisation would be capable of adequately responding to external developments and anticipating and even influencing developments (as Schlange suggests in Box 5.1). It is noted that a large organisation tends to be effective through its mass rather than through its agility (Drucker 1962).

These observations suggest that a flexible and adaptive organisation is needed but it is noted that rapidly changing short time organisational structures will likely lead to internal and external uncertainties that will affect effectiveness and efficiency. Flexibility should therefore refer less to the structure of the organisation but rather to its response to external developments and needs, and thus mainly to staff attitudes.

5.3.2. Critical success factors and management recommendations

The research has revealed that successful electricity supply to rural areas requires the control of a number of critical success factors of which the following are considered to be the most important.

Political and social stability

It is generally accepted that political and social instability is a major obstacle for international community support and the involvement of the private sector. Moreover, a long-term commitment by the government is necessary to make rural electrification programmes more independent of short-term political interference. To maintain stability and to avoid the neglect of the poorer sections of the community, governments should pay particular attention to the protection of the interests of small consumers in both urban and rural areas when embarking on liberalisation programmes. There is good reason to fear that these consumers may not receive adequate attention from utilities in a more liberalised electricity market. The promotion of a sustainable energy economy, and the relevant technological research and development can be added to the issues which need government attention.

Appropriate legislation and institutional framework

The challenge for a government is to create the institutional conditions that will allow utilities to effectively respond to customers needs. This does not necessarily mean that the electricity sector in developing countries must be subjected to all features of the neo-liberal ideology prevalent in many industrialised countries. Developing countries, with an immature electricity infrastructure, should avoid throwing themselves into massive liberalisation of the electricity market with the associated unbundling of assets, bidding systems and the establishment of an autonomous regulation authority, its bureaucracy, and the apparently inescapable squabbling about stranded assets and ownership of the monopolistic grid.

In countries with an immature electricity infrastructure, the emphasis of reform will probably be on large-scale power generation, and transmission on a national basis, with some private involvement. The rate of return on investments will largely be determined through independent regulation and there is no good reason to expect a top return. One or more concession-based distribution utilities, with decentralised organisational structures, will also likely be part of the power sector.

The greatest challenge in many developing countries is to "depoliticise" the power and water sectors, to design and implement effective legislation, and to develop an appropriate and consistent policy. Another onus on government is the elimination or reduction of import duties and subsidies that create price distortions, and hamper energy efficiency and the deployment of renewable energy technologies. Successful rural electrification depends heavily on the way it is approached by the government, utilities, donors and other funding organisations but a proactive approach by the government will be of assistance in getting financial and development communities on board.

The basis for any new arrangement should be that the utility management can conduct operations without governmental interference, but within a regulatory framework with clear and non-conflicting performance objectives and adequate tariffs. The utility should work at more than an arm's length from the political world and should be free to design and implement its own organisation and approach. Possibly the most important prerequisite for an effective electricity company is a high degree of autonomy.

As was determined elsewhere in this work, the introduction of competition is not the answer to the development of rural electricity supply in developing countries. Concession-based utilities with monopolistic features are probably the most effective solution for the electrification of rural areas. These companies obtain a long-term concession and the exclusive right to provide an area with electricity. In many developed countries this system worked well during the development of the electric infrastructure. Although the ownership of these utilities is of less importance, strong provincial and municipal ties imply a risk that the organisation could become the plaything of local political interests. The success of co-operative ownership tends to depend on local circumstances and does not seem to be the preferred option if relevant experience is absent. The establishment of a co-operative solely because of the perceived success in other countries will almost certainly result in failure.

The regulatory framework for rural electrification should be properly defined and enable private participation and innovative institutional, technical and financial solutions, including sophisticated credit schemes. National guidelines should help in setting tariffs and the return on investments at an acceptable level. Utility regulations and power purchase agreements should be adapted to encourage customer-based power generation.

Integrated rural development

The electrification of rural areas is only in part a technical issue. Other aspects include the social implications of electrification, and the willingness and ability to pay of the community. Moreover, the required market-pull can only occur in combination with general economic growth. All these observations emphasise the need to combine electrification efforts with rural development programmes.

Ministries of rural development, energy, water resources and agriculture have interrelated interests in and responsibilities for rural electrification. Therefore, rural electrification programmes would be more effectively co-ordinated by an interministerial body, perhaps by a rural electrification committee rather than through a line agency directly attached to a single ministry. During the research no examples of such an approach were found.

Stakeholder communication

Over the last 10 to 15 years, the number of stakeholders within the environment of utilities has increased. Customers, including local industries and their associations, and consumer and women associations want a say in how the service is delivered. National, provincial, and municipal governments, NGOs, and donors exert influence, for example, to force the utility to deploy renewables and to implement energy efficiency measures on both the supply and the demand sides. Case 5.6 illustrates the importance of developing and maintaining good relationships with stakeholders. Personal contacts between local utility staff and customers would seem particularly important in newly electrified areas.

Regarding the delivery of the services stakeholders should be given a voice at both policy development and operational levels and, to this end, consumer committees are important. The last few years utilities in industrialised countries make great efforts to reach their stakeholders: in local newspapers, through regular company news, by means of commercials on national television and radio stations, and even by sponsoring sporting clubs.

As appears from Case 5.6 and other research (Zomers 2000) stakeholder communication is even more important in the rural areas of developing countries because of the perceived need for customer education and awareness raising. As is elaborated in Section 3.5, the electrification of rural Bangladesh involves the distribution of electricity through member owned co-operatives (PBSs). In these PBSs elected customers serve as advisors to the Board of Directors of the local co-operatives. A customer-member survey followed by a pilot project to improve stakeholder relations, revealed that insufficient communications with the customers-members is the major cause of a lack of awareness and satisfaction. Because radio, television, and postal services are not widely used in rural areas, many respondents preferred printed information in the form of posters in local offices, bill boards and via monthly electricity bills. The Bangladesh Rural Electrification Board and PBSs are now in the process of developing an overall communication plan including a reconsideration of the PBS Member Service Departments, and a village advisory programme. Member Service Departments will also provide assistance to potential small industrial and commercial clients to promote productive uses of electricity, and may in some cases co-ordinate with financing institutions.

Case 5.6: Assessment of rural electrification benefits

The ongoing World Bank/multidonor Rural Electrification Beneficiary Assessment Study can be regarded as a continuation of the Electric Power Utility Efficiency Improvement Study (see Case 4.3 in Chapter 4) in so far the relationships between the utility and the beneficiaries are concerned. The aim of the study is:

- To identify the perceptions of rural and semi-rural customers concerning the actual and potential benefits of electricity supply and the service delivered by power utilities. The latter subject is also examined from the perspective of the utility.
- To examine the current methods used to assess the benefits of rural electrification.
- To suggest improvements in the benefits assessment methodology and to apply the results in a future case study.
- To suggest improvements in the approach of the utility.

Three case studies in Africa, Latin America and Asia were used to generate the necessary data for this study and basically two groups of beneficiaries were distinguished: the primary and secondary beneficiaries. The first group consists of the consumers of electricity, and the latter includes those who are not consumers but who benefit from the electricity supplied to offices, businesses and public facilities.

The areas investigated were either serviced through extension of the national grid or through diesel generators with a local distribution grid. In the latter case electricity was only available for a limited number of hours.

The case studies relied on participant observation[86] and interviews. This summary only concerns the results to date that concerns the service of the utilities. So far the study has resulted in the following observations:

- The average monthly residential consumption can be as low as 20 kWh, and the consumption of small commercial/industrial businesses only 50 kWh/ month.
- The price per kWh for rural residential use varied between US$ 0.06 to 0.30, even within one country. This difference was a major cause of consumer dissatisfaction. A tariff setting based on housing density was also perceived as unfair and continually fluctuating monthly costs were perceived as very inconvenient.
- In some countries, popular payment methods for rural people include post office money orders and registered mail. The long distances to utility offices problematical as are the separate locations of technical and commercial utility departments. The number of defaulting consumers appears to depend on the distance to the utility office and/or post office and on factors such as fluctuating (seasonal) income. Bill payment systems using a utility cashier to collect cash from clients proved to be unsuccessful for a variety of reasons. The incidence of illegal connections appeared to be low in those areas where penalties were severe.
- The most common complaints included the limited hours of service, voltage fluctuations and unscheduled outages. Delays in restoring a service was, in some cases, an even greater cause of dissatisfaction than the outage itself. Consumers clearly place a very high value on having access to electricity 24 hours a day, particularly because a limited service thwarts productive uses of electricity.
- On the customer side there appears to be a considerable lack of knowledge on many issues. In some instances users wanted training and a greater role in decision making. In general, there appears to be a discrepancy between information offered by the utilities and the information that the consumers need. In most of the locations, the utilities were perceived as credible sources of information, although confidence in local staff was not always apparent. Utility staff are the critical link between a utility and its consumers. Meter readers are not always considered impartial and therefore one should be reluctant to combine the meter reading function with other utility services.

86 For a discussion of this methodology see Salmen (1987). Participatory research methods have been widely applied in health care, agriculture and similar projects but not in rural electrification. It is noted that this methodology, particularly in the case of utility service assessments, requires a carefully selected research team. Moreover hearsay and prejudice must be isolated from criticisms that can be substantiated to avoid a biased judgement of utility performance.

- The availability of credit programmes could help consumers finance the costs of house wiring and meters. These costs present huge difficulties to potential users.
- The procedures for connection, meter reading and billing are often unclear. In quite a few cases the instructions and bills were not understood by the consumers with delays in payments and complaints as a consequence. The absence of adequate information is a major cause of customers' mistrust.
- In a number of cases the respondents highly value the services of the utility despite the perceived problems. There are some indications that consumers tend to have less trust in the financial performance and impartiality if the utility is small.

On the basis of the observations, the following general recommendations were suggested:

- Utilities should improve customer relationships including the communication with consumers. In this respect the implementation of a programme to inform, educate and communicate is important. Personal contacts between utility staff and customers are also important. Local and regional media including radio stations should be used for information purposes.
- Implement appropriate billing systems based on customer surveys and utility needs.
- Introduce customer credit programmes and innovative means so that low-income clients can control their electricity costs through fixed tariffs with demand limits and prepayment systems.
- Improve service reliability with particular attention given to the time needed for restoration. Consider having a technical office with skilled staff in rural areas.

Sources: Kandawire (1999), Stalworthy (1999), personal observations.

Electrification process

All technical options must be considered when planning rural electricity supply: decentralised renewable and traditional power generation, grid supply and combinations thereof, and also Solar Home Systems. When assessing their suitability life-cycle emissions should be one of the considerations. Utilities should consider the installation of SHSs as a fully-fledged step in the rural electrification process for which an adequate service structure is needed. These systems are complementary to a grid-based electricity supply and therefore a coherent planning and implementation strategy is needed. This is another reason why the utility should be involved in SHS projects.

Utilities should consider small-scale industrial generators and independent power producers (see Cases 5.1 and 5.2) as valuable partners in the rural electrification process. Innovative public-private partnerships (see Case 5.3) could pave the way for attractive and environmentally benign solutions for the generation of electricity. The participation of local communities in both planning and fund raising is another salient feature of successful electrification programmes.

The delivery of the various services and the management of a multipurpose power system (see Figure 4.3) will be one of the most challenging activities in the near future, in both technical and commercial senses. In rural areas the increases in power demand and power supply diversity could be great. Management need to be aware that these future, non-conventional, activities in rural areas are much more complicated and time consuming than those related to grid connection.

Reliability of supply will be a key factor in the future, even in rural and remote areas. If electricity is unreliable, it will never act as a stimulus to economic development, even if all the other conditions are present. Thus succssful rural electrification is not just a matter of implementing a project, but ensuring sustainability over the years. Monitoring devices and remotely operated facilities will be needed to achieve an acceptable reliability level.

Strategy development

As was suggested in Section 5.3.1, a situational analysis is needed to determine the correct corporate strategy and the principles behind the organisational structure and management approach. The strategic trend in industrialised countries is towards a focus on the core business, outsourcing other activities. This might well be an appropriate strategy for utilities in industrialised countries with a mature infrastructure but is probably not for utilities electrifying rural and remote areas in the developing world. The strategy there should depend on the local situation including the presence of service providers, and not on prevailing world fashions. Because local installers can play a key role in implementing and maintaining a rural electricity infrastructure, the strategy should aim to promote relevant entrepreneurial activities.

Utilities in the industrialised world tend to extend their activities with additional products and value-added services such as telecommunications, media, and water supply. The emphasis of utilities serving rural areas in developing countries should also be on the provision of multiple services. These services should include energy efficiency activities because, as was concluded in Chapter 4, the establishment of special energy service companies in rural areas is unlikely to occur.

Essentially, the success factors for regional utilities include the purchase, upgrading and sales of electricity and other utility services. The annual costs of a utility that purchases its energy can in general be said to be two-thirds energy purchase and one-third grid related. Thus it cannot control its major cost. End-use analysis, marketing, and power purchasing are increasingly important issues.

In industrialised countries distribution utilities now aim at also deliver services "beyond" the meter.

For most traditional utilities this implies a shift from "technical orientation" towards "market orientation". Even with an absence of competitors energy utilities need to develop relevant technological and commercial competences and communicative skills.

The strategy should include the recognition that the future success of utilities depends on expertise and skills in developing and maintaining customer relationships and co-operation with local industrial generators, in recognising opportunities, and in effectively delivering customer services.

Provided utilities in developing countries are performing in a sustainable way, they will be able to obtain low-interest loans or grants from various sources and should therefore be able to offer attractive credit schemes to customers. Utilities are also able to amortise the investments associated with, for example, photovoltaic systems over a rather long period thus making the service more affordable to the consumer base. To take advantage of this situation, the strategy should include the establishment of partnerships with local financing institutions.

In this respect it is noted that since the required market-pull has to come from the rural community this potential can only be developed if services are made affordable through access to credit and micro-financing schemes.

Organisational and management approach

When designing the organisational and management approach, the utility management should not forget that the structure should be based on a corporate strategy. In this respect it is also noted that decentralisation gives an opportunity to leadership development.

It would appear that with the current liberalisation trends, and the fact that in developing countries large areas still have to be electrified, regionally oriented electrification with relatively autonomous regional utilities are the most effective and efficient approach. These need not be independent organisations but could be part of a national and even international utility. Such a regional utility could be established and supported as part of a regional development programme. It is crucial that the entity has sufficient autonomy and an established budget, does not suffer from political influence on operations, and can rely on support from an umbrella organisation.

As was shown in the previous section, the organisational structure and the associated management approach will depend on the specific situation in which the utility has to operate. In the past, most utility efforts were based on the central grid approach for which grid management is rather straightforward. The growing emphasis on decentralised systems implies another approach because the various options (such as solar home systems, wind turbines, grid extension, diesel and CHP units, hybrid based mini grids) require different implementation strategies.

The management of decentralised assets is more complicated and labour intensive, and requires a process-oriented rather than a function-oriented organisation (see Table 5.1). It is evident that the management approach, the corporate culture and staff attitudes should be tuned to this situation. In this respect, it is argued that command and control approaches are not appropriate to rapid decision making and creative approaches.

It is fair to conclude that circumstances will continue to change and this would suggest that the organisation and management model should be flexible enough to respond to these changes. In order to avoid neglecting service delivery, unrest, and uncertainties for stakeholders, any re-organisation should be completed within a reasonable time frame[87].

Support from the international community

Rural electrification, both traditional and renewable, is likely to remain a nonprofitable business needing investment support. Moreover, power sector reform implies a changing role and additional responsibilities for utilities and support will be needed to assist these organisations in adapting to the new situation. Hence, the support of the international community remains crucial for the implementation of rural development and electrification programmes, and for institutional adaptations. Support in the form of grants, financing schemes and training is needed.

Climate change is considered one of the most serious global problems and the build-up of greenhouse gases, such as carbon dioxide, is held largely responsible for this threat to the sustainability of the world's environment. The 1997 Kyoto Protocol provided the basis for a quantified decrease of the overall emissions of greenhouse gases of the developed countries and countries in transition. The Protocol also provides the principles for three mechanisms to assist these countries in meeting their targets cost-effectively: an emissions trading system, joint implementation of emssions-reduction projects, and a Clean Development Mechanism (CDM).

The latter mechanism is interesting for developing contries because it could help these countries with the introduction of electrification schemes based on renewables. The Sixth Conference of the Parties to the Framework Convention on Climate Change (COP-6) was held in The Hague, from 13-25 November 2000 and was expected to provide operating rules and procedures on the Kyoto Protocol mechanisms. Although difference of opinions remain regarding CDM project eligibility, there is agreement on the principle of the CDM. There are currently a number of special bilateral and multilateral programmes available to help leverage capital for renewable energy projects, and to implement

87 Experience in Latin America reveals that many privatised utilities tend to spend the initial years after establishment on reorganisation matters (personal communication, ESMAP 2000).

appropriate financing and technical assistance schemes. An attractive opportunity to foreign assistance to produce lasting benefits is the development of joint ventures involving local expertise (Khatib 1993). Over the last few years, some multinationals have shown an interest in investing in rural electrification projects in developing countries. The incentives differ and can include efforts to extend business scope, social and green image building, and the promotion and deployment of renewables to satisfy carbon dioxide equivalent emission reduction requirements.
Prerequisites for international community support include appropriate enabling conditions in the country, long term commitment by the government, confidence that the electrification process is properly organised and managed, and that it will contribute to the alleviation of energy poverty, and that the result is sustainable.

5.4 Recommendations for further research

This study has analysed the historical aspects of rural electrification in both the industrialised and developing world. It has also identified the nature and scope of recent developments and trends in the electricity supply sector and discussed their likely impacts on the electrification of rural areas. On the basis of the findings, the critical success-factors for electricity supply to rural areas were determined. The subjects that are beyond the scope of this study but that need further research include the following.

- The management challenge faced by utilities in developing countries and, in particular, the relationship between modern management practice and cultural circumstances, could be the subject of further useful research[88].
- Opinions about the "appropriateness" of existing utilities in developing countries to promote renewable energy technologies seem to differ. Further study could address this subject and lead to conclusions and recommendations.
- The Tennessee Valley Authority established the Electric Home and Farm Authority (EHFA)[89]. This raises the question as to whether an organisation such as EHFA would be useful in developing countries to support the transition to a more electricity based economy.
- Solar Home Systems can offer a number of services such as electric lighting, outlets for audio and video equipment and a small refrigerator. The implementation of these systems is sometimes denoted as "pre-electri-

88 Kubr and Wallace (1983) addressed, in their World Bank study, management strategies and their implementation in developing countries. The research of Hofstede (1983) revealed the difficulty in applying foreign management techniques and systems in developing societies.

89 See Section 3.3.1.

fication" and this suggests that after some time another kind of electricity supply will be needed. Further research could reveal whether and if so when the demand for electricity services is likely to increase beyond the capability of the Solar Home System.

- Technological developments pave the way for new rural electrification concepts both grid-based and decentralised. Further investigation could address schemes, standards, costs and other relevant issues.

Chapter 6

Future Developments

Pointing towards future developments involves substantial crystal-gazing. Though the crystal ball is not part of the scientific toolbox, in this last chapter one can reflect on the future developments of electricity supply, in particular to rural and remote areas. One must try to avoid wishful thinking and look forward no further than the next 25 years because within this time span developments are not so likely to be beyond ones imagination.

6.1. Technological developments

Recent energy chain analyses[90] have revealed that substantial fuel and emission reductions are possible if more energy services are electrified. With growing saturation of the consumer markets in industrial countries, manufacturers of electrical appliances will turn to the markets in developing countries. This will promote electricity demand and electricity is expected to remain the fastest growing choice for end-use energy in both urban and rural areas. Its share in the world's total energy use will continue to grow.

Patterson (1999) expects that existing electricity transmission systems will be replaced by gas or oil pipelines supplying fuel to distributed dispersed heat and power plants and that suppliers will provide service rather than power. An alternative view is that large high voltage alternating and direct current transmission systems will remain the backbones of power supply to large urban and industrial areas and will be needed to exploit remote regional energy resources such as large-scale hydro power. The most important development in electricity transmission could be the use of high critical temperature superconducting wires (Thérond 1996).

The developments in large-scale generation are likely to include efficiency improvements in gas turbines and combined cycle units. The latter units combine gas turbine technology with steam turbine technology; electricity generation efficiencies of 55% have already been achieved. Further improvements in cooling and protective coating techniques will allow a further increase in gas turbine inlet temperature which could, in combination with developments of other components, lead to 60% efficiency (Europower,1995).

If appropriate emission and energy-efficiency regulations are in place, then clean coal technology and particularly coal gasification with CO_2 gas fixation technology will have to be further developed and put into operation for large plants. In the competitive regime expected, magneto-hydrodynamic generation and thermonuclear fusion reactor plants will only enter into commercial operation if unit costs are lower than those of other generating facilities.

Solar thermal installations with capacities over 2 MW using low concentration solar collector designs and steam turbines are likely to become available. These

90 For instance "From source to service" (Kema 1995).

installations are expected to cost US$ 1,200/kWp and the electricity cost would be US$ 0.05 to 0.07 per kWh under Australian conditions (Mills 1994) which compares well with conventional generation technologies. These installations could generate the same annual energy per square metre of collector as central PV systems with an expected total system efficiency of 28%. The use of thermal storage and backup fuels would allow round-the-clock electricity supply.

It appears that both centralised and decentralised systems will be needed in the near future to satisfy electricity demand and to achieve a sustainable energy supply. It is not a case of either/or. But this does not mean that the existing power systems will basically remain as they are.

Flavin (1994a) seems correct in saying that “a move to a power system that relies on a broad mix of large and small generating plants could simultaneously improve efficiency and lower the environmental burden of today's electric power systems”. Patterson (1999) argues that future electricity systems will be dominated by small local heat and power plants and also that an environmentally, socially and economically sustainable electricity supply to the currently unserviced rural and remote communities will need a solution based on small dispersed power plants.

In the authors’ view Patterson is only partly right: it is indeed likely that embedded or dispersed generation will play a more prominent role in the production of power, particularly in countries with natural gas resources. In these cases pipelines can be used to fuel both industries and decentralised power stations, at least during the initial stage of electricity supply to rural and remote areas[91]. But whether rural and remote power systems will be decentralised or connected to a central grid, will depend on the local situation such as the availability of energy resources, the distances, and the available sites for power stations and transmission lines.

The medium voltage distribution grids are likely to undergo the most important changes. Their complexity will increase as a consequence of the deployment of diverse embedded generators such as PV systems, CHP units, windturbines, storage facilities and sophisticated power electronics to maintain power quality. Hybrid medium voltage grid concepts based on both AC and DC are likely to appear and computer-based grid management systems will be needed to operate and maintain the system, and to optimise output.

Energy storage is crucial in future energy systems, particularly in small-scale decentralised systems. Mechanical flywheel units are suitable for the MW range and un-interruptable power supplies using batteries for the kW scale. Though the development of these systems will continue, superconducting magnetic

91 As examples (personal communications): Natural gas pipelines through Bolivia, enabled the Cooperativa Rural de Electrification (CRE) to construct small gas-fuelled power stations with associated distribution grids in rural areas. In Bangladesh piped natural gas will probably be used to fuel small power stations to support (centrally supplied) rural grids.

storage systems (SMES) are also likely to be introduced as soon as high critical temperature superconducting wires are commercially available.

The power sector is moving towards a future in which energy needs are increasingly satisfied by renewable resources. In this context, a transition to a hydrogen economy has often been suggested. However hydrogen technology is still in its demonstration phase and a real breakthrough is not expected in the next few years. The direct conversion of sunlight into hydrogen through biological systems is still in its infancy (Hoagland 1995).
Wind energy has come of age during the last 15 years and current wind farms can supply electricity for 5 to 8 USct/kWh[92]. The emphasis of future developments will likely be on large wind farms and on the deployment of novel conversion concepts using power electronics. Hydropower will continue to play a major role in satisfying energy needs. The available hydro resources, particularly in the developing world, will be further developed.
The contribution of biomass to electricity generation will probably remain small. Compared to PV systems and windturbines, biomass cultivation needs much more land because with the latter less than 1% of the available sunlight is captured. Apart from this substantial land use, current electricity generation from biomass needs rotating equipment that is more complicated to operate and maintain than the static PV systems.

PV technology would seem to offer the best opportunities and, in the years to come, the use of photovoltaics is likely to expand enormously in both developing and industrialised countries. In the latter mainly through promotion and regulation measures introduced by government and in developing countries through support from donors for rural development.
To offer economically attractive PV systems without a subsidy, the cost per kWh must be reduced from the present US$ 0.5 to around US$ 0.10. Over the near future most effort will be directed towards cost reduction but it remains to be seen whether a substantial increase in demand and thus production capacity could trigger such a substantial reduction. Present photo-voltaic technology is probably only a step towards more advanced technologies and new solar cells may well be commercially introduced within the next decade.
Future electricity supply scenarios could also include solar power satellites (SPS) using photo-voltaics. These extraterrestrial systems would use photovoltaic cells and a microwave or laser beam to transmit the power to earth. Extraterrestrial locations have the advantage of a substantially higher daily solar radiation relative to the conditions on earth.

92 ELSAM Danmark (personal communication P.Gipe in “Renewable Energy; prospects for implementation”, SEI, Stockholm 1993).

In the past few years, representatives of power utilities and space specialists have met a few times to discuss the feasibility of such a power system[93]. Originally, the idea was proposed by P.E. Glaser three decades ago and, according to current news, such a system could not be operational within the next 25 years. Electricity could be supplied for 2 USct/kWh (SPS 1992, Nansen 1995, Deschamps 1997). Mataré et al (1993) accept the technical feasibility of such a system but their estimates suggest that the costs per unit of electricity will be much higher. It also remains to be seen whether such a system, from the point of view of the associated risks, will be accepted by society.

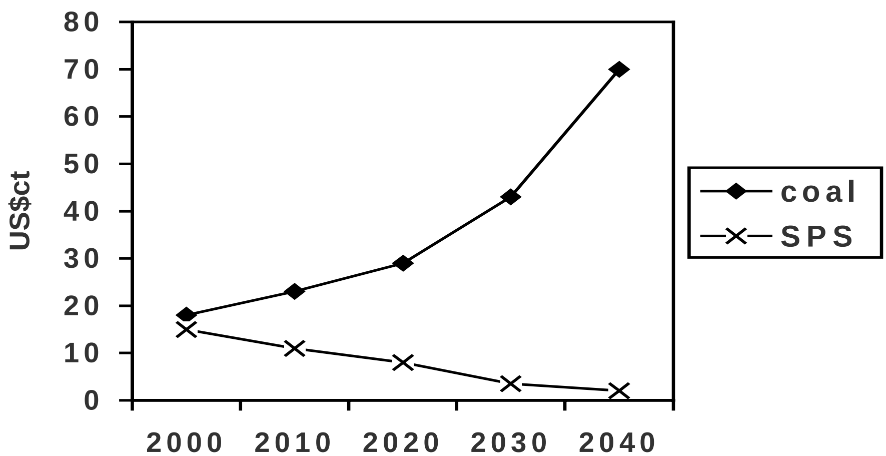

Figure 6.1. *"Off-power station" cost of electricity per kWh produced by coal fuelled power stations and space power stations (SPS). (Source: Nansen 1995)*

Nansen (1995) argues that in the next few decades the cost of electricity produced from new coal fuelled power plants will substantially increase due to rising fuel costs, tightened emission standards and maintenance costs. Space Power Systems could produce electricity for much less. Though the actual figures of Nansen's cost estimations in Figure 6.1 are debatable, the results give an idea of the likely trend.

The so-called Grumman project is investigating a space power plant of 9000 MW with and offshore earth receiver. Essentially the number of these space power plants is unlimited (Kleinpeter 1995) but it is not clear whether and in which way rural areas could benefit.

93 Rio de Janeiro, 4 June 1992; Montréal, 24-28 August 1997.

6.2. Rural power systems

Though there are still opportunities to lower the costs of centralised grid based rural electricity supply, PV systems appear to be the most attractive option for still unserviced rural and remote dwellings, not in terms of capability but in terms of affordability by the rural consumer[94]. The futurists Das et al (1995) foresee a bright future for photovoltaics in the rural areas of the developing world and even designed a special rooftop with 23 m² of modules which would only cost US$ 400. This rooftop is suitable for traditional huts and would, in combination with the use of a battery, generate 2.3 kW electricity. Given the current market prices of PV modules and the cost reduction expectations their cost estimate seems somewhat optimistic.
Rural grids are often weak, and high peak loads and relatively large inductive loads can occur. As the number of irregular, decentralised, power generators increases, so will their impact on the dynamic behaviour of the power system. As a result, these grids will increasingly suffer frequency and voltage stability problems along with other service quality deficiencies. Sensitive loads such as computers, non-linear end-user equipment and processor-based industrial systems will force grid owners to focus on power quality and down-time. It is fair to conclude that future rural electricity supply systems will have to be capable of supplying continuous high quality power.
The interconnection of grids can smooth out peak loads but a storage system could carry out the same function and permit an efficient and round-the-clock operation of small-scale decentralised power systems. It is likely that future power quality requirements will lead to an increased deployment of electricity storage in power systems, particularly in small-scale decentralised systems.
Small-scale superconducting magnetic energy storage (SMES) devices are already commercially available and will probably be deployed in future rural power systems. SMES units have already been used in the United States[95] as a temporary solution to improve the voltage stability of a system supplying a largely rural area.

Future rural power systems will include both decentralised systems and grid based multi-purpose systems. To achieve the required service quality, most decentralised systems will be of a hybrid type and include combinations of wind turbines, diesel generators, storage devices, PV systems and hydro plants. Future grid-based multi-purpose systems will be used to generate, receive, store and supply power and to maintain the integrity of the service. In these systems diverse dispersed generators will be found including reciprocating engines, gas turbines, fuel cells, and wind turbines. A number of utilities including Tokyo

94 See Sections 2.7.1 and 4.3.1.
95 Wisconsin Public Service Corporation (WPS), Green Bay, Wisconsin.

Electric Power Company, Southern California Gas, Pacific Gas and Electric Company and NUON Netherlands have already deployed fuel cells, wind turbines, gas fuelled mini CHP units and PV systems in their distribution grids.

6.3. Institutional aspects

There is no doubt that the electricity sector is going through a period of rapid and fundamental changes triggered by institutional and technical developments and environmental pressures. The process of liberalisation will continue, and the power supply industry will increasingly operate at more than an arm's length from the government. As a consequence, the next few years will see governments, in both industrialised and developing countries, spending considerable time and money on regulating the sector in order to avoid that energy efficiency, technological innovation, renewables and the interests of certain consumer groups being neglected.

6.4. Continued support from the international community needed

Few will deny that current global problems transcend the narrow bonds of party politics and electoral opportunism. Moreover, many people now believe that the political elite is no longer the proper instrument for solving social and other problems but, rather, that it perpetuates those problems and even hampers finding solutions (Ankersmit 1996). However, as argued by Wöltgens (1996), it is by no means certain that the present neo-liberalism will improve the situation.
In developing countries, some degree of deregulation of the power sector will almost certainly pave the way for further improvement in the performance of the sector and encourage private investments in the exploitation of available resources and large-scale power generation. In view of the monetary and political aspects and the consequences for the ecological health of our planet, the focus of the political world will remain on large-scale energy production, transmission and trading. This will include the associated international agreements, technology transfer and international private sector involvement.
History provides much evidence that an unshakeable belief in market forces, as frequently advocated today, often leads to a neglect of rural areas. It may be feared that history will repeat itself, and that the future will only have a limited pro-active role by the political world regarding the development of the rural areas in the developing world.

These observations suggest that future initiatives to benefit the rural population in developing countries will mainly come from local stakeholders, non-governmental organisations, donors and such organisations as the World Bank, the United Nations and regional development banks. It is fair to conclude that during the decades to come continued financial and technical support from the international community will be needed to assist the developing world in improving the situation of the rural and remote communities. There is also reason to believe that the willingness of the world community to provide this support will increasingly depend on the stability of the countries and on the efficiency and effectiveness of efforts to alleviate poverty and develop rural areas.

For this development assistance huge amounts are needed: as has been suggested in Section 1.1 of this study some 800 billion US$ is needed to provide some two billion rural dwellers with electricity only. If the total annual development assistance budget of the Netherlands would be used to only finance these activities, it would take over 300 years to complete the work.

Summary

Background

The majority of the population living in developing countries does not have access to electricity and most of these two billion people live in rural areas. Rural development and particularly agriculture, needs to be stimulated to foster adequate living conditions for the rural population and to ensure sufficient and sustainable food supplies through crop growth, adequate processing and storage technologies. To achieve this objective, both traditional and modern forms of energy, including electricity, will be needed.

It is generally accepted that there are well-performing utilities in the developing world, even in terms of electrification of rural areas. But there are many other developing countries where efforts to provide electricity to rural areas have only had limited success. Despite international support, many utilities continue to show substandard performance.

Growing concerns about the environmental effects of energy production and use have promoted the development and deployment of energy efficient technologies and renewables. In recent years, many countries have agreed on concerted actions to mitigate atmospheric pollution and to improve the sustainability of energy supply.

Other important developments, which are mainly driven by neo-liberal ideology, are the recent regulatory changes and the introduction of competition into the electricity supply industry in industrialised countries. This development has changed the face of the power industry.

These changes were conducive to starting this research on electricity supply to rural areas. This research jointly addresses the impact of the developments and trends on the approach to rural electrification in developing countries, and the implications for the electricity supply sector.

The research is scientifically and societally relevant and links existing theoretical knowledge, practical experience and empirical findings with the aim of increasing the specific expertise needed for organising utility operations. The present work seeks to complement existing literature and to act as a vehicle for transferring specific managerial know how and, in particular, know why. Thus it can contribute to the betterment of the situation of rural communities in the developing regions, and to the performance of the organisations serving their areas.

Though the outcome of the research is mainly relevant to developing countries, countries with a mature electric infrastructure might also find some of the results useful.

Research domain

Most of the earlier research on electricity supply to rural areas addressed issues such as the technical and financial performance of both grid connected and decentralised power systems and the socio-economic impact of electrification. The implications of recent power sector developments and trends for utility organisation and management seem to have received less attention. The objective of the research underlying this study, is to identify and assess relevant trends, to look ahead to opportunities for electricity supply to rural and remote areas, and to translate the results into recommendations for decision makers. The research is approached from an utility perspective and the analysis focuses on three themes: the rural market, the available technologies, and institutional aspects.

Rural electrification programmes implemented in both industrialised and developing countries, are analysed and conclusions drawn. Technical developments and institutional trends are assessed and their implications discussed. Subsequently the implications of the findings for rural electricity supply organisations are identified and critical success factors outlined. Various case descriptions illustrate certain developments and conclusions.

Rural energy supply is only in part a technical issue, and it is generally accepted that substantial contributions from economic, management and social sciences are needed. The research is therefore marked by its width and multidisciplinary character.

Research findings

The analysis of a number of cases reveals that economic circumstances were not apparently a decisive factor in the wide-scale electrification of rural areas in industrialised countries.

It is fair to conclude that at a national level, in most cases, politicians have been far from proactive. The power of lobbies and pressure groups was probably a larger determinant. In many countries the rural population had to rise up against neglect before any actions on the electrification of their areas were taken. In general, the political leverage of the rural population in developing countries is low and this underlines the importance of a proactive and worldwide approach to the problems that rural populations experience.

There is a salient difference between presently developing countries and the industrialised nations around 1900. The latter already had reasonably developed economies and rural infrastructures, and they could afford to invest in electrification. In many European countries, electrification was considered to be more than merely an economic activity, the electricity supply to rural areas was seen as socially important. The economies of the majority of developing countries are weak and do not allow major investments in infrastructure.

As the historical analysis has shown, the electrification of rural areas should not be assessed as an independent activity, but rather as one of the components of a rural development programme. We should not ask ourselves whether electrification of certain areas is feasible, but what we are willing to spend for rural development in general.
There is evidence that an integrated approach to rural development, including electrification, could lead to productivity and business activity synergies.
A general conclusion is that rural electricity supply has always been considerably more expensive than the supply to urban areas. If affordable tariffs are assumed, a cost-benefit analysis of an electrification project in itself will usually show a negative outcome. This is particularly true for smaller decentralised power systems using, for example, diesel power stations.

The analysis of a number of electrification projects reveals that the average investment cost of a connection to a central grid, including the cost of generating capacity, transmission and distribution grid, and service connection amounts to approximately US$ 1900.
If the principle of “the customer pays the real costs” were to be generally applied, the poorest of the rural population in particular would be unable to use electricity despite the fact that they usually consume a very limited number of units and could afford to pay for their consumption against a lifeline rate.
There is evidence that the rural population in only very few instances have shown initiative to self-finance the electrification of their areas. In nearly all countries affordable electrification was only achieved through special national programmes and financing arrangements. Up to 50% government subsidies have been given towards the initial investments, and long-term, low-interest, or interest free, loans were provided to finance the electrical infrastructure. Cross-subsidisation was and still is generally applied. It has been estimated that in Ireland, at the end of the sixties, rural prices were lower by some 29% and urban prices higher by almost 9% than they would have been without cross-subsidisation. Despite financial support, returns on investment were as low as 5% in some cases.

In many countries, either a national or a provincial power utility was considered appropriate in order to avoid municipal boundaries hampering the development of an economically justified electricity infrastructure, and to achieve an acceptable area coverage and sufficient uniformity of tariffs.
Small-scale private rural utilities have seldom proved to be successful. In quite a few countries co-operatives have been successful, but success seems to be linked with the specific situation and culture in the country, and the opportunities for technical, administrative and managerial support.
In many industrialised countries, and some developing countries, separate organisations were made responsible for the implementation of rural electri-

fication programmes. These organisations were frequently decentralised offices of national utilities or, in some cases, specially established co-operatives.
Semi-governmental monopolies proved to be a good solution in the power sector and the experiences in the industrialised world showed that this arrangement safeguarded the continuity of the utility and avoided neglect of financially less attractive supply areas. However rigid legislation and a bureaucratic attitude have often given monopolistic utilities the reputation of being non-participative and have hampered energy-efficient joint power generation with, for example, industry.

The main causes of the substandard performance of utilities and the disappointing results of a number of rural electrification projects in some developing countries, are the uneconomically low tariffs, a lack of operational autonomy and extreme political interference. This disappointing performance, and the inability of governments to finance the construction of the infrastructure, often led, under international pressure, to reform and privatisation of the power sector in these countries.
The experience in many countries shows that the performance of government-owned utilities can be satisfactory provided they are able to operate at an arm's length from the politicians and are reasonably autonomous. Such organisations have established and maintained a reliable and affordable electricity supply and have also demonstrated in other respects an appropriate performance. The ongoing reform of the power sector in industrialised countries is therefore not induced by a substandard performance of the utilities, but is rather the result of the prevailing neo-liberal ideology. Privatisation and the introduction of competition in the power sector are seen as means to improve the efficiency relative to that in a monopolistic situation. Under a liberalised regime the government is perceived as withdrawing from the power sector, but experience shows that strong regulation is needed to avoid the neglect of energy efficiency issues and the deployment of renewables, and to protect certain consumer groups. Government intervention is also required to control the monopolistic grids and the charges for the transmission of electricity.
During the creation of the electricity infrastructure, many power utilities were vertically integrated to ensure an appropriate tuning of generation, transmission and distribution of electricity. In many industrialised countries, deregulation changed the monopoly-based electricity sector into one with a competitive market in both generation and retail sell of electricity. The unbundling of generation, transmission and distribution is seen as a necessity in establishing a successful open electricity market.
This unbundling implies a fragmentation of the electricity supply sector with the associated risk of insufficient co-ordination between the sub-sectors. Such a situation might be acceptable and manageable in case of mature infrastructures and low demand growth, but it involves substantial risks if the infrastructure is

expanding and demand is increasing at more than 7% per annum, as is the case in many developing countries.

The unsatisfactory situation in several developing countries demands reforms to the electricity sector. In these cases the main objectives should be a substantial reduction of political influence, and the creation of an attractive environment for private investments, particularly in large-scale power generation. However, the extent of any reform should be approached with “a healthy degree” of scepticism: the market is relatively small, the infrastructure is limited and expanding, and often the human resources needed for strong regulation are lacking.

While industrialised countries could ask themselves the question what is the *maximum* amount of power sector reform that is desirable, the question for the developing regions could be what is the *minimum* reform needed to stop political interference and government intrusiveness.

The electrification of rural areas has traditionally been based on electricity supply from a central grid. This preference emerged at the beginning of the last century due to the “economies of scale” achieved with large power stations. Decentralised schemes with, for example, diesel generators often led to relatively expensive electricity supply systems. However, as a result of recent technological advances, various alternative options have emerged involving both traditional and renewable sources. These technologies that offer enhanced opportunities for decentralised power systems include photovoltaic systems, wind turbines, biomass-fuelled combined heat and power units, and fuel cells.

These technological developments coincide with a growing concern for the ecological health of our planet and, in particular, the impact of emissions from the burning of fossil fuels. International and national agreements are forcing utilities to reduce emissions and, as a consequence, programmes are being implemented to increase the efficiency of the production and use of energy, and to promote the deployment of renewables.

Although a renaissance for decentralised power supply is clearly visible, centralised grid systems will continue to play a major role in power supply, though the function of the grid will change. In countries with a mature electric infrastructure, the emergence of decentralised generators has already caused the function of some distribution grids to change from a passive one-way system into a dynamic multi-functional one. In some cases, expensive adaptations to the existing grids are needed to safeguard power system stability.

In many developing countries, rural areas offer opportunities to deploy power systems based on small-scale hydro power, solar energy and biomass. These areas offer an “electrification green field” where the selection of the technological option can be determined by the locally available resources, the financial situation, the features of the supply area, and the environmental impact.

Implications

Leaving fairness and equity aside, the world can no longer continue to neglect, in terms of access to affordable electricity, the still unserved rural and remote areas. Progressive unification will gradually force the international community to satisfy the material needs of the global population, and energy, particularly electricity, will play an important role in this respect. The question will not be, are rural areas to be electrified, but rather when.

More so than in the past, the electrification of rural and remote areas in developing countries will be based on decentralised power facilities, including Solar Home Systems. The latter system is an attractive option for satisfying initial electricity needs. However, as wellbeing increases so does electricity demand with the consequence, that after time, a more powerful electricity supply will be needed. This evolution is one of the reasons why any rural electrification activity should be designed and implemented within a policy framework and in a well-planned manner. Excess power generated by rural industrial enterprises can be used to support public electricity supply and small-scale independent power producers should be seen as fully fledged suppliers of electricity.

All these developments imply that a close co-operation between the utility and rural customers will be needed along with a well-developed marketing and technical function.

It is generally accepted that rural electricity supply is expensive relative to urban electricity supply and is has therefore often been considered by utilities as somewhat of a chafe. But, continuation of the "business-as-usual" approach is not a solution for the two billion people still without access to electricity. In view of the currently available technological options and international community support rural electrification should be seen as a challenge.

To succeed in this challenge the appropriate circumstances are needed and in this respect this research has revealed a number of critical success factors:

- A politically and socially stable environment.
- Proper institutional conditions. Appropriate legislation, regulation and subsidy schemes to enable a commercial approach to power supply and utility operations at more than an arm's length from the political world.
- Support from the international community. The majority of the rural population in developing countries are poor, but nevertheless willing to pay a substantial part of their income for reliable electricity. Despite this, subsidies on initial investments and appropriate financing schemes will be needed.
- An appropriate electrification process. To meet the demand for energy services in the most efficient, sustainable and environmentally and socially acceptable ways, the electrification process should consider all the local opportunities for power production. Electrification should preferably be a component of an integrated rural development programme.

- A well-developed strategy. The strategy should be based on the importance of establishing close relationship with all stakeholders, energy efficiency measures, the deployment of renewables, and consideration of a “multi-function utility”.
- An appropriate utility organisation. The organisation should be adapted to the environment in which the utility has to operate, and be based on decentralisation and operational autonomy.

The objective of the research was not to give detailed recommendations for the organisational structure and management approach of electric utilities serving rural areas. The situations and backgrounds differ from country to country and, as an obvious consequence, the decision makers will have to adopt those solutions which are appropriate to their local circumstances.

However, there are more-or-less universal organisational and managerial preconditions. Classical organisation theories focus on internal events and to a large extent neglect the external situation. However a universal and situation-independent organisational and management approach does not exist and given the dynamics of the environment of contemporary utilities, classical organisation theories would seem inappropriate to tackle utility organisation problems.

Contingency theory takes the situation and the environment in which the problems occur as a starting point followed by the selection, from existing theories, of the appropriate organisational and managerial principles. This theory therefore provides a basis with which to address an organisation as a socio-technical system in interaction with its environment, and would thus seem an appropriate tool for the design of organisation structures and the associated management concepts under the current dynamic circumstances.

Apart from the nature of the organisational and managerial problems and the success factors, a manager must have a proper understanding of the environment in which they occur. The last chapter of this study presents a model that illustrates the interrelationship between the organisation and its major influence domains.

Samenvatting

Achtergrond

Van de ongeveer twee miljard mensen op deze wereld die niet over elektriciteit beschikken, woont verreweg het grootste gedeelte in de rurale gebieden van ontwikkelingslanden. Een belangrijk deel van deze mensen heeft zelfs geen toegang tot andere geschikte energiebronnen.
Terwijl de wereld onder invloed van verbeterde telecommunicatiemiddelen en de uitgebreide reismogelijkheden steeds meer het karakter van een "global village" krijgt, neemt de sociale en politieke druk toe om de levensomstandigheden in deze rurale gebieden te verbeteren. Een goede energievoorziening is daarbij van groot belang.
Het is bekend dat er in sommige ontwikkelingslanden uitstekend functionerende elektriciteitsbedrijven zijn. Maar ondanks internationale financiële en technische steun geven de bedrijfsvoering van meerdere elektriciteitsbedrijven in ontwikkelingslanden en de resultaten van sommige rurale elektrificatieprojecten aanleiding tot grote zorg.
De zorg om de milieueffecten van onze energievoorziening neemt toe en maatregelen zijn in voorbereiding en deels in uitvoering om de emissies te beperken en de duurzaamheid te vergroten. Door recente technologische ontwikkelingen zijn er alternatieve opties aan zowel de vraagkant als leveringskant beschikbaar gekomen.
Tenslotte moeten ook de door de neoliberale ideologie ingegeven institutionele ontwikkelingen in de energiesector worden genoemd als een factor die van invloed is op de toekomstige benadering van de rurale elektriciteitsvoorziening.
Vorengenoemde ontwikkelingen vormden mede de aanleiding tot het onderzoek waar deze publicatie verslag van doet. Tijdens dit onderzoek stond de vraag centraal wat de effecten van de verschillende ontwikkelingen op de elektriciteitsvoorziening van rurale gebieden in ontwikkelingslanden kunnen zijn en welke benadering het meest geschikt is voor de toekomst.
Het onderzoek is zowel wetenschappelijk als maatschappelijk relevant en verbindt bestaande theoretische kennis, praktische ervaringen en resultaten van empirisch onderzoek met elkaar teneinde de kennis op het gebied van de bedrijfsvoering van rurale elektriciteitsbedrijven te vergroten. Deze publicatie hoopt, zij het op indirecte wijze, ook een bijdrage te leveren aan de verbetering van de levensomstandigheden in de rurale gebieden van de "derde wereld". Alhoewel de resultaten voornamelijk relevant zijn voor ontwikkelingslanden, is een aantal aspecten wellicht ook voor landen met een volwassen rurale infrastructuur van belang.

Aanpak van het onderzoek

De elektriciteitsvoorziening van rurale gebieden is zeker geen nieuw onderzoeksterrein. Er is op het gebied van de technische, financieel-economische en socio-economische aspecten al veel onderzoek gedaan. De implicaties van recente ontwikkelingen en trends in de energiesector voor de benadering en organisatie van rurale elektrificatie, hebben echter weinig aandacht gekregen.
Vanuit het perspectief van het elektriciteitsbedrijf worden in het onderzoek rurale elektrificatieprogramma's in zowel geïndustrialiseerde landen als ontwikkelingslanden geanalyseerd en recente ontwikkelingen belicht. De conclusies zijn gegroepeerd in drie thema's: de rurale markt, de beschikbare technologie en de institutionele aspecten. Vervolgens worden de resultaten vertaald in aanbevelingen voor de besluitvorming over de meest geschikte aanpak van rurale elektriciteitsvoorziening in ontwikkelingslanden. Verscheidene case beschrijvingen illustreren bepaalde ontwikkelingen en conclusies.
De energievoorziening van rurale ontwikkelingsgebieden is maar ten dele een technisch vraagstuk en duidelijk een gebied waar technologie, organisatie, sociale en economische wetenschappen moeten samenwerken. Het onderzoek wordt dan ook gekenmerkt door een breed en multidisciplinair karakter.

Onderzoeksresultaten

Uit de analyse van de in geïndustrialiseerde landen uitgevoerde rurale elektrificatieprogramma's blijkt dat de economische omstandigheden in het betrokken land niet doorslaggevend waren voor de uitvoering van rurale elektrificatieprogramma's. Op nationaal niveau was de politieke elite zelden pro-actief en dikwijls moesten door de bevolking via pressie en lobbygroepen acties worden ondernomen om hun gebieden geëlektrificeerd te krijgen. Omdat met name in ontwikkelingslanden de rurale bevolking een beperkte politieke invloed heeft, onderstreept deze ervaring de noodzaak om op wereldniveau de energieproblematiek van de rurale bevolking in ontwikkelingslanden pro-actief te benaderen.
De situatie in de rurale gebieden in geïndustrialiseerde landen rond 1900 is niet vergelijkbaar met die in ontwikkelingslanden nu. Eerstgenoemde gebieden hadden al redelijk ontwikkelde economieën en infrastructuren en bovendien konden de landen het zich veroorloven om in elektrificatie te investeren. Overigens werd in vele Europese landen elektrificatie gezien als meer dan een economische activiteit; het werd ook in sociaal opzicht belangrijk geacht.
De economieën van ontwikkelingslanden zijn zwak en er zijn nauwelijks mogelijkheden om rurale elektrificatie te financieren. De infrastructuur van de meeste rurale gebieden is slecht ontwikkeld.

De elektrificatie van rurale gebieden in ontwikkelingslanden moet niet worden beoordeeld als een op zich zelf staande activiteit, maar als een onderdeel van een ruraal ontwikkelingsprogramma. We moeten ons niet afvragen of de elektrificatie van bepaalde gebieden financieel haalbaar is maar wat we bereid zijn te betalen voor rurale ontwikkeling in het algemeen. Er zijn overigens voldoende aanwijzingen dat een integrale aanpak van rurale ontwikkeling, inclusief elektrificatie, tot synergie effecten op het gebied van productiviteit en bedrijvigheid kan leiden.
De algemene conclusie is dat rurale elektriciteitsvoorziening altijd aanzienlijk duurder is geweest dan die in stedelijke gebieden. Als het principe "de klant betaalt de werkelijke kosten" zou worden doorgevoerd, dan zouden in het bijzonder de rurale armen geen elektriciteit kunnen gebruiken ondanks hun zeer geringe verbruik.

Een analyse van een aantal uitgevoerde projecten leert dat momenteel een aansluiting op een centraal elektriciteitsnet, inclusief het benodigde opwekvermogen, het transport en distributienet en de huisaansluiting, gemiddeld een investering van ongeveer US$ 1900 vergt.
De rurale bevolking heeft zelden initiatieven genomen om de elektrificatie van de eigen gebieden zelf te financieren. In nagenoeg alle landen kon een betaalbare rurale elektrificatie alleen worden bereikt door middel van speciale nationale programma's en bijzondere financiering. Er werd tot 50% subsidie op de investeringskosten van het distributienet gegeven en zelfs dan was het investeringsresultaat laag, soms zelfs 5%. Ook werden renteloze en laagrentende lange termijn leningen verstrekt. Dwarssubsidies waren (en zijn) algemeen. Zonder deze subsidie zou in Ierland eind jaren zestig de kWh prijs ongeveer 29% hoger zijn geweest en in de steden 9% lager.
Om infrastructurele problemen door uiteenlopende gemeentebelangen te vermijden, werden vaak nationale en provinciale bedrijven gesticht die op concessiebasis hun regio's volledig moesten elektrificeren. Kleinschalige private rurale elektriciteitsbedrijven waren zelden succesvol. Er zijn succesvolle coöperatieve bedrijven maar hun succes lijkt nauw samen te hangen met de situatie en cultuur in het betreffende land en met de mogelijkheid voor steun op technisch, administratief en management gebied.

In veel industrielanden en in een aantal ontwikkelingslanden werden afzonderlijke organisaties belast met de uitvoering van rurale elektrificatieprogramma's. Deze organisaties ressorteerden onder nationale elektriciteitsbedrijven, maar waren ook soms afzonderlijke coöperaties.
Overheidsmonopolies in de elektriciteitssector waren er niet voor niets en het onderzoek heeft aangetoond dat er in de geïndustrialiseerde landen voldoende redenen waren om nutsbedrijven dicht bij de overheid te houden. Deze redenen hebben onder andere betrekking op het waarborgen van de continuïteit van het bedrijf en op het vermijden van achterstelling van financieel minder

aantrekkelijke voorzieningsgebieden. Anderzijds hebben monopoliebedrijven zich als gevolg van starre wetgeving en een te bureaucratische werkwijze te weinig participerend opgesteld.

De belangrijkste oorzaken van de relatief slechte resultaten van nationale elektriciteitsbedrijven in bepaalde ontwikkelingslanden en de beperkte duurzaamheid van meerdere rurale elektrificatieprojecten zijn veel te lage tarieven, een gebrek aan autonomie en vergaande politieke bemoeienis met de dagelijkse bedrijfsvoering. De slechte resultaten van deze elektriciteitsbedrijven en de onmogelijkheid van de betreffende overheden om infrastructurele werken te financieren hebben, vaak onder internationale druk, tot herstructurering en privatisering van de energiesector in die landen geleid.
Overheidsbedrijven blijken wel degelijk goed te kunnen functioneren, mits de juiste omstandigheden aanwezig zijn. Een van de belangrijkste voorwaarden voor een adequate bedrijfsvoering is dat het bedrijf autonoom en op meer dan een armlengte van de politiek kan functioneren en dat het beleid niet wordt doorkruist door het korte termijn denken van de politiek.
De vele semi-overheidsbedrijven in de geïndustrialiseerde wereld bewijzen dat zij een betrouwbare en betaalbare elektriciteitsvoorziening kunnen opbouwen en handhaven.
De huidige institutionele wijzigingen in de energiesector van de geïndustrialiseerde wereld worden dan ook niet ingegeven door een slechte bedrijfsvoering maar door de vigerende neoliberale ideologie. In dat verband worden privatisering en de introductie van concurrentie in de energiesector als middelen gezien om de doelmatigheid te vergroten ten opzichte van een monopolie-situatie. Alhoewel er wordt uitgegaan van een meer bescheiden rol van de overheid, toont onderzoek aan dat op overheidsniveau een sterke regulering nodig is, onder andere om te voorkomen dat energie efficiency en duurzame energie te weinig aandacht krijgen en bepaalde groepen klanten de dupe worden van concurrentiestrijd. Ook vraagt het beheer van de monopolistische elektriciteitsnetten en de tariefstelling voor het transport van elektriciteit daarover, aandacht van de overheid.
In het verleden, tijdens de opbouw van de elektrische infrastructuur, waren vele elektriciteitsbedrijven verticaal geïntegreerd waardoor de afstemming van opwekking, transport en distributie van elektriciteit zeker was gesteld. De in het kader van de liberalisering doorgevoerde scheiding van opwekking, transport en distributie en dienstenlevering, impliceert een fragmentatie van de elektriciteitssector met het risico van een slechte coördinatie tussen deze deelsectoren. Dat is wellicht bij een volwassen elektrische infrastructuur en geringe groei van de vraag verantwoord, maar het kan riskant zijn tijdens de uitbouw van de voorziening, zoals dat in ontwikkelingslanden voorlopig het geval is.

Er zijn in meerdere ontwikkelingslanden voldoende redenen om een herstructurering van de elektriciteitssector door te voeren. Enerzijds moet de

politieke invloed sterk worden verminderd en anderzijds moet privaat kapitaal kunnen worden aangetrokken voor met name, grootschalige opwekking. Maar toch is een zekere scepsis ten aanzien van de omvang van deze herstructurering op zijn plaats. De markt is relatief klein, de infrastructuur is beperkt en groeiende en de mankracht voor krachtige regulering ontbreekt vaak. Verder lijken noch privatisering noch concurrentie oplossingen te bieden voor de rurale elektrificatie in ontwikkelingslanden. Terwijl industrielanden zich kunnen afvragen wat de *maximale* omvang van de herstructurering kan zijn, moeten ontwikkelingslanden zich afvragen welke *minimale* herstructurering geschikt is.
Vaak is de elektrificatie van rurale gebieden gebaseerd op centrale elektriciteitsvoorziening die aan het begin van de vorige eeuw is ontstaan als resultaat van de "economies of scale" die op het gebied van de opwekinstallaties kon worden bereikt. Decentrale systemen, bijvoorbeeld door middel van dieselcentrales, blijken in veel gevallen tot een relatief dure voorziening te leiden. Door recente technologische ontwikkelingen is er een groot aantal kleinschalige mogelijkheden beschikbaar gekomen waarmee op doelmatige wijze decentraal elektriciteit kan worden opgewekt. Deze ontwikkelingen vallen samen met een toenemende zorg voor het milieu en de door het verstoken van fossiele brandstoffen veroorzaakte emissies. Internationale en nationale afspraken dwingen de energiebedrijven tot het terugdringen van de emissies en daarom zijn er programma's ontwikkeld om de efficiency van de opwekking en het gebruik van energie en de toepassing van duurzame energiebronnen, te bevorderen. Een en ander heeft in landen met een volledige elektrische infrastructuur al geleid tot een sterke toename van het aantal decentrale opwekeenheden, ook in rurale netten. Deze decentrale generatoren, zoals kleine warmtekrachteenheden, windturbines en netgekoppelde photovoltaïsche eenheden hebben effect op het gedrag van het bestaande elektriciteitsnet. De meeste rurale netten zijn gebaseerd op "eenrichtingsverkeer" en dit soort netten kunnen vaak de grotere dynamiek die met de aansluiting van decentrale eenheden gepaard gaat, niet aan. Vaak zijn kostbare aanpassingen nodig om de gewenste netstabiliteit te waarborgen.

Alhoewel er duidelijk sprake is van een renaissance van de decentrale elektriciteitsopwekking, betekent dit niet dat de centrale elektriciteitsnetten hebben afgedaan. Wel dat de functie van de rurale netten anders wordt, en daarmee ook de planning en configuratie: het net krijgt een multifunctioneel karakter.
In ontwikkelingslanden beschikken rurale gebieden vaak over een potentieel aan duurzame energie zoals kleinschalige waterkracht, zonne-energie en biomassa. Eerdergenoemde kleinschalige opweksystemen bieden de mogelijkheid om dit potentieel te benutten. Daarbij wordt de toepassing van de verschillende technologische opties bepaald door de locaal aanwezige energiebronnen, de financieel-economische aspecten, de specifieke eigenschappen van het voorzieningsgebied en niet in de laatste plaats, door de milieueffecten.

Implicaties

Afgezien van aspecten als rechtvaardigheid en gelijkheid, kan men zich in een wereld die steeds meer de trekken van een “global village” krijgt, niet veroorloven een groot deel van de mensheid achter te stellen. Toenemende politieke en sociale druk zullen de internationale gemeenschap stimuleren bij te dragen aan de verbetering van de levensomstandigheden van de wereldbevolking als geheel. Daarbij zal energie en in het bijzonder elektriciteit, een grote rol spelen. De vraag is daarom niet *of* rurale gebieden zullen worden geëlektrificeerd, maar *wanneer*.
Naar verwachting zal de elektrificatie van rurale gebieden in ontwikkelingslanden meer dan in het verleden worden gebaseerd op decentrale systemen, inclusief photovoltaïsche eenheden (Solar Home Systems). De toepassing van laatstgenoemde systemen is duidelijk een optie om in de eerste behoeften aan elektriciteit te voorzien. Met toenemende welstand echter zal ook de vraag naar elektriciteit groter worden en om aan deze vraag te voldoen is op termijn een zwaarder elektriciteitssysteem nodig. Deze evolutie is een van de redenen waarom elk ruraal elektrificatieprogramma op een geplande wijze en binnen bepaalde beleidskaders moet verlopen. De in rurale gebieden industrieel opgewekte elektriciteit moet ook voor de publieke voorziening kunnen worden benut terwijl kleinschalige zelfstandige opwekkers (Independent Rural Power Producers) als volwaardige energieleveranciers moeten worden beschouwd. Bovengeschetste ontwikkelingen vragen om een hechte relatie met de klant en een goed ontwikkelde marketing en technische functie.

Het is bekend dat rurale elektriciteitsvoorziening ten opzichte van urbane gebieden duur is en dat het daarom in het verleden vaak werd beschouwd als stiefkind van de energiebedrijven. Maar een voortzetting van de “business-as-usual” benadering is bepaald geen oplossing voor de ongeveer twee miljard mensen op deze wereld die niet over elektriciteit beschikken. In het licht van de huidige technische mogelijkheden en steun van de internationale gemeenschap, moet rurale elektrificatie in ontwikkelingslanden eerder als een uitdaging worden gezien. Om die uitdaging aan te kunnen gaan zijn wel de juiste voorwaarden nodig en in dit verband worden in het onderzoek de volgende kritische succesfactoren genoemd:

- Het land moet politiek en sociaal voldoende stabiel zijn.
- Geschikte institutionele omstandigheden. De wetgeving, regulering en subsidies moeten een commerciële benadering van de elektriciteitsvoorziening mogelijk maken en het elektriciteitsbedrijf moet op meer dan een armlengte van de politiek kunnen functioneren.
- Steun van de internationale gemeenschap. Het grootste gedeelte van de rurale bevolking in ontwikkelingslanden is arm maar er is bereidheid om een relatief groot deel van het toch al lage inkomen aan elektriciteit te

betalen. Niettemin zal subsidie op investeringen nodig zijn en ook moeten geschikte financieringssystemen beschikbaar zijn.

- Een goed onderbouwd elektrificatieproces. Om de vraag naar elektriciteit op de meest efficiënte, duurzame en ecologisch acceptabele wijze te realiseren, moet bij de bepaling van het elektrificatieproces de benutting van alle locale mogelijkheden voor decentrale opwekking worden betrokken. De elektrificatie moet bij voorkeur samengaan met een integraal ruraal ontwikkelingsprogramma.
- Een goed ontwikkelde strategie. Hierbij moet het belang van goede “stakeholder relations” een belangrijke plaats innemen evenals energie-efficiency, duurzame energie en de eventuele vorming van een “multi-utility”.
- Een organisatie aangepast aan de omgevingscondities en gebaseerd op decentralisatie en operationele zelfstandigheid.

Het onderhavige onderzoek was niet bedoeld om een complete leidraad op te leveren voor het ontwerpen van organisaties voor rurale elektriciteitsbedrijven. De situaties in de verschillende landen zijn zo verschillend dat gedetailleerde en algemeen geldende instructies onmogelijk en ook niet zinvol zijn. Wel wordt de gewenste benaderingswijze aanbevolen op grond waarvan het management, rekening houdende met de specifieke situatie, beslissingen kan nemen.
Klassieke organisatietheorieën richten zich op de interne situatie van organisaties en nauwelijks op de omgeving. Er bestaat echter geen algemeen geldende en van de situatie onafhankelijke organisatiestructuur en management benadering. Gelet op de grote dynamiek in de omgeving van elektriciteitsbedrijven, moeten daarom klassieke organisatietheorieën als minder geschikt worden aangemerkt voor beschouwingen over de gewenste organisatiestructuur.
De contingency theorie daarentegen stelt dat de organisatie, die wordt beschouwd als socio-technisch systeem, met zijn omgeving interactief is. Deze theorie gaat verder uit van een pluralistische benadering van bestaande organisatietheorieën en stelt dat de specifieke situatie bepalend is voor de structuur en managementbenadering. De contingency benadering lijkt daarom een geschikt middel om – onder de huidige dynamische omstandigheden – organisatievraagstukken aan te pakken.
De toepassing van deze benadering impliceert een nauwkeurige analyse van de omgevingscondities en ook de manager moet een goed zicht hebben op de omgeving waarin zich de organisatievraagstukken afspelen. In dit verband is in het laatste hoofdstuk van deze publicatie een model opgenomen waarmee de relatie van de organisatie met de omgeving wordt geïllustreerd.

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