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NIKOS

CLEAN COAL TECHNOLOGY IN CHINA

A strategy for the Netherlands

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Master thesis
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ABSTRACT

Purpose of this research report

Clean coal technologies (CCT) are technologies designed to enhance both the efficiency and the environmental impact of coal extraction, preparation and use. This report mainly focuses on clean coal technologies that are employed in the power generation and fuel-oil substitution sector.

China is world's third largest country, the second largest economy measured by purchasing power parity (after the US), the most populated country, as well as the most heavily polluted country, and the second largest energy consumer (after the US). All these elements indicate that China operates on a large scale, both in a positive and negative sense.

Coal is the backbone of China's energy system. It meets just over 60% of the country's primary energy needs. Coal's importance in the overall fuel mix has been growing in recent years, due to booming demand for electricity, which is almost 80% coal-generated. Since China is characterized by its striking dependence on coal, now and in the future, China is potentially the biggest market for clean coal technologies. This market is increasingly attracting international attention from countries (including The Netherlands) and organizations, some of which have already been exploring on clean coal technologies in co-operation with China for years.

Design/methodology/approach

This research centers around the question 'What strategy does the Netherlands has to apply regarding the transfer of its clean coal technology to China?'. With the help of specific sub-questions, the main question is answered. Through the study of relevant theories and empirical practices, literature reading and comparisons, a case study and interviews with industry experts and industry players, this research intends to critically analyze the main opportunities in the field of CCT in China, for Dutch organizations. The specific clean coal situation for China and the Netherlands are studied with a hybrid approach that confronts macro level factors with specific factors of clean coal technologies on a micro-level. In order to get a deeper insight into the Dutch competence of one technology, CO_2 sequestration: an analytical framework is added for a future meso-level study.

Findings

The findings of this research indicate that the clean coal technologyand activities of the Netherlands are not well understood in China. Chinese research institutes and business organizations do not have enough knowledge about specific activities and expertise about CCT of Dutch organizations. As a result, the Netherlands should focus on specific clean coal technologies in which it could become a renowned key player, instead of covering a wide range of CCT.

The first step in starting co-operation in CCT must be research. China is described as the 'mainboard' of clean coal technology: the most advanced technologies are being explored by China. China collects and absorbs technologies, and then develops them further. The Netherlands can tag along with these developments by putting more effort in knowledge and expertise transfer with China, for instance by setting up joint training and R&D programs and exchange of employees (engineers) and students (MSc, PhD.).

The Chinese situation

Future development of Clean Coal Technologies in China

Short term (one year or less)	Medium term (2-10 years)	Long term (10 or more years)
• **Coal washing** • **Various efficiency improvements** • **Small circulating fluidized bed boilers** • **Flue Gas Desulphurization (FGD)** • **Coal gasification**	• Larger scale fluidized bed boilers • Supercritical boilers for coal fired power plants • IGCC • Coal liquefaction	• Carbon Capture and Storage (CCS)

Opportunities

By further developing knowledge and technology in the Netherlands regarding coal blending (mixing of coal for a better composition), Integrated Gasification Combined Cycle (IGCC), Carbon Capture and Storage (CCS), Enhanced Coal Bed Methane (ECBM), and other efficiency-based clean coal technologies, opportunities arise to support upcoming coal based economies, like China, with the development of a modern and clean energy system. When China does not set emission targets for CO_2 reduction, CCS standalone, is not very advantageous for China. Dutch activities should therefore focus among other things on Enhanced Coal Bed Methane (ECBM) in China. This technology improves the gas winning by injecting CO_2 into coal beds and pushing the methane gas out. Besides an efficiency improvement of up to 50%, application of ECBM also lowers the pressure on China's scare gas supplies. In the beginning of July 2008, a financial support program (Asia Facility) of the Dutch government was granted to a mutual knowledge transfer program with Dutch and Chinese parties. This program is interesting in itself, but possible future spin-offs could be even more interesting.

Competition and collaboration

The competition on the Chinese market for clean coal technologies is high. On the one side, there is competition from giants like Japan, the US, Canada and Australia who are investing billions in Sino-research programs to position their technologies on the Chinese market. On the other side, China is developing clean coal technologies very rapidly by itself. The forms of collaboration are not limited to the Dutch border, simply because teaming up with other European organizations can drive an even stronger attempt to seize a share of the Chinese market. The Dutch focus to become a key-player in CCS can be of future importance for building a competitive advantage over other countries but also to reach its own climate targets for CO_2 reduction. Besides this, the focus on CCS fits perfectly into the European framework, especially in the European strategy for China. Attractive organizational modalities are available for Dutch organizations that intend to co-operate with China in the field of CCT. Yet a number of obstacles hinder successful technology transfer to China. Examples of these obstacles lie in the field of intellectual property rights, finance, technological capabilities, and unfavorable governmental policies. By reading this report, organizations will better understand the current situation and will be more favorably positioned to overcome potential obstacles in seizing opportunities on CCT in China.

Research limitations and future research

The sample contains of 11 players with very different backgrounds (energy producer, governmental organizations, research organization) this limits the generalization of the outcome. Because of the 'snapshot' that is taken of the clean coal technology market, no developments can be measured during the research based on own primary research data. Also the research findings are limited to the Chinese and Dutch borders and cannot be generalized for other countries that are dependent on coal as a primary resource of energy. More research is needed on all technical aspects of carbon sequestration, fundamental processes (e.g., pore behavior), leakage rates and safety, storage capacities, and measurement-monitoring-verification, as well as on policy aspects including permitting and liability. Also the Dutch competence on CO_2 sequestration needs to be analyzed further. Therefore, this research presents an analytical framework that can be used.

Origin/value of this paper

While current studies provide insight in clean coal technology opportunities in China on different research levels, this research provides interesting opportunities specifically for the Netherlands. The proposed approach aims to study the clean coal technology market in China at both a macro- as in a micro level and makes a connection with Dutch activities so that knowledge with regards to the Chinese and Dutch practices, opportunities and threats can be achieved by organizations, universities and businesses.

PREFACE

This report is the result of the research executed to obtain my Master of Science degree in Business Administration. This research was carried out in Enschede, Beijing and Kortenhoef. I would like to thank all the people who have invested their time, energy and haven given their support to make this research a success. I hope that this report forms a positive stimulation for future cooperation with- and clean coal technology transfer to China.

Kortenhoef, January 2009.

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List of abbreviations and acronyms	
ADB	Asian Development Bank
APEC	Asia-Pacific Economic Cooperation
ASEAN	Association of Southeast Asian Nations
BRICC	Beijing Research Institute of Coal Chemistry
CATO	Knowledge network for organizations in CO_2 Capture, Transport and Storage in the Netherlands
CBM	Coal Bed Methane
CCCT	Clean Coal Combustion Technologies
CCICED	China Council for International Cooperation on Environment and Development
CCII	China Coal Information Institute
CCPIT	China Council for the Promotion of International Trade (China Council)
CCS	Carbon Capture and Storage
CCT	Clean Coal Technologies
CDM	Clean Development Mechanism
CDM EB	Clean Development Mechanism Execution Board
CER	Certified Emissions Reductions
CFB	Circulating Fluidized Beds
CFBC	Circulating fluidized Beds Combustion
CO_2	Carbon Dioxide
COE	Cost Of Electricity
COP/MOP	Conference of the Parties
CSLF	Carbon Sequestration Leadership Forum
CTL	Coal to Liquid: Coal liquefaction
CUCBM	China United Coal bed Methane
CWM	Coal Water Mixture
ECBM	Enhanced Coal Bed Methane
EOR	Enhanced Oil Recovery
EPEI	Environmental Protection in the Energy Industry
EU	European Union
FDI	Foreign Direct Investment
FGD	Flue Gas Desulphurization
gce/kWh	Gram coal equivalent weight/kilowatt-hour
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Green House Gas
GNP	Gross National Product
GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
IPR	Intellectual Property Rights
NDRC	National Development & Reform Commission
NO_x	Nitrogen

nZEC	Near Zero Emissions Coal
OECD	Organization for Economic Cooperation and Development
OPEC	Organization of Petroleum Exporting Countries
PC	Pulverized Coal
PFBC-CC	Pressurized Fluidized Bed Combustion
SC	Super Critical
SO_2	Sulfur Dioxide
SOE	State Owned Enterprise
SPCC	State Power Corporation of China
TPES	Total Primary Energy Supply
UCE	Utrecht Centre for Energy Research
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
U-SC	Ultra- Super Critical
USCPC	Ultra- Super Critical Pulverized Coal
VROM	Ministry of Housing, Spatial planning & Environment of the Netherlands
ZEP	Zero Emission Fossil Fuel Power Plants

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1. INTRODUCTION

1.1 BACKGROUND INFORMATION

The relevance of research on clean coal technology is high, mostly because coal is simultaneously the fossil fuel with the highest carbon content per unit of energy and the fossil fuel with the most abundant resources in the world. This is particularly true for China which is currently by far the largest and most active market for clean coal technologies, at present and in the coming decennia. (Philibert and Podkanski, 2005)

What are clean coal technologies?

Clean Coal Technologies (CCT)are defined by the objective to reduce the output of certain by-products of coal production and consumption, which is the main reason to use the word 'clean'. In the World Coal Institute report 'Coal Power for Progress', CCTs is defined as "technologies designed to enhance both the efficiency and the environmental acceptability of coal extraction, preparation and use". (World coal institute, 2002) These technologies reduce emissions and waste and increase the amount of energy gained from each ton of coal. CCT represents a continuously developing range of options to suit different coal types, different environmental problems, and different levels of economic development (World coal institute, 2004).

As a general rule, coal-use technologies are regarded as 'clean' if they offer an improvement over those technologies which are currently in use. Hence, it is more accurate to use the word 'cleaner coal' than the commonly used term 'clean coal'. Moreover, technologies, which are clean in one country, may not be regarded as clean in other countries (Vallentin and Liu, 2005). But, since most sources use the word 'clean coal', this report will also stick to this term.

In this research, the field of clean coal technologies will be mainly explored with regard to clean coal technologies that are used in the power generation and fuel-oil substitution sector. This is due to the fact that China's power sector is the largest consumer of the coal industry (Vallentin and Liu, 2005). Coal accounts for 60% of China's energy supply, and is the largest source of local pollution and CO_2-emissions.(Energy Working Group, 2008)

High prices and the economic vulnerability associated with oil and natural gas dependence have triggered interest in coal gasification and liquefaction in many countries, including China. In addition, air pollution, acid rain precipitation, and climate change are increasingly generating interest in cleaner coal technologies, including CO_2 capture and storage. (Zhao, 2007)

Clean coal is already the subject of numerous forms of international collaboration, aiming either at reducing local polluting emissions or global CO_2 emissions from coal use. Collaboration on research, development and demonstration (RD&D) occurs, in particular, through joint efforts undertaken by industrialized countries' governments and industries, independently or together. Many such efforts, and probably the best documented ones, have been performed in China.

Embassy of the Kingdom of the Netherlands

The principal of this graduation research is the Economic and Commercial Department of the Embassy of the Kingdom of the Netherlands, located in Beijing, China. The Dutch economic network in China strives for extension and improvement of the economic links between the Netherlands and China. The Dutch economy has a vested interest in China. The Netherlands is, after Germany, the second largest European trade partner of China. 'In the energy sector, government R&D programs have been significant ways of generating new knowledge, in addition to the R&D financed and pursued by the capital goods industry. Policy, therefore, needs to be formed to make sure that there is funding for new knowledge creation and that there are actors willing to do the research.'(Jacobsson and Johnson 2000)

Cluster approach

The Dutch Embassy in Beijing has noticed that the Dutch players were very fragmented and there was no comprehensive approach. Also there is a vigorous competition from other countries on the Chinese market. The idea behind a more clustered approach is that by connecting government policy, research, and the market, a more sustained co-operation with China is possible. With a joint approach, complementarities in skills and competences can be achieved. A central idea in such efforts is to connect fragmented users and help them to formulate and articulate their offer, i.e. to create or improve the functioning of the market. A new energy system based on many technologies and involving many actors, some of which are small and poor in resources, would seem to be an excellent arena for applying such a policy more extensively. Involved parties are the government, universities, knowledge institutions and businesses. The areas of interest of the cluster approach are based on the Dutch Innovation Platform and its key areas: flowers & food, high-tech systems and materials, water, the chemicals industry, the creative industry and pensions and social insurance. ICT and energy play an important role as innovation axis in all areas of the economy. For the activities of the Dutch Embassy in Beijing regarding energy, this effort has been named the 'Energy Transition Approach'. This approach is derived from principles and rules of science, government and business (Netwerk van het Koninkrijk der Nederlanden, 2007). Through the connection of expertise with China, a win-win situation is created. In this way, the Netherlands can help in finding solutions for Chinese issues. The Dutch cluster approach and specifically the Energy Transition approach are a required condition in able to get a strong position on the Chinese market. The energy section of the economic department wants to know what the opportunities for Dutch organizations, universities and businesses are, when talking about clean coal technologies. Therefore the researcher is tasked with the assignment to perform an exploratory research into the clean coal technology market of China.

1.2 CONTEXT

This study is mainly focused on a national level of China since the country's power sector is still controlled by the central government. Hence, the diffusion of CCT is strongly affected by the national government's energy policy and power sector management (Vallentin & Liu, 2005). However, as the deployment of specific technologies and devices is also influenced by provincial factors (e.g. economic development, environmental awareness), this study includes considerations and suggestions regarding decentralized levels. This research has a geographic focus on China as well as the Netherlands. Considering the duration of implementing CCT through co-operation and research trajectories, we can look for strategic opportunities in the short term, medium term and long term (respectively: one year or less, 2 till 10 years, 10 or more years).

1.3 RESEARCH OBJECTIVES AND RELEVANCE

Through the study of relevant theories and empirical practices, literature reading and comparisons, a case study and interviews, this research critically analyzes the field of CCT in China, for Dutch organizations. Current studies provide limited insight in clean coal technology opportunities in China that are potentially interesting for the Netherlands. The proposed approach aims to study the clean coal technology market in China and make a connection with Dutch activities so that knowledge with regards to the Chinese and Dutch practices, opportunities and threats can be revealed. This research will contribute to a better understanding and will present a strategy for the of transfer clean coal technology to China. As a result, Dutch organizations will improve in exploiting chances for co-operation and the exchange of knowledge and technology in the field of clean coal technologies to China. The first objective of this research is to make an analysis of the clean coal technologies in China which are currently applied, and those that will be applied in the future. What is identified here, is the Chinese need for clean coal technology. The second objective is to identify what the Dutch have to offer. After this identification, the specific opportunities and threats for the transfer of Dutch clean coal technologies to China are analyzed. An important objective here is to identify the competitive advantages of a Dutch technology in order to make appropriate recommendations. A third objective of this report is to present the bare bones of an analytical framework for measuring the economic competence of CO_2 sequestration technology of the Netherlands. By studying this report, Dutch organizations will be better positioned to exploit chances for co-operation and exchange of knowledge and technology in the field of clean coal technologies to China.

1.4 PROBLEM DEFINITION

China is after the US the biggest energy consumer in the world. To keep up with the pace of its unprecedented economic growth, on average nearly 10% GDP-growth during the last 30 years, China's dependence on energy sources will only increase. As a result, China has a strong demand for both cleaner and more sophisticated technologies in the field of fossil fuels (coal, oil, gas) and in the field of durable energy generation (Sun, 2008). Currently, the use of coal accounts for at least 60% of China’s total energy production. This situation is not expected to change dramatically in the foreseeable future and poses serious environmental challenges. Clean coal technologies (CCT) can deliver realistic opportunities to address these challenges (Vallentin and Liu, 2005). Being the largest coal producer and consumer in the world, China could be the largest and most important market for clean coal technologies. The severe environmental pollution caused by China's inefficient coal combustion and poor clean-up processes provides an important rationale for widespread implementation. The global challenge of climate change and international pressure, increases the urgency of implementing new clean coal technologies in China. Even though China possesses significant capabilities in terms of both technological and policy solutions for its environmental problems, there is a clear need for additional assistance from international companies and governments. This Chinese demand could lead to possibilities for transfer of clean coal technologies from the Netherlands. Since there is a long row of suppliers of clean coal technology for China, the Netherlands needs to find their competitive advantage. At present, the opportunities and threats for Dutch organizations in the field of clean coal technologies in China, have not yet been clearly defined. Finding these opportunities is a key element of this research effort.

Based on the research objectives, the outcome of the research should give a recommendation for the Netherlands on how to profit with their technologies, from the growing demand for clean coal technologies in China.

1.5 STRUCTURE OF THE REPORT

The structure of the report comprises 7 chapters, beginning with an introduction and ending with a reflection chapter. The second chapter gives an overview of used literature and highlights the theoretical framework. The next chapter, chapter 3, elaborates on the research design and the used methodology. In chapter 4, the results of the research are described. The results are discussed in chapter 5. Chapter 6 contains the conclusions and the reflection is written in chapter 7.

2. LITERARY REVIEW: MODELS AND THEORIES

This paragraph presents an exploration and description of the models and tools which will be applied in the research and has a double purpose: it describes a step-by-step guidance that provide as a basis for the formulation of the scientific questions, and motivates why certain models are used to find a solution for the problem definition.

2.1 LINK OF THE LITEARY REVIEW WITH THE OBJECTIVES AND PROBLEM DEFINITION

In order to formulate research questions, a research design and a methodology to perform the research, a literary review needs to be accomplished to assess how this can be executed. Therefore, the literary review is initially focused on what the concept of technology essentially is, and what factors determine the future important technologies in a country. With the help of this factors, the future important clean coal technologies in China can be determined. Because, only when the Chinese needs are determined, it is legitimate to identify what clean coal technologies the Netherlands has to offer (no literary review involved). When this technologies have been identified, the Dutch competitiveness needs to be assessed. Therefore the literary review exposes those factors that make it possible to identify competitive activities and compare them with Dutch activities, after which sources of competitive advantage can be identified. Proceeding on this overall picture, the literary review then focuses on what factors determine which technologies make it, as a suitable candidate for transfer to China. The literary review concludes with an examination of different strategy theories to list various strategy options for the Netherlands to profit from their technologies, based on the market circumstances that make them successful. The figure below shows in graphic wants to be known from the literary review:

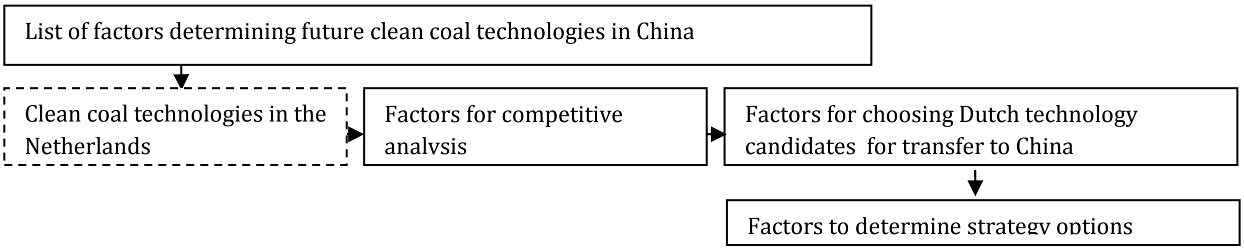


Figure 2.1: Previous overview of the literary review

Initially, general literature about different concepts of technology is consulted in order to construct a solid subject definition. This is the logical first step to be researched, in order to clarify what the research is about.

2.2 CONCEPTS OF TECHNOLOGY

The term technology has become a global buzzword and is often treated as a 'black box'. For this research it is required that a clear and practical working definition of technology is established. Steenhuis & de Bruijn (2005) have made an extensive exploration of different definitions of technology: In the strategic management literature, technology is seen as an instrument, management of the technology and technology investments should contribute to the value of the enterprise (Steenhuis & de Bruijn, 2005). In the production management literature, technology is classified by production process characteristic, such as unit or mass production (Steenhuis & de Bruijn, 2005). In the marketing literature, technology is viewed in relationship with a technology life cycle. This gives insight on when and how to sell technology (Steenhuis & de Bruijn, 2005). Since even detailed definitions of technology have severe drawbacks because they require expert knowledge, or on the other hand are too loose to cover the wide field of clean coal technologies, this research follows the line of Steenhuis and de Bruijn (2001) by not defining technology but 'sensitizing' it, starting with four components: hardware, software, infoware and orgaware. In the technology transfer literature, technology is generally described as being embodied in three components: software, hardware and humanware (Laseur, 1991)." Hardware stands for equipment and instruments. Software stands for drawings, manuals etc. Humanware stand for human-embodied components. The fourth component 'orgaware' (Ramanathan, 1994)

can also be added to this list and stands for; institution embodied components.
Ramanathan (1994) elaborates on the work of Sharif (1986) and Laseur (1991), to clarify issues that practicing managers are likely to raise. According to Ramanathan “it is pointed out that the four-component definition of technology - technoware, humanware, inforware, and orgaware - that falls under the “technology as embodiment forms” perspective appears to have the most value in terms of opening up the “technology black box.”(Ramanathan,1994, p. 221) the four components are complementary to one another and are interrelated. They are required simultaneously in a operation and no transformation can take place in the complete absence of any of the four components. (Ramanathan, 1994) the component orgaware looks similar to the management component, that Steenhuis and de Bruijn (2001) use disorderly. management contains of the number of managers, management skills, the ability to use the skills, the organizational structure and the organizational culture.

List of factors determining future clean coal technologies in China

2.3 FACTORS DETERMINING FUTURE CLEAN COAL TECHNOLOGIES IN CHINA

Since the potential clean coal technologies in China are unclear, research on the factors that determine which technologies will be important needs to be done. For this reason, several models and methods will be analyzed to assess their usefulness to help identify what clean coal technologies will be important in China.

Environmental assessment methodologies

A common used method for systematic consideration in strategic decision making is strategic environmental assessment (SEA), as described by Finnveden et al. (2003). This method is intended to be used on policies, plans and programs. Various analytical tools can be used within the SEA process, including economic valuation methods, life cycle assessment and risk assessment. Life cycle assessment (LCA) can be used to assess the environmental impacts (such as global warming) and resources used throughout a product’s life from raw material acquisition through production use and disposal. A negative downside of the SEA-method is that there is a lack of methodological guidelines for its application. Also the strong focus on environmental impacts of the SEA does not match with the goal to find a tool to identify future clean coal technologies.
Another environmental assessment tool is the input-output analysis (IOA). IOA is a well-established analytical tool within economics and systems of national accounts, using a nation or a region as the object of the study. The input–output matrices describe trade between industries. By performing an input/output analysis a calculation of the sectors or industries involved in the production of a product or service going to final demand can be calculated. (Finnveden et al., 2003) Nonetheless, this tool is not suitable for forecasting future prospects nor forecasting technologies that are not imported into the country, and thus is not useful in this study.
The last environmental assessment methodology as mentioned by Finnveden are surveys. Surveys are useful when environmental consequences cannot be calculated in a meaningful way. An example of such a situation is economic research in preferences and valuations, for instance when people are asked to express their willingness-to-pay (WTP) for certain environmental features. They can be used to examine how people balance environmental protection with their economic and social needs and wants. An example is the WTP-study of Wang and Mullahy (2006) in Chongqing, China to estimate the economic value of saving one statistical life through improving air quality. This study contains 500 face-to-face household interviews designed to question the respondents' willingness to pay for air pollution reduction. While this could be a very interesting way to identify if different stakeholders in China want to pay for clean coal technologies, it will be hard and impractical to measure, and therefore does not support the research goal.

Quantitative energy models

There are many mature energy models used throughout the world, whose applications relate to every field of energy, below they will be analyzed in order to assess if they are useful to find future clean coal technologies in China. Wei et al. (2006) give a classification of several primary energy models. Below the most important models are listed:

Table 2.1: Overview of quantitative energy models

Classifying methods	Model classification	Typical models	Research focus	Time scale
By research contents	Energy-Economy model	MACRO	Energy-economy	Long-term
	Energy-Environment model	AIM	Energy consumption and Energy environment	Long-term
	Energy-Economy-Environment model	3Es model	Energy-economy-environment and policy	Long-term
By research approaches	Energy optimization model	MESSAGE	Energy technology and economy and policy	Long-term
By functions of model	Energy technology model	ERIS	Energy technology and generation electricity	-
By research scope	Departmental energy model	LEAP	Energy-economy environment	Long-term
By modeling approaches	Bottom-up model	MARKAL	Energy technology and environment	Long-term

- The 3Es-model is used to simulate the relationship of macroeconomic, energy and environment, and to forecast the trend of the economy, energy and environment, under the scenarios of saving, carbon tax and improvement in energy efficiency.
- MACRO is a macroeconomic model, which describes the relationship of energy consumption, capital, labor force, and GDP by production function.
- The MARKAL Model, is a dynamic linear programming market allocation of technologies model,
- The MESSAGE model, is a model for energy supply system alternatives. It is a common used dynamic linear model for the analysis of medium/long term energy planning, energy policy and scenarios.
- The LEAP model (Long range Energy Alternatives Planning System), forecasts the energy demand, consumption and environment impact of each sector and analyses in detail, the economic benefits of each energy scenario. A study of Zhang et al (2007) uses LEAP software to develop a simple model of electricity demand and to estimate gross electricity generation in China up to 2030 under three scenarios. According to Zhang et al. (2007) the LEAP model can simulate over existing as well as advanced technologies that may be deployed in the future. A negative downside of the LEAP-model is its lack of transparency in technology choice under different scenario's and unavailability of required data.

The ERIS model intends capturing the main mechanisms regarding the endogenous analysis of research and technology development policy under uncertainty, and to allow for a consistent cost-benefit analysis of specific policies aimed at technology prioritization.

Model limitations for this study

According to Wei et al. (2006) energy-engineering models are good at simulating an energy system, but it is difficult to collect all the data of technologies and this causes and overestimation of the potential of technologies progress. Based on review of all the models as described above can be said that energy-economy models based on macroeconomic theory are convenient to economic analysis, but they cannot reflect in detail the impact of technological progress on the macro economy and underestimate the potential for technology progress. (Wei et al., 2006) According to Finnveden et al. (2003) it is an advantage of modeling that quantitative information on, for example, future energy use and fuel mix can often be produced. A disadvantage with complex models is the possible loss of transparency. But an even more important disadvantage that limits the usability for this study is the risk that models based on assumptions and mechanisms that describe the current situation are used for long-term future studies, where these assumptions and mechanisms cannot be presumed. This disadvantage is reinforced by the study of Miranda-da-Cruz (2007) that emphasizes that in many cases, the necessary detailed, high quality, consistent and timely data is not available for such comprehensive models to be constructed, in particular in large and complex developing economies expected to be major energy users in the near future. In the majority of countries (including China), the non-availability of the reliable energy and technology data required by more complex analytical frameworks such as the MARKAL family is a fact. The same is true for econometric forecasting models, sectoral engineering stock models, engineering economic models and optimization and policy analysis. In addition, developing detailed energy supply and demand models requires massive resources and many years, particularly in the case of large and complex developing economies.

Focus on individual macro components

While the quantitative energy models are not suitable for this study, because they give little insight in the choice for future clean coal technologies, they do point at the importance of macro environmental factors in the future of energy policies and energy choices. This can be emphasized by looking at the statements of Duncan (2007) and Wei et al. (2006), who did extensive research on energy models. Duncan states that “Energy choices in the real world are complex decisions. A business owner would be primarily concerned with prioritizing energy efficiency, curbing carbon emissions and on-site generation measures, not power plant options. Governments may be most interested in which measures to promote through incentives, or may be choosing projects for their own consumption.”
This is confirmed by Wei et al. (2006), who state that “An energy system is a complex system which involves politics, economics, society, environment, climate and many other considerations. Because the integrated complex system has characters which its subsystems do not have, and the characters will not be showed by each subsystem when decomposing the integrated system, the analysis of subsystems cannot explain the total conductions of an integrated system. Therefore, models that only consider the single energy-economy, energy-environment and energy-technology have great limitations.”(Wei et al. 2006, p124)

This means that the model we search for in the literary review should extensively handle components of the macro environment in the search for future clean coal technologies in China, by analyzing clean coal technologies from several macro environmental perspectives. But, the model should also incorporate characteristics of specific clean coal technologies, that makes them more or less interesting under certain environmental circumstances.

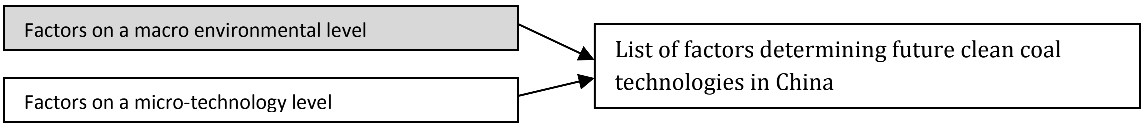
A method to both incorporate the individual parts of the energy macro environment and specific technology characteristics, is by studying the factors that determine the choice for clean coal technologies, by looking at what factors influence the process of technological dominance. In many product categories, the market accepts a particular product’s design architecture as one that defines the specifications for the entire product category; that design is referred to as the dominant design (Srinivasan et al. 2006). Here, dominant design is defined as ‘the specification (consisting of a single, or a complement, of design features) that defines the product category’s architecture.’(Srinivasan et al 2006:p.2) This research will follow the line of thinking of Srinivasan et al. with the drawing of a distinction between dominant designs and standards. This is because the term standards is used to denote the technical specifications for quality, reference, compatibility, adaptability, and connectivity which are required for the proper functioning of products, such as railway tracks. A dominant design may not necessarily be the one that embodies superior technical performance. Sometimes it is a satisfying design in terms of technical possibilities driven by the accommodation of commercial interests. However, dominant designs do not emerge in all product categories (e.g., videogame consoles). (Srinivasan et al., 2006) The factors that favor a dominant design, are used in this study to prioritize and choose for certain technologies.

Technology dominance

The study of Suarez (2003) that proposes 'an integrative framework for understanding the process by which a technology achieves dominance when competing with alternative technologies, is useful for this study because it identifies factors that have to be studied to determine which clean coal technologies will be dominant in China. Since the technology characteristics and goals of the technologies are so different from each other, the framework needs to be broad enough to cover this. The framework of Suarez has linked the ideas and conclusions coming from different studies and streams of literature. According to the study, two broad groups of factors influence the outcome of a technology battle: firm-level factors and macro environmental factors. This broad distinction is consistent with the existing schools of thought in management that stress the importance of firm-level capabilities, resources and environmental factors on the performance of different firms in an industry. However, technology battles have very special dynamics and it is therefore important to identify the specific factors that play a role in the process. Since clean coal technologies are complex systems that require a number of actors to be aligned for a technological design to achieve dominance (Suarez, 2003) and the focus of this study is on a national level, it is better to speak of technology factors on a micro-level instead of firm-level factors.

To study what factors have an influence on the technological dominance process, the literary review will now identify these factors on both a macro environmental level and on micro-technology level. In order to close the gap between bottom-up and top-down approaches, the so-called hybrid top-down/ bottom-up approaches have been developed (Schenk et al. 2006). A hybrid approach improves the understanding of energy systems by linking actual technologies to macroscopic developments. This is similar to what Suarez means with his framework.

Since the aim of this research is identifying which clean coal technologies are applied and will be applied in China, it is not necessary nor practical, to analyze the meso level for all technologies. Clean coal technologies are used in several industries and contain so many individual actors that it would be unwise to make a detailed study on meso-level. That is why this research uses a funnel approach for selecting technologies for further research: a hybrid approach is used to analyze the energy system in China by linking actual clean coal technology on a micro level, to macroscopic developments. By choosing the hybrid approach it is specifically not intended to explain the energy system, but to funnel out technologies for further research.



2.4 MACRO-LEVEL ANALYSIS

The environmental factors as mentioned by Suarez (2003), can be categorized into six main environmental factors: political, economic, socio-cultural, technological, environmental and legal. The PESTEL (also called PESTLE) analysis gives an overview of the key factors that have an influence on the general environment. Macro-level perspectives on energy systems regard the energy system at high aggregation levels and are associated with 'top-down' analysis. Macro-level energy analysis describes the overall functioning of systems and is able to cover all relevant actors, therefore this type of analysis is a valuable monitoring and prognostic instrument (Schenk et al. 2006). The actors, though, are generally treated as being homogeneous. The effect of simplifying heterogeneous actors to homogeneous actors influences the dynamics of the system, especially regarding initiatives to alter the system (e.g., policies). A disadvantage of top-down energy analysis is the lack of structure due to the high aggregation level (Schenk et al. 2006). Wood and Robertson (1999) evaluate what information experienced exporters favor, when evaluating a macro market environment. Based upon a literature review, Wood and Robertson identified approximately 200 indicators of a foreign environment relevant to analyzing export opportunity. The best indicators are categorized into six dimensions. The order of dimensions based on importance for evaluating the Chinese market is as follows: market potential, politics, legal, infrastructure, economics and culture. The indicators of politics, economics and competition from the work of Wood and Robertson(1999) are used in this research for evaluating the Chinese macro environment regarding clean coal technology, because to qualify as an indicator, the information has to offer a general insight into a market's potential for success and/or failure of a technology. Wejnert (2002) has done extensive research on three macro environmental factors that affect the diffusion of innovations. This three external factors are geographical settings, societal culture and political conditions. This factors are very applicable in this study to analyze their effect on technological dominance. (Wejnert, 2002).

The literary review will now focus on the various dimensions of the macro environment to identify the factors that influence the technological dominance process:

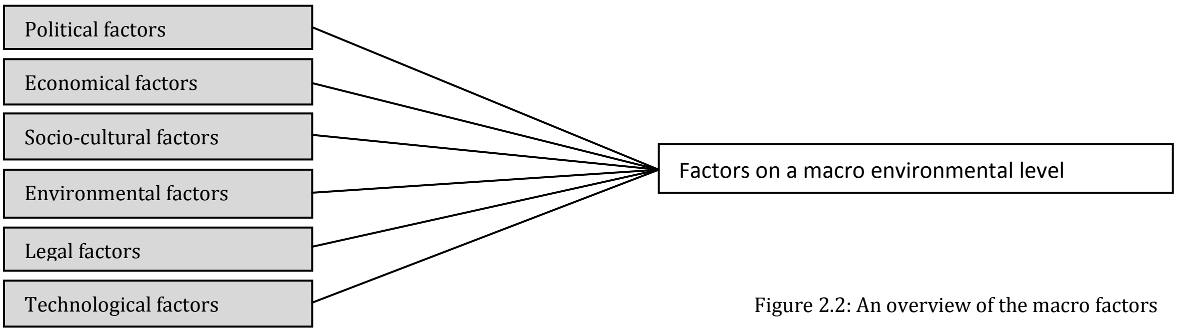


Figure 2.2: An overview of the macro factors

2.4.1 POLITICAL FACTORS

In this paragraph, the political factors that have an influence on the choice for specific clean coal technologies will be explored. According to Wejnert (2002), political situations inhibit or postpone adoption of innovations and appear to be important variables affecting diffusion of new technologies, including the adopting of clean coal technologies. Wejnert elaborates on political systems, along with the regulations and norms inherent in the legal systems that control actors' behaviors. Variables include national policies and the structure of the government. Particular emphasis has been placed on the extent to which state policy affects the rate of adoption, by protecting domestic technologies from replacement by technologies from foreign countries. Now the literary review will focus on academic work, to support the findings of Wejnert. The importance of the national institution framework is examined by Casper (2000) that examined the national institutional framework of Germany, focused on biotechnology. Casper had found empirical evidence in Germany to support his statement, that a national policy can have a strong influence on technology development. While Dohse (2000) describes the same German case, he adds that technological policy can play a key role in the process of technological change.

The work of Bozeman (2000) shows three paradigms for governmental interference: the market failure technology paradigm, the mission paradigm and the cooperative technology policy paradigm. The market failure technology paradigm is based on the view that the free market is the most efficient allocator of goods and services. A free market will lead to optimal rates of technical change and economic growth. In this paradigm, the government role in technology transfer should be limited to removing barriers to the free market. The mission paradigm assumes that the government should perform R&D in service of well-specified missions in which there is a national interest not easily served by private R&D. The third paradigm, the co-operative technology policy paradigm, features an active role for government actors and universities in technology development and transfer. This means that finding out what paradigm China chases regarding clean coal technologies, should be an important element of the analysis of the China market, because it strongly influences the national and international policy. The research of Hoekman, Maskus and Saggi (2005) analyzes national and international policy options to encourage the international transfer of technology. This would promote the choice for foreign clean coal technologies. According to this study, investments by multinational enterprises (MNEs) may provide developing countries with more efficient foreign technologies and results in technological spillovers. A basic challenge for host developing countries is to improve the local environment, regarding factors as an effective infrastructure, transparency and stability in government, and a reasonably open trade and investment regime, because this directly affects international technology transfer and its diffusion. Put it differently, hindering technology policies, hindering capital market regulations, and hindering taxes, can discourage technology transfer and innovation. Hoekman, Maskus and Saggi (2005) also deliver the evidence that joint ventures obtain less advanced technologies, while the Chinese policy has encouraged joint ventures more than inward FDI.

The identified indicators as described by Wood and Robertson (1999) to evaluate the political dimension, as is done by experienced exporters, supports the above described indicators. The most important indicators as found in the study of Wood and Robertson are (inter-)national policies, structure of the government, presence of foreign technology discriminating policies, and electricity and sector structure. By looking at this structure, the institutes that are most powerful and their influence can be mapped out in order to analyze their influence on the technological dominance process. Also the energy and resources pricing policy and mechanisms, provide a good insight in the choice for specific clean coal technologies (for example when the coal price is high, energy producers will choose for more efficient technologies to produce energy from coal). But also, energy price expectations can have a strong influence on investments in clean technology. Where energy prices fluctuate in unpredictable ways, investors may tend to delay investments in new technology, and be unwilling to adopt low emission technology where this entails increased up-front costs. (Obasi and Töpfer, 2001) This indicators should be studied to get a better understanding of the political influence on the technology choice.

2.4.2 ECONOMIC FACTORS

According to Hadjilambrinos (2000), the economic perspective is based on neoclassical economic theory and considers technology as an intermediary factor relating the two basic factors of production and capital, with the output of economic goods. Referring back to the macroeconomic models, as described in paragraph 2.3, top-down models evaluate the system from aggregate economic variables and apply the macroeconomic theory and econometric techniques to historical data on consumption, income, prices and factor costs. (Kahouli-Brahmi, S. 2008) This is useful to model the final energy demand and demand for clean coal technologies. Looking at what managers find important when analyzing the Chinese market, according to the macro environmental study of Wood and Robertson (1999), information and knowledge concerning the economic market seems particularly important. Especially economic potential and potential buyers' ability to pay for a product, are important indicators of potential success. Wood and Robertson (1999) prescribe some very explicit indicators to measure the economic potential and potential buyers' ability, including product consumption trends, gross national product (GDP) in the target market, wealth in natural resources and the extent of their development and per capita energy consumption in the foreign country (e.g. oil, gas, coal).

By looking at the GDP and (potential) investments in the energy infrastructure, consumption trends can be analyzed. This gives a relevant indication of which clean coal technologies have good chance of becoming important or are important already, especially when this is linked with the availability of natural resources (oil, gas, coal) and the future demand for energy.

The findings of Wehrmeyer et al. (2004) on Future-oriented Technology Analyses (FTA) supports this findings by stating that technology is one of the most fundamental drivers of social and economic change. According to a report of Forbes on energy efficiency (Zumbrun, 2008), "A country with a very high GDP and relatively little energy consumed is likely to be a very energy-efficient economy. Conversely a country with huge energy consumption and relatively little GDP is unlikely to be efficient." In his study on the energy systems of Denmark and France, Hadjilambrinos (2000) describes that energy consumption patterns can be studied by looking at energy intensity (in terms of both total primary energy supply (TPES) per unit of gross domestic product (GDP) and total final consumption (TFC) per unit of GDP). A low GDP, might indicate that there is no economic potential for efficient technologies, such as clean coal technologies. Or, as Obasi and Töpfer (2001) state, that some technologies might not be widely used simply because they are too expensive from a economic perspective. Prices can also have an important influence on the consumption of resources. When the prices would reflect environmental and other social costs associated with resource use, and external costs were fully reflected in prices, they would encourage producers and consumers to adopt environmentally sustainable technologies and practices. (Obasi and Töpfer, 2001) Obasi and Töpfer, also describe that there are many situations where users are unable to purchase equipment that is financially viable to them or beneficial to the society, simply because they do not have access to the private or government investment funds, necessary to install the equipment. Analyzing the options to finance clean coal technologies forms an important part of the buyers potential and therefore should be a part of this research.

2.4.3 SOCIO-CULTURAL FACTORS

In the socio-cultural dimension, the nature of internal and external shared lifestyles, customs, and social relationships is of primary interest. In this paragraph an exploration of socio-cultural factors is performed to find factors and indicators that have an influence on the technological dominance process. An important outcome of the study of Wood and Robertson (1999) is that cultural information is poorly valued by export managers and is the least important dimension of all. Note that the study of Wood and Robertson is focused on scanning multiple markets for market potential and that there is little reason for an export manager to seek out cultural details of an export market if the market potential and legal- and political environment have little potential. Hadjilambrinos (2000) proves that the factors population does not play an important role in electricity technology choice, by showing that small European nations, like Belgium and Finland have adopted to nuclear technology, while large nations (like Italy) have not, despite their high dependence on energy imports. Hill et al. (1993) describe the concept of national culture. They propose a categorization of culture according to the degree of stability of the individual factors. Factors inherent to the culture over time, tending to dominate the culture and very resistant to change, are classified as constants. Examples include geography, language, currency, social norms and traditions. But, it is these factors that do not have a direct influence on the technological dominance process. Factors which are more readily changed include employee morale and education levels. In the study of Hill et al., differences in motivation of workers and education levels are an important component for predicting organizational commitment to technological changes, but their influence on adopting clean coal technology would be hard to ascertain and is therefore not taken along in this study.

Wejnert (2002) describes a wide spectrum of societal cultural variables/factors that can affect the technology diffusion process, including belief systems (values, norms, language, religion, ideologies), cultural traditionalism, cultural homogeneity, and socialization of individual actors. But, this factors give no explicit indication why one specific clean coal technology would be preferred over another. One factor that could indicate choosing one clean coal technology over another is 'characteristics that confer high status', thereby having a significant impact on adoption behavior, which can be linked with one of Hofstede's dimensions as explained below. The next phase in this exploration is to determine how to measure cultural influences on the technological dominance process. When you want make grounded assumptions about culture, one of the most important and widely applied (and criticized) studies which attempts to establish the impact of culture differences on management is conducted by Hofstede (2001). Hofstede identified four 'value' dimensions on which countries differed: power distance, uncertainty avoidance, individualism, and masculinity. In 1985, a fifth dimension is added: long-term orientation. Power distance indicates the extent to which a society accepts the unequal distribution of power in institutions and organizations. Uncertainty avoidance refers to a society's discomfort with uncertainty, preferring predictability and stability. Individualism reflects the extent to which people prefer to take care of themselves and their immediate families, remaining emotionally dependant from groups, organizations, and or collectivities. Masculinity refers the bias towards either masculine values of assertiveness, competitiveness, and materialism, or towards feminine values or nurturing, and the quality of life and relationships. (Schneider and Barsoux, 2003) The fifth dimension, long-term orientation (LTO) versus short-term orientation deals with virtue regardless of truth. Values associated with long-term orientation are thrift and perseverance; values associated with short term orientation are respect for tradition, fulfilling social obligations, and protecting one's 'face'.(Hofstede, 2001) Although the Hofstede dimensions are widely used, they have been criticized for falling short of describing all important aspects of national cultures. (Everdingen and Waarts, 2003) Everdingen and Waarts investigate the effects of the five Hofstede national culture dimensions on country adoption rates, tested in a study concerning Enterprise Resource Planning. The results of this study indicate that variables describing national culture have a significant influence on country adoption rates. According to their research, the higher the country's masculinity score, the more likely companies in that country are to adopt innovations, and thus the higher the adoption rate. The same research indicates that high-levels of long term orientation have a significant positive influence on the adoption rate of new technologies. (Everdingen and Waarts, 2003) This means that for measuring the socio-cultural influence mostly the masculinity index and the long-term orientation can be used to make forecasts about the use of clean coal technologies.

Criticism on the Hofstede indexes
In this research, China is modeled as a single geographic region. Geographic disaggregation would significantly increase the complexity of the index, but also would increase in fundamental insights into technology choices, because China consists of very developed and very underdeveloped regions. From own empirical findings can be said that China is immensely big and just driving outside of the borders of a metropolis like Beijing, shows a very different China than within the city borders. There is not one universal culture in China, because the largest ethnic group in China are the Han-Chinese. But there are also Tai, Tibetans, Mongolians, Turks and even more ethnic groups. And besides Confucianism, Taoism, Buddhism and Christianity there are several other faith systems and beliefs. The most spoken dialects in China are Mandarin and Cantonese but some ethnicities speak Thai, Korean or Turkic. This has its influence on the validity of the LTO index. While the high score might count for big cities, the index simply does not represent the sum of all parts of the country. Hopper and Northcott (2007) describe in their criticism that equating culture with nation states ignores the multi-cultural composition of countries which have different ethnic regional groups. Another of their criticism on Hofstede's study is that it was restricted to middle level managers in city locations that worked for IBM. This gives an unreliable and non-generalizable view of the concept of culture. While the values for the fifth dimension were added in 1985, and the other measures were derived in the late 1960s and early 1970s, all the measures are out of date. Nonetheless, the index scores will be used with a notification of the criticism.

2.4.4 ENVIRONMENTAL FACTORS

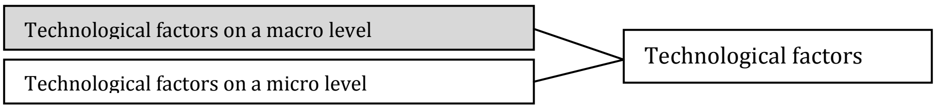
This paragraph will explore environmental factors that have an influence on the technological dominance process. The environmental factors are combined with environmental legal factors because environmental policies are integrated in implications for legal conditions. According to Wejnert (2002), geographical settings affect technology adoption by influencing the applicability of the innovation to the ecological infrastructures of the potential adopter. Examples are the impact of ecological infrastructures such as weather or soil conditions. From the interviews with industry experts, it turns out that clean coal technologies that need large amounts of water are forbidden by the authorities, because of water scarcity in China. This brings certain technologies to a halt or slows them down. In a regulatory research project, the Chinese Academy for Environmental Planning (2002) has analyzed what factors are caused by pollution of energy production and are not included in the energy price in China (external costs of electricity), but are paid by society. These factors are cost of health care, agricultural losses, resource degradation and resource depletion. This costs might be included by regulations and laws in the future, since the Chinese Academy for Environmental Planning (2002) advises to fully incorporate the environmental cost of pollution in electricity prices, to ensure that the total cost (environmental cost and electricity cost) is minimized. That is why this factor needs to be taken along in the future demand for clean coal technologies. Snyder et al. (2003), who performed a study on the chlorine industry, suggest that regulation can help to solve environmental problems whilst at the same time making industry more competitive. In theory this can be achieved if regulation encourages the development and application of innovative technologies and production techniques. This means that emission and pollution regulation need to be studied that can be linked with the rate of technological change and choice for specific clean coal technologies, based on their characteristics such as efficiency rates and NOx-, SO2 emissions.

2.4.5 LEGAL FACTIORS

This paragraph explores the influence of legal factors on the technology dominance process and choice for clean coal technologies. Legal factors can be divided into factors regarding trade, and factors regarding emission and pollution control. Factors for emission and pollution are explored in the environmental dimension, while factors regarding trade are handled in the political dimension. Nonetheless, Wood and Robertson (1999) describe several general legal factors that can prohibit or hinder the export to a foreign country, but they also mention some very specific indicators that might open the way or hinder technological dominance of a foreign technology in a country, in this case China. Examples are exact tariffs, import duties, and taxes. This factors are incorporated in the political dimension.

2.4.6 TECHNOLOGICAL FACTORS ON A MACRO LEVEL

The discussion on technological factors, is divided into technological factors on a macro- and micro level:



The work of Srinivasan et al. (2006) elaborates on the work of Suarez (2003) by developing indicators to make predictions about if there will emerge a dominant design in a product category, and if it does, how long it will take before a dominant design emerges. The model of Srinivasan incorporates the effects of several technical environmental characteristics including appropriability of the rents associated with the product, network effects, size of the product's value net, the standard setting process, radicalness of innovation and R&D intensity on the probability and the time of dominant design emergence. Network effects, radicalness and R&D intensity will be dealt with on the technological micro-level, since it refers to specifications of individual technologies.

Appropriability refers to aspects of the product category that govern firms' ability to capture innovation rents in the product category. Since this construct is overlapping with other macro environmental dimensions of this research, the construct is measured in other dimensions and not handled explicit here. The construct of appropriability contains the following aspects: patents, lead time for development of the product, learning curve efficiency and sales and service effort that underlies the innovation. Learning curve efficiency and sales and service effort are not explicitly measured during this study since most technologies are not yet on the market. Patent issues will be dealt with in the legal political dimension and lead time for development will be handled as a technological factors on a micro-level.

Value net refers to a firm's linkages with its suppliers and producers of complementary products that are important sources of relational rents for it and utility for its customers. The more firms in the value net, the greater the incentive for each firm to support a dominant design (if it emerges) because of higher resultant revenues. The construct of value net will not be analyzed in this research since there is a focus on the demand side for clean coal technologies in order to determine the future demand for clean coal technologies in China. Value net incentives are above all interesting for suppliers of technology.

The standards setting process identifies to ways of standard setting: de facto and de jure. In a *de facto* standards setting process, standards for the product category are set by market forces. The operating system for personal computer is an example of a product category that initially had several *de facto* standards (e.g.,CP/M, MS-DOS). In a *de jure* standards-setting process, standards are established through formal processes by standards organizations which may include independent bodies such as the International Telecommunications Union (ITU). As explained below the standard setting process has an influence on the time it takes before a design becomes dominant.

2.5 TECHNOLOGICAL FACTORS ON A MICRO-LEVEL

One author that specifically discusses the micro-level of clean coal technology transfer to China is Watson (2000). Watson underlines that sometimes the clean coal technology can be stimulated and integrated from bottom-up philosophy. A disadvantage of bottom-up energy analysis is limited information on the interaction of system elements on the overall system performance, which results in questionable representativeness of data and allocation problems (Schenk et al., 2006). Because technologies are generally implemented where the specific local circumstances are favorable, and because contextual requirements, like infrastructure are neglected, bottom-up methodology introduces an 'optimistic bias' in the data. This 'optimistic bias' results in bottom-up approaches overly optimistic conclusions regarding possible system changes, which is known as the 'engineering paradigm' (Schenk et al. 2006). Therefore, bottom-up analysis is unable to assess changes in the energy system, like the implementation of new technologies or the possibility to save energy. Since this research has a strong focus on implementation and transfer of new technologies, using the bottom-up approach alone is not sufficient, therefore the hybrid approach is used.

The framework of Suarez (2003) contains the following factors on micro-technology level:

- Technological superiority: how well performs the technology vis-à-vis competing alternatives?
- Credibility: e.g. reputation and manufacturing capabilities
- Installed base: A larger installed base will be associated with higher rates of adoption for a specific technology. The size of the installed base provides an "extra push" to the chances of dominance for a specific technology.
- Strategic maneuvering: This captures the key elements of strategy that engages in a technology dominance battle.
    - Entry timing
    - Pricing
    - Licensing and relationships with complementors
    - Marketing & PR to manage expectations

Since the focus here lies on the technology level, the last two factors of strategic maneuvering are not usable because they involve strategic choices on a company level. No single factor of dominance is strong enough to tilt the balance in favor of a particular technology; the final outcome is always the result of the interplay of several firm- and environmental-level variables. Suarez gives as an example the case of Sony where technological superiority did not help in promoting Sony's Betamax over JVC's VHS in the VCR industry.

As noted in the discussion of the theory of Srinivasan et al. (2006) that indicates factors that can make predictions about if there will emerge a dominant design; network effects, radicalness and R&D intensity are dealt with on the technological micro-level, since it refers to specifications of individual technologies. The term 'network effects' as described by Srinivasan et al. (2006) refers to the positive effects when a customer's utility from a product increases as the number of customers who use the product (or compatible products) increases. A well known example is the use of peer-to-peer torrent programs that enables people to share computer data. The more users, the more data is offered at a higher speed. Radicalness as described by Srinivasan et al.

(2006) refers to radical products (microwave ovens) that involve new technologies that offer significant advances in both technology and consumer benefits. Radical products offer a low initial performance-price ratio and face limited market acceptance. The evolution of radical products is characterized by high uncertainty, and numerous product variants are developed to identify viable technological trajectories and consumer preferences (Srinivasan et al., 2006). R&D intensity as described by Srinivasan et al. (2006) refers to the depth and breadth of knowledge required to design and commercialize a product. The results of the study of Srinivasan et al. (2006) show that a dominant design is more likely to emerge with weak network effects, low product radicalness, and high R&D (research and development) intensity. According to Srinivasan et al., dominant designs that do emerge, emerge faster when there is are a large number of firms in the value net, de facto standards and low product radicalness.

As stated in the problem definition, the Netherlands needs to find its competitive advantage in able to profit from the Chinese demand for foreign clean coal technologies. Therefore the literary review will now focus on how the competition can be analyzed and will review theory about competitive advantage.

Factors for competitive analysis

2.6 CONCEPTS OF COMPETITIVE ANALYSIS

When the (future) demand for clean coal technologies in China is identified, the clean coal technology activities of the Netherlands have to be compared with technology activities from actors outside the Netherlands. A method to study the nature of competition, is by analyzing the five competitive forces of Porter (1990): the threat of new entrants, the threat of substitute products or services, the bargaining power of buyers, the bargaining power of suppliers, the rivalry among existing competitors. The strength of the five forces determines the long-term profitability. This method is not used during this research because it requires extensive input of information that is not available for potential technologies. An example is the unknown bargaining power of buyers and suppliers for a technology that is not yet on the market in China. A more suitable way to make a comparison with the competition is performed in this study: a competitor scan as part of a larger benchmark study on clean coal technologies. 'Benchmarking is a continuous systematic process for evaluating the products, services, and work processes of organizations that are recognized as representing best practices for the purpose of organizational improvement.' (Finnigan, 1996) There are two keywords in this definition of benchmarking that will not be taken along during this research, these are best practices and continuous. While it is certainly important to look for best practices, this goes far beyond the competitor 'scanning' what is done for this research. The keyword 'continuous' will not be applied during this benchmark since the competitor activities at one point in time will be measured. The scanning of competitors in this phase is focused on screening the market for identification of competitors and their main clean coal activities.

2.6.1 CONCEPT OF COMPETITIVE ADVANTAGE

When the clean coal technology activities of the competitors on the Chinese market are identified, the research continues by focusing on the question what factors provide a competitive advantage to the Netherlands. By analyzing differentiated activities and specific activities in the field of clean coal technologies in the Netherlands, competitive advantages are analyzed in the various subfields. In exploring possible competitive advantages, the still widely applied theory of Porter (1998) is used. In 'The competitive advantage of nations', Porter (1990) describes a recent view on comparative advantage, the so-called 'technology-gap' theory.
This theory matches with the statement made in the problem definition that there is a clear need in China for additional assistance from international companies and governments in the field of clean coal technologies. According to the technology-gap theory, nations will export in industries in which their firms gain a lead (gap) in technology. Exports will fall as technology inevitably diffuses and the gap closes. Differences in national economic structures, values, cultures,

institutions, and histories contribute profoundly to competitive success. Nations succeed where country circumstances support the pursuit of the proper strategy for a particular industry or segment. Creating competitive advantage in sophisticated industries demands improvement and innovation, finding betters ways to compete and exploiting them globally, and relentlessly upgrading the firm's products and processes. 'Nations succeed in industries if their national circumstances provide an environment that supports this kind of behavior'. (Porter,1990, p. 67)

After identifying the competitive advantages of the Netherlands in certain clean coal technologies, the literary review now focuses on what technologies should be candidate for transfer to the Chinese market. Therefore a method to decide on a product candidate will be reviewed, after which the concept of technology transfer will be discussed.

Factors for choosing Dutch technology candidates for transfer to China

2.7 DECIDING ON THE TECHNOLOGY CANDIDATE

When the products of the Netherlands have been analyzed, the technology with the most promising prospects for transfer to China needs to selected. The quite aged but still up-to-date theory of Root (1994) gives an overview of the characteristics of an ideal product candidate for foreign markets, and is still used by practitioners and scholars. Characteristics include: ready market acceptance, high profit potential, availability from existing production facilities and sustainable marketing is much the same abroad as at home. For clean coal technologies the variable 'availability from existing production facilities' can best be altered into 'existing technology'. The marketing variable is kept out of the research because of a lack of information on this research level.

2.8 CONCEPT OF TECHNOLOGY TRANSFER

The Netherlands can benefit from their technologies in China by putting them in action in China. This sounds logical but it has some academic challenges. Therefore, this paragraph will review concepts of technology transfer and tries to find possible opportunities and threats in based literature. When the potential clean coal technologies for China are identified, the research continues by researching the opportunities and threats for the Netherlands regarding clean coal technology transfer to China.

First, the concept of technology transfer and factors that influence successful technology transfer are studied in the literature. The term "technology transfer" has been in use for quite some time. Sometimes it is also referred to as technology flows or diffusion of technology. Basically, the term technology transfer implies the movement of technology from the technology owning entity (the transferor) to a receiver, and if the transfer is successful, the proper understanding and effective use of the technology by the receiving entity (transferee). If the transferee is unable to understand and use the technology effectively, the transfer is considered incomplete. (Ramanathan, 1994) Another definition is that of Derakhshani (1983, cited by Madu 1989) who defines technology transfer as the acquisition, development and utilization of technological knowledge by a country other than that in which this knowledge originated. The definition of Ramanathan will be used in this research because the definition of Derakshani is simply to out-dated and broad since the focus of this research is on the actual movement of technology. According to Jayaraman et al. (1997), the difference in technology levels of the transferor and transferee causes a technological gap. If there is a technological gap between the transferor and transferee, there exists a potential for technology flow. The technological gap is defined as the difference in technological capabilities between countries. 'In general there are two major classes of technology transfer, namely, vertical technology transfer and horizontal technology transfer. Vertical technology transfer represents a flow from laboratory research through developmental stages and ultimately to commercialization. Horizontal technology transfer is essentially the transfer of an established technology from one operational environment to another. In some situations, technology acquired elsewhere is adapted and perhaps improved before use. In such a case both horizontal and vertical transfers have taken place.'(Ramanathan,1994,p.253) For this exploratory research there is beforehand no explicit focus on horizontal or vertical transfer technology transfer.

The next step, is to find possible opportunities and threats for technology transfer in based literature. There is a broad spectrum of literature about factors that influence technology transfer, for example, Steenhuis & De Bruijn (2005) provide geographical, cultural (explained further below), economic and government factors that influence successful technology transfer. Some factors have been identified as extremely important such as high culture differences (Hussain, 1998; Kedia and Bhagat, 1988) leading to difficulties in technology transfer. Legg (1991, cited by Steenhuis & De Bruijn, 2005) used an in-depth approach to search for important factors in technology transfer projects between the UK and China. Legg found that the efficiency of a technology transfer process is influenced by technical system factors (poor quality of products and production delays), social system factors (for example skill shortages) and external influences (for example government influence). In earlier work, Steenhuis and the Bruijn (2001) showed that a technology cannot be viewed in isolation but organizational factors and environmental factors influence the productivity of a technology. Therefore the functioning of technology should be viewed as dependent on its location. The location of an organization links the organization to its environment. It usually determines the language used (there might be a language barrier between a source company and a destination company). The distance between the source company and the destination company (time zones) also relates to the ease of communication between the two organizations.

The factor bad technical system factors is underlined by Madu (1989) who notes that attitudes of skepticism have begun to evolve, and critics of multinational corporations often label policies of technology transfer as 'social irresponsibility'. These critics argue that technology transfer has led to social retardation, economic stagnation and environmental pollution. Madu identifies eight (critical) factors that lead to the successful transfer of technology. These factors are: needs and objectives, capabilities, education, training, research and development, identification and implementation of appropriate technology, managerial effectiveness, stable governments and political systems . Appraisal of this factors helps to identify future obstacles in technology transfer. A more extensive review of this factors can be found in the annexes.

Factors to determine strategy options

2.9 CONCEPTS OF STRATEGY

To give future direction to the actions of the Netherlands regarding its clean coal technology transfer to China, an important research objective is to prescribe a future strategy. Therefore, this paragraph of the literary review analyzes various definitions of strategy for the purpose of clarifying the concept and placing it in context. In 'The fall and rise of strategic planning", Henry Mintzberg (1994) points out that the definition of strategy is used in a number of ways, including:

1. Strategy is a *plan*, a "how," a means of getting from here to there.
2. Strategy is a *pattern* in actions over time
3. Strategy is *position*; that is, it reflects decisions to offer particular products or services in particular markets.
4. Strategy is *perspective*, that is, vision and direction.

This definitions imply that determining the positioning strategy, what is the aim of this research, best matches with the third definition of strategy by Mintzberg.

In an article named 'What is strategy?', Michael Porter (1996) gives another definition of strategy: 'Strategy is the creation of a unique and valuable position, involving a different set of activities.' This definition strongly looks like the third definition of Mintzberg, but due to the fact this definition is more focused on competition it matches better with the highly competitive clean coal technology market in China. According to Porter, a company can outperform rivals only if it can establish a difference that it can preserve. Strategic positioning means performing different activities from rivals' or performing similar activities in different ways. An example

Porter mentions is employing more advanced technology than competitors. According to Porter, there are three alternative strategic positions in an industry: cost leadership, differentiation (offering product or service variety), and focus. Porter explains that it is necessary to choose one of the strategies, because when this is neglected you will come stuck in the middle.
In ‘Customer intimacy and other market disciplines’, Treacy and Wiersema (1993) identify three paths (value disciplines) that can serve as the basis for strategy: operational excellence, customer intimacy, and product leadership. The operational excellences strategy is focused on leading in the production and delivery of products and services, based on price and convenience. A customer intimacy strategy is focused on tailoring and shaping products and services to fit an increasingly fine definition of the customer. The objective is long-term customer loyalty and long-term profitability. The third strategy, product leadership is focused on producing a continuous stream of state-of-the-art products and services.
This last strategy is especially focused on quick commercialization of idea’s which implies that processes are have to be engineered for speed and bureaucracy has to be banned out. Choosing for one value discipline implies aligning the whole company to serve this value: including culture, business processes, management systems etc.
The value disciplines of Treacy and Wiersema are very similar to the strategic positions of Porter (cost leadership, differentiation, and focus). While Porter explicitly prescribes choosing one strategic position, Treacy and Wiersema explain that it is necessary to provide industry standards in the other two value disciplines. This approach better suits a highly competitive market as the Chinese clean coal technology market, where performance under market standards is simply not acceptable.

2.10 AN ANALYTICAL FRAMEWORK FOR ANALYZING THE ECONOMICAL COMPETENCE OF CO2 SEQUESTRATION TECHNOLOGY OF THE NETHERLANDS

As described in the paragraph on research objectives, the third objective of this report is to present the bare bones of an analytical framework for measuring the economic competence of CO_2 sequestration technology of the Netherlands. It is not the objective of this research to actually perform study on this subject. The knowledge that CO_2 sequestration is a potential profitable technology for the Netherlands, comes from the findings of this report.
A common method to get deeper understanding of a technological system, such as CO_2 sequestration, is by making an technological system analysis. A useful theory from Carlsson (1997) about technological system analysis, as described by Schenk et al. (2006) is applied for a meso-level analysis framework for one specific clean coal technology, namely CO_2 sequestration. With the help of the technological system analysis, performance of the system can be measured in order to determine the competitive advantage of the Netherlands on CO_2 sequestration.

2.10.1 THE MESO-LEVEL ANALYSIS

An element of the technological system analysis, is the meso level analysis. The meso-level involves the dynamic behavior of the individual system elements and the coupling of individual technologies, resulting in interdependencies and regimes. Increased insight into the meso-level of energy systems can contribute to a more consistent and coherent understanding of energy systems. It is acknowledged that energy systems need to be known at the micro-, macro-,and the meso-levels (Schenk et al., 2006). Fig. 2.1 shows that the meso-level is wedged between the macro- and the micro-levels. Therefore, the meso-level describes the energy system from an intermediate aggregation level, here the sectoral-level, and this type of analysis acknowledges the mutual coherence of groups of actors. Meso-level analysis is associated with so-called systems analysis (Battjes, 1999 cited by Schenk et al. 2006), and depends on data acquired from both bottom-up and top-down energy analyses (Schenk et al. 2006).

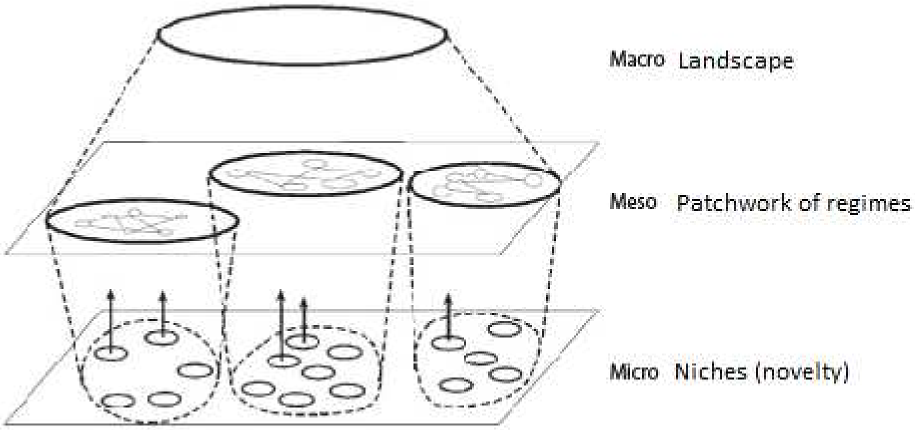


Fig 2.3 Schematic representation of micro-,meso-,and macro-levels. Source: Geels (2002) merged with Schenk et al (2006) for this research.

Meso-level analysis of energy systems makes energy analysis more consistent and coherent by bridging the gap between the micro- and macro-levels. In contrast to the hybrid top-down/bottom-up approaches, the gap between the macro- and micro-levels is not circumvented in meso-level analysis. Instead, meso-level analysis focuses on dynamic interactions between individual elements of energy systems as indicated in the figure. Moreover, meso-level analysis provides additional information on system's responses to changes. Meso-level analysis provides insights in energy technologies relevant for long-term planning. For this research it is important what clean coal technologies are relevant at this moment, but more important, in the future. This makes the meso-analysis valuable for this research. A consequence of not understanding systems sufficiently is to implement the wrong policy, or 'to bet on the wrong horse' as described by Schenk et al. (2006). This would mean that the Netherlands would focus on a transfer of a clean coal technology (CCT) to China or another foreign country while it has no competitive advantage in this technology.

2.10.2 SELECTING AN INNOVATION SYSTEM APPROACH

Innovation systems involve the creation, diffusion and use of knowledge. Studying this concept is important for the design of an analytical framework to map out CCT developments. There are several options to analyze this innovation system. One option is the national innovation approach, such as for example Porter (1990) describes. Another option is the regional innovation system approach with a focus on cultural variables. But there is also the technological systems innovation approach, as described by Carlsson et al. (1997). The technological systems approach is constructed around specific technologies. This method is particularly useful in analyzing opportunities in this research because this method is mostly about knowledge and competence flows instead of goods and services. Another main reason for choosing the technological system approach for this research is because this approach connects perfectly with the Dutch innovation approach which is based on the 'Innovation Platform' as explained earlier and focuses on whole sectors, instead of individual activities. A technological system has been defined here as a network of actors operating in a particular field of technology. The theory of Carlsson is very applicable to identify the strengths and weaknesses of such a system.

2.10.3 THE TECHNOLOGICAL SYSTEM APPROACH

What Carlsson (1997) does not mentions in his publication is that the above described meso-level analysis is associated with systems analysis (Battjes, 1999 cited by Schenk et al. 2006). The technological system approach helps in mapping the field in terms of problem areas of, in this research, subfields. Then the approach helps to identify the actors i.e. the organizations or working groups in the various subfields. In this research, this is very applicable because of the deep insights that come into being, in analyzing the composition and structure of the system. The next step is finding out, exactly, what they do, how they do it, with who they collaborate etc. The constituent parts of the system specific innovation system are actors and their competence, networks and institutions. Systems consist of components, relationships among these, and their characteristics or attributes. Components are best described as the operating parts of a system. They can be of a variety of types: actors or organizations such as individuals, business firms, banks, universities, research institutes, and public policy agencies (or parts or groups of each). They can also be institutions in the form of legislative artifacts such as regulatory laws, traditions, and social norms.

Relationships are the links between the components. The properties and behavior of each component of the set influence the properties and behavior of the set as a whole. At the same time, each component depends upon the properties and behavior of at least one other component in the set. Also, if a component is removed from a system or if its characteristics change, the other artifacts in the system will alter characteristics accordingly (Hughes, 1987, p. 51), and the relationships among them may also change—provided that the system is robust. Relationships involve market as well as non-market links. The greater the interaction among the components of a system, the more dynamic it is. But even a highly dynamic system may not be able to survive, unless it evolves in the right direction. One of the most important types of relationships in innovation systems involves technology transfer or acquisition. *Attributes* are the properties of the components and the relationships between them; they characterize the system. "Because the components of a technological system interact, their characteristics derive from the system" (Hughes, 1987, p. 52).

2.10.4 ECONOMIC COMPETENCE OF A TECHNOLOGICAL SYSTEM

The main features of the system are the capabilities (together representing economic competence) of the actors to generate, diffuse, and utilize technologies that have economic value. Economic competence is defined as the ability to identify and exploit business opportunities (Carlsson and Eliasson, 1994). An important issue is how to measure the (economic) performance of the system. What is to be measured, and how can performance be measured at the system level rather than at component level? Certainly, it is of great interest to measure or at least assess performance when similar systems are compared. This involves four types of capability. The first is selective (or strategic) capability: the ability to make innovative choices of markets, products, technologies, and organizational structure; to engage in entrepreneurial activity; and to select key personnel and acquire key resources, including new competence. The key question here is one of effectiveness: are we doing the right thing? The second element of economic competence is organizational ability. This is the main function of middle management in an organization: to organize and coordinate the resources and economic activities within the organization in order to meet the overall objectives. This includes the ability to generate and improve technologies through new combinations of existing knowledge and skills. The third element is technical or functional ability. It involves the efficient execution of various functions within the system to implement technologies and utilize them effectively in the market. The key question here is that of efficiency: are we doing things right? The fourth element is the learning (or adaptive) ability, the ability to learn from success as well as failure, to identify and correct mistakes, to read and interpret market signals and take appropriate actions, and to diffuse technology throughout the system. (Carlsson and Eliasson, 1994)

2.11 CONCLUSION

This chapter explains the literature found on the research topic and gives a broad overview of the theories found and why this theory applies to this typical situation.

Since the potential clean coal technologies in China are unclear, as described in the problem definition, research on the factors that determine which technologies will be important needs to be done first. For this reason, several models and methods are analyzed to assess their usefulness to help identify what clean coal technologies will be important in China. While the quantitative energy models are not suitable for this study, because they give little insight in the choice for future clean coal technologies, they do point at the importance of macro environmental factors in the future of energy policies and energy choices. This means that the model we search for in the literary review, should extensively handle components of the macro environment in the search for future clean coal technologies in China, combined with characteristics of specific clean coal technologies.

A method to both incorporate the individual parts of the energy macro environment and specific technology characteristics, is by studying the factors that determine the choice for clean coal technologies, by looking at what factors influence the process of technological dominance, as done by Suarez (2003). The model focuses on individual components of the macro environment, including politics, economics, environment, and the socio-cultural-, legal and technological environment. Then the work of Srinivasan et al. (2006) is used to elaborates on the work of Suarez (2003) by developing indicators for the effects of several technical environmental characteristics to make predictions about if there will emerge a dominant design in a product category, and if it does, how long it will take before a dominant design emerges. This leads to a method to identify the future clean coal technologies in China.

The next step in the literary review is a competitor scan as part of a larger benchmark study on clean coal technologies is performed, to analyze the competition. After the competitor analysis, the competitive advantage theory of Porter (1990) is used that describes a recent view on comparative advantage, the so-called 'technology-gap' theory. This theory matches with the statement made in the problem definition that there is a clear need in China for additional assistance from international companies and governments in the field of clean coal technologies. After this, the method of Root (1994) is used to decide on a product candidate. While this method is quite aged, it is still widely applied in business and academics. The different concepts of technology transfer are extensively discussed, since the choice for a definition has a great influence on the outcome of this study. The definition of Ramanathan (1994) is used in this study and is defined as: the acquisition, development and utilization of technological knowledge by a country other than that in which this knowledge originated. The theory of Madu (1989) on factors that lead to the successful transfer of technology is used next, to identify future obstacles in technology transfer.

This chapter reviews various definitions of strategy for the purpose of clarifying the concept and placing it in context to be able to prescribe a strategy for the Netherlands. The value discipline options of Treacy and Wiersema that will be used to define a strategy for the Netherlands, are very similar to the strategic positions of Porter (cost leadership, differentiation, and focus). But, while Porter explicitly prescribes choosing one strategic position, Treacy and Wiersema explain that it is necessary to provide industry standards in the other two value disciplines. This approach better suits a highly competitive market as the Chinese clean coal technology market, where performance under market standards is simply not acceptable.

3. RESEARCH DESIGN AND METHODOLOGY

This paragraph specifies which research methods, sources and analysis instruments are used in order to obtain the answers to the formulated research questions.

3.1 INTRODUCTION: TYPE OF RESEARCH

The research performed is an exploratory, cross-sectional study. The explanatory study is used to analyze the current development, utilization, acquisition and coalition projects. The objective of an exploratory research is finding out what is happening and seeking new insights (Saunders et al., 2007). For this research, it is an advantage that the research methods of the exploratory research are highly flexible, unstructured, and qualitative, and that the researcher begins without firm preconceptions as to what will be found' (Aaker et al, 1995). The field of CCT in China is very large and opportunities can be found on different areas. This is why the exploratory research is very suitable for finding (business) opportunities in China in the field of clean coal technologies.

3.2 RESEARCH QUESTION

Now the literary review has led to the creation of a research framework, the research question and sub questions can be formulated.

The literary review has ensured that the subjects of the problem formulation and research goals are split into 'researchable' components. While the problem definition vaguely describes possibilities for clean coal technologies from the Netherlands in China, the literary review has shown that chances for technologies from one country into another lie in technology transfer. Another important component of the literary review is, that there are different strategies the Netherlands can handle in their strategic approach of the Chinese market.

This had led to the following research question:

What strategy does the Netherlands has to apply regarding the transfer of its clean coal technology to China?

3.3 SUB-QUESTIONS

The research question is the direct answer to an underlying research that is split up into sub-questions, which each deals with a component of the central problem formulation. The research questions are constructed in such a way, that together they provide an answer to the central problem formulation and fulfils the research objectives.

Since the potential dominant clean coal technologies in China are unclear, research has to be done to find out what the dominant technologies will be. Based on the literature review, the analysis of the factors influencing the dominance process, is separated into macroscopic (political, economic, socio-cultural, technological, environmental and legal) factors that influence the process of technological dominance of clean coal technologies and technological specific factors (characteristics) of clean coal technologies The first sub-question is:

1) What is the influence of macro-environmental factors on the process of technological dominance of clean coal technology in China?

To complete the analysis of technological dominance factors, the technological factors of specific clean coal technologies (micro-level) including technological superiority (efficiency and emission reductions), installed base, entry timing and pricing, need to be analyzed. This leads to an overview of the characteristics of potential clean coal technologies for the Chinese market. Therefore the second research question is formulated as:

2) What is the influence of technological specific factors of clean coal technology on the dominance process in China?

To analyze the potential opportunities for clean coal technology transfer from the Netherlands to China it is necessary to identify the clean coal activities of the Netherlands and to find out

what factors provide potential competitive advantages. Sources of competitive advantage are discussed in the literary review and are operationalized in paragraph 3.3. The first step is to analyze the activities of the Netherlands and its competitors in the listed clean coal technologies in China. This will give an overview of current competitor activities, strengths and weaknesses and it will help to find competitive advantages and opportunities in the form of market niches for the Netherlands. By this, a list will be drawn of which technologies from the Netherlands have the best perspectives for transfer to China.
3a) What are the competitive activities for the Netherlands regarding the clean coal technology market in China?
3b) What factors give the Netherlands a competitive advantage?
3c) What are the opportunities and threats of transferring clean coal technology to China?
After analyzing the opportunities and threats, it is needed to identify what strategy (operational excellence, customer intimacy or product leadership) is most suitable for transferring clean coal technology to China.
3d) What are the different strategies, the Netherlands can handle in their strategic approach of the Chinese market?

3.4 MEASURES

This paragraph will describe how the mentioned indicators of the different models and methods of the literary review will be measured, in order to find answer to the research question.

The influence of the macro-environmental factors as questioned in sub-question 1, is measured in the following way:
Political measures: The indicators of Wood and Robertson (1999) are national policies, structure of government, presence of foreign technology discriminating policies, electricity sector structure and political perspectives. Here, special attention goes to international pressure on China to clean their energy system. This indicators can be measured by analyzing the national policies regarding its use of clean coal technologies and the structure of the energy (pricing) policy making and administration.
Economic measures: Wood and Robertson (1999) prescribe some very explicit indicators to measure the market potential and potential buyers' ability, including product consumption trends, gross national product in the target market, wealth in natural resources and the extent of their development and per capita energy consumption in the foreign country (e.g. oil, gas, coal). Therefore the future energy demand for the coming 20+ years, should be extracted from official sources, to determine the future demand. The historic development of the GDP can also be found in official sources and give a good indication for buyers' ability. By looking at the GDP and (potential) investments in the energy infrastructure, consumption trends can be analyzed. This gives a relevant indication of which clean coal technologies have a good chance of becoming important or are important already, especially when this is linked with the availability of natural resources (oil, gas, coal) and the future demand for energy. Current energy efficiency rates, can be compared with other countries to determine if there is an efficiency gap that indicates the use of out-dated technology. An overview of available financing options for clean coal up-front investment costs, gives an indication of buyers' ability and can be found in international policy publications of for instance the World Bank and Asian Development Bank.
Socio-cultural measures: The influence and commitment of education to clean coal technologies can me measures by analyzing which clean coal technologies are supported by Chinese research institutes and universities in order to use this high technology and develop it further. The masculinity index of Hofstede is used as an indicator for the factor 'characteristics that confer high status' that could influence the choice of one clean coal technology over another. For example choosing a more complex, expensive technology over a cheaper, less complex technology to get international status.
A high index on the long-term orientation dimension of Hofstede could indicate choosing for long-term, more expensive, more advanced technologies that keeps the environment clean for

future generations in sharp contrast with the choice for short-term focused ,cheap and polluting technologies, corresponding with a low index score.

Environmental measures: As formulated in the literary review, the most important factors that influence the technology dominance process and the choice for specific clean coal technologies are emission and environmental policy regulations. This includes technology specific specifications such as efficiency rates, emission rates of CO2, NOx and SO2 rates and for some technologies the use of water resources. Also the potential that external costs are internalized must be estimated since this might have an important influence on the choice for future clean coal technologies. The effects of environmental factors can be measured by looking at what plants get permission to be build, what plants get operated, how much is invested in pollution control, and how much is invested in energy efficiency. This gives extra weight to the outcomes of the comparison of technological superiority as part of the technological analysis on a micro level.

Legal measures: The process of technological dominance can be accelerated or slowed down by legal factors. This can be measured by searching for the following indicators that hinder the import of foreign clean coal technologies to China: legal considerations besides tariff and non-tariff barriers that hinder the import (e.g. intellectual property protection) - Exact tariffs, import duties, and taxes assessed by the foreign country on imported products - Tariff concessions allowed by the foreign country (i.e. drawbacks, preferential tariffs) - Non-tariff product standards imposed by the foreign country (e.g. safety and environmental regulations) - Patent, copyright, and trademark protection in the foreign country. The existence of tax reductions and other comparable measures indicate a legal situation that accelerates the adoption of clean coal technologies. Analyzing the presence and influence of this indicators gives a good prospect for the chances of foreign clean coal technologies in the Chinese market.

Technological measures: When there is a standard available on the market, the standard setting process will be analyzed based on involved parties, to decide in which way (de facto or de jure) the standard was set and to analyze the time needed before a design is market ready. De jure standard setting processes typically include manufacturers, suppliers, and complementors, exclude end users and tend to support current or known technologies over emergent or new ones. In contrast, 'de facto' standards-setting processes are characterized by aggressive market competition without intervention by standards bodies, while 'de jure' standard-setting delays the emergence of a dominant design because there are many member participants in the standards organization with potentially conflicting interests, which makes it more difficult to achieve consensus. (Srinivasan 2006)

Micro level technology measures: The technological superiority of a clean coal technology will be analyzed by comparing the thermal efficiency, and emission of the most environmental harmful waste substances of CO_2-, NOx and SO2. Credibility has a focus on a company level and will not be easy to measure, moreover since this research does not focus on a company level, it will not be measured. Nevertheless the reputation in China of the Netherlands will be analyzed. The installed base will be measured by analyzing the current percentage of total market share of specific technologies in China. The entry timing is analyzed by looking at the status of the technology is in, in China. This can be in commercial operation, under development, mainly imported from abroad and have entered into commercial demonstration and being improved and perfected. The pricing is measured by analyzing the costs of electricity in kWh for every technology with and without CO_2 capture. The network effect will be measured by analyzing if the investment costs decline when a larger quantity of customers makes use of a specific technology to produce energy and if the technology can be used to produce energy at a higher efficiency rate. The indicators for a radical technology are analyzed: low initial performance-price ratio, limited market acceptance, high uncertainty, and numerous product variants. The R&D intensity is measured in the socio-cultural dimension.

Measuring competition: As explained in paragraph 2.6 on measuring competition, the market is screened for competition. The scanning of competitors in this phase is focused on screening the market for identification of competitors and their main clean coal activities. For competitive screening, Wood and Robertson (1999) identify several measures in their market screening model. These are: the number of competitive products, competitors' market share, coverage, and growth rate, advantages and weaknesses of competitors and the price levels on competitive products in the foreign market.

Measuring national competitive advantage: As explained is paragraph 2.6.1, the concepts of Porter on competitive advantage are used. Special attention goes to sources of (national) competitive advantage and factors that hinder/enable technology transfer. The four attributes of a nation that shape the environments which promote or impede the creation of competitive advantages, as described in the previous chapter, will be assessed:

1. Factor conditions. The nation's position in factors of production, such as skilled labor, natural resources, capital or infrastructure, necessary to compete in a given industry.

Factors can be grouped in a number of broad categories:

- Human resources: the quantity, skills and cost of personnel, working hours, work ethics.
- Physical resources: the abundance, quality, accessibility and cost of the nations land, water, mineral, or timber, power sources, climate conditions, nations location, geographic size.
- Knowledge resources: the nations stock of scientific technical and market knowledge bearing on goods and services. Knowledge resources reside in universities, government research institutes, private research facilities, government statistic agencies, market research reports etc.
- Capital resources: the amount of cost of capital available to finance industry. Capital in various forms, such as unsecured debt, bonds, equity, venture capital etc.
- Infrastructure: the type, quality, and user cost of infrastructure available that affects competition, including the transportation system.

2. Demand conditions. The nature of home demand for the industry's product or service,
3. Related and supporting industries. The presence or absence in the nation or supplier industries and related industries that are internationally competitive.
4. Firm strategy, structure, and rivalry. The conditions in the nation governing how companies are created, organized, and managed, and the nature of domestic rivalry. This last factor will not be taken along in the research because it strongly focuses on the firm level, not on the national level.

Measuring product characteristics for choosing a candidate product: As explained in the previous chapter, Root (1994) provides an overview of the characteristics of an ideal product candidate for foreign markets, these are: Ready market acceptance: measures with the status of a technology in China. High profit potential: measured by looking at future demand for orders from China. And 'availability from existing technology sources': measured with the status of a technology in the Netherlands.

Technology transfer measures: As noted in the literary review, there is only demand for technology transfer, when there is a technology gap. This co-consists with the competitive advantage a country like the Netherlands can reach, based on a leading position that creates this gap. The technology gap between China and the Netherlands is measured by comparing the energy efficiency indexes of China with both Germany and the UK, which are of course next to the Netherlands and have comparable natural resource endowment and levels of economic development. This is done, because the index for the Netherlands is unknown. A common way to calculate the energy efficiency is by dividing the CO_2 emissions by the GDP.

Different factors will be researched in order to analyze possibilities and threats for technology transfer. Therefore first objective is to identify which parts of technology are actually transferred (software, hardware, humanware, orgaware). The parts of technology that are transferred in former technology transfers are analyzed. The location factors that can hinder technology transfer as described by Steenhuis and de Bruijn (2001), namely language barrier, distance, time zone barrier and ease of communication are analyzed. The factors that are elaborated in the previous chapter will be measured: geographical factors and the eight (critical) factors that lead to the successful transfer of technology as described by Madu (1989) will be analyzed: needs and objectives, capabilities, education, training, research and development, identification and implementation of appropriate technology and stable governments and political systems.

Choosing a strategy for the Netherlands: Now, the three value disciplines of Treacy and Wiersema (1993) that can serve as the basis for a strategy: operational excellence, customer intimacy, and product leadership, have to be measured to decide what value discipline weighs the heaviest regarding market demand from China and on what value discipline the Netherlands can outbid the competition, based on price and convenience, tailoring products to fit a definition of the customer or producing a continuous stream of state-of-the-art products and services.

Measures for a follow up study: The measures for a follow-up on 'Dutch competitiveness on carbon sequestration'- study are operationalized as:
Meso-level measures: For one clean coal technology (CO_2 sequestration) in the Netherlands that has potential in China, a elaboration of the literature is made to finalize the analytical framework for measuring the economic competence of CO_2 sequestration in the Netherlands. The meso analysis is made based on the technological system approach. This will expose more details about opportunities and threats and also gives a much deeper insight into the possible competitive advantage that the Netherlands has one the specific clean coal technology CO_2 sequestration. This is done in the following manner: the actors are identified: according to experts, all Dutch parties that are involved in research of CO_2 sequestration are joined in CATO, a network of Dutch actors in the field of carbon capture and storage. Then, a description can be made of what they do exactly (attributes), how they do it, with who they collaborate (relationships). The next step is the measuring of the economic competence.
Economic performance measures: When the actors are identified, the indicators that are drawn from Rickne (2001, cited by Carlsson and Eliasson, 1994) could be a possibility to measure economic performance indicators. These indicators are: the number of patents, number of engineers or scientists, the mobility of professionals, the technological diversity, the timing and stage of development, regulatory acceptance, number of partners, distribution licenses, employment, turnover, growth and financial assets. This indicators can be suitable because Rickne (2001, cited by Carlsoon and Eliasson, 1994) studied similar young technologies, namely biomaterials. Other indicators can be market share and exports. Conventional indicators of the economic use of knowledge can be used, such as employment, sales, and growth figures. In addition, the financial assets the firms have managed to raise, can be used as supplementary information of the ability to exploit knowledge commercially, indicating, e.g. 'staying power' as well as the interest in the firms from other companies or from the capital market. (Carlsson et al, 2002:244) For an immature system like carbon sequestration, the measurement problems are greater. Several measures have to be combined to give an assessment of the performance in the early phase. After consulting industry experts, the list of indicators was drastically brought down because most of them are not suitable for measuring performance when looking at CO_2 sequestration. According to experts, the number of patents is not a good indicator because, in exploration and production, patents are seldom used because of the fact that multiple parties are involved in projects and knowledge is transferred within projects. Turnover and employment rates are too general and do not give enough information about carbon sequestration activities. Since the number of partnerships is extremely high and diverse, this is not a practical indicator. In one interview with an industry expert, it turns out that the performance in carbon sequestration is build on three pillars: operations, knowledge and capability. Capability covers the question: do you have the required people and capabilities? Operations covers: how many times did you do this before? Knowledge covers the required knowledge field.
To measure the performance of business in the CO_2 sequestration field, the focus is more on experience (operations) and capabilities than knowledge. This is because of the fact that every oil company possesses the knowledge to store CO_2 underground: knowledge for CO_2 sequestration is similar to knowledge for other activities like oil exploration and production; for

instance well drilling, reservoir engineering, geological monitoring etc. In other words, the CO_2 sequestration knowledge exists mostly of knowledge from existing knowledge fields that is, in the standard-toolkit of oil companies. Therefore, the number of engineers/scientists active is carbon sequestration appears to be a good indicator of activities next to publications about demo-projects of involved parties. A problem hereby is that some parties, like Exxon, do not publish anything about their activities. In order to assess the whole Dutch system on carbon sequestration, instead of the individual components, the overall qualitative 'score' is taken into consideration instead of the score of the individual components. This in then related to activities from other technological systems focused on the same technology in a different geographical bordered area.

3.5 DATA SOURCES

The method of data collection is about the choice of primary and secondary data, the selection of techniques to use for data selection and the optional design of these methods. The definition of primary data in this research is: ' Data collected for the research project being undertaken.' (Saunders et al., 2007) Primary data contains specific detailed environmental topics that are involved in strategic decisions. The definition of secondary data in this research is: ' Data used for a research project that were originally collected for some other purpose' (Saunders et al., 2007). The main advantage of secondary data is the low cost and the ready availability. Secondary data is useful in providing indications concerning the market and the research to be executed. Disadvantages of secondary data, in comparison to primary data is that the secondary data is more general and sometimes outdated. (Saunders et al., 2007)
For this research, a multi-method qualitative data method is chosen: interviews, a case study and research of secondary data, and analysis of this data using non-numerical procedures. The secondary data sources include: books, journals, newspapers, government publications, reports, theses, company reports and conference proceedings. Interviews and written communication by e-mail have been used as primary sources of data.

3.6 POPULATION AND SAMPLING

The population for this research contains of the government, organizations, universities and businesses in the Netherlands and China that are active in the field of clean coal technologies. In order to identify Dutch competitive advantages, it is also necessary to include the activities of foreign governments, organizations, universities and businesses that are active in the field of clean coal technologies. Since it is impracticable to analyze the entire population because of budgets, capacity, and time available, a sample is taken.
For selecting the samples, the non-probability sampling technique is used. This means that the probability of each case being selected from the total population is not known and it is impossible to answer research questions or to address objectives that require to make statistical inferences about the characteristics of the population. It is still possible to generalize from the non-probability sample about the population, but not on statistical grounds. The companies in China are selected on the judgment of the Embassy (so called purposive sampling). This was because of practical reasons, because the appointments for the interviews are made months before this research. This means that the researcher had no input in selecting this respondents. The first organizations in the Netherlands for the sample are found through 'convenience sampling', which means that the names of organizations that are easiest to obtain out of secondary data were contacted. Also member lists of network organizations, active in a specific clean coal technology were used to find respondents. During the communication with this Dutch organizations, the snowball method was used; by asking every respondent if they know more parties that are active in clean coal technology, also parties that were more difficult to identify were found.

3.6.1 RESEARCH POPULATION AND SAMPLE FOR THE DUTCH MESO ANALYSIS

The population for the meso analysis consists of organizations situated in the Netherlands that have activities in carbon sequestration. A list of potential respondents can be found in the annexes. The first objective is to decide if a specific actor belongs to the technological system. For this objective the membership list of CATO is used. CATO is the Dutch platform were all important carbon storage and sequestration organizations are united.

The second objective is to find all actors in the system. According to industry experts, every important organization in carbon sequestration is a member of CATO. Other methods were used to make sure every actor is included. When actors are identified, the snowball method can be used by asking each participant to point out further participants. Since the use of patents is not suitable for carbon sequestration activities this method for finding actors cannot be used.

3.7 RESPONSE RATE

All the people and organization in China that were approached by the Embassy and asked for their cooperation, gave their full cooperation. This means a response rate of 100%. Dutch organizations that were approached were mostly eager to participate. Three of them (VROM, ECN ad Procede) were not able to answer the questions by phone but replied by e-mail. This also means a response rate of 100%. This high response rate is because of the topic that interests most organizations, and the multiple ways the respondents were approached. When no response came, a member of the Embassy used his network of contacts to get the questions answered. This turns out to be very useful.

3.8 INTERVIEWS

Semi-structured and unstructured interviews are favored in exploratory research. For the gathering of primary data, semi-structured interviews is the most suitable way of getting the information necessary for the research. ‘Semi structured interviews are used to gather data, which is analyzed qualitatively. A list of themes and questions is covered, although these may vary from interview to interview. This means that sometimes some questions are omitted or added, given a specific organizational context. The order of the questions may also be varied.’ (Saunders et al., 2007) The nature of the questions and the ensuing discussion mean that the data is recorded by note taking. The interviews are held face to face, with an interpreter when the interviewee does not speak English or Dutch. The interpreter (William Sun) works at the Embassy at the energy department and has deep insights into the Chinese energy market. By asking every interviewee if he or she knows interesting people to talk to next, the research tries to explore if there are people who have critical information but are not contacted yet. This is called the ‘snowball method’ (Saunders et al., 2007). The notes of the interviews are accessible on request for review and further research.

3.8.1 RESPONDENTS

Interviews (personally or via phone) with the following persons and organizations were conducted:

- Bert Bekker - (15-05-2008, personal interview). Mr. Bekker is the EU Natural Gas Manager of the EU-China Energy and Environment Program
- *Li Hongjun and Jinyan Wu (20-05-2008, personal interview): Both Mr.* Li Hongjun and Mr. Jinyan Wu work at the China Coal Information Institute (CCII).
- China University of Mining and Technology
  (24-06-2008, personal interview)
  Xie Qiang – Ph.D. Professor
  Shu Xinqian – Ph.D. Professor
  Flora Yang – Section chief of foreign experts co-ordination
  Dr. Zhu Shuquan – Professor

- Sander van Egmond (19-06-2008, telephone interview) CATO
- Royal Netherlands Embassy in Beijing, China
  Ilse Pauwels – (22-05-2008, personal interview) Counsellor VROM
  Eric van Kooij – (29-05-2008, personal interview) Counsellor for Science and Technology
- Shell Global Solutions
  Eur.Ing Henry K.H.Wang and Mrs. Gu Jing (18-06-2008, personal interview). Mr. Wang is the GM & Principal Service and Manager Clean Coal of China, Shell Gas & Power.
  Mrs. Gu Jing is Shell's strategy and portfolio manager of Clean Coal Technology
- Piet Binkhorst (20-06-2008, telephone interview). Mr Binkhorst works at Hilux5, part of AMSTAR-Europe. In a conversation the technology of Hilux5 is introduced together with several advantages that boiler owners have when using this technology.
- Shenhua
  (03-06-2008, personal interview)
  Gao Min – Business Manager - Shenhua Group – Coal to Oil & Chemicals Department
  Lu Bing – General Manager - Shenhua Group – Department of International Co-operation
  Chen Kuangdi – Business Manager
  Zhang Zhilong – Project Manager
- TNO Built Environment and Geosciences
  (09-05-2008, personal interview)
  Frank van Bergen – Geologist/Geochemist
  Henk J.M. Pagnier – Manager CO2 Storage

3.8.2 EMAIL COMMUNICATIONS

To persons who could not participate in the telephone interview, the interview questions were sent and returned by email.

- Nick ten Asbroek (23-06-2008) Procede Enschede
- Willem van de Kamp (16-07-2008) ECN. Mr. van de Kamp works at ECN and performs the task of Manager Heat & Power at the Unit Biomass, Coal and Environment
- Annemarieke Grinwis (17-07-2008) VROM

3.9 CASE STUDY RESEARCH; SINGLE CASE STUDY

For the investigation of possible threats for technology transfer to China, a case study is performed on the case: ' Toward institutionalized collaboration on knowledge development for sustainable integrated exploitation of coal.' This project provides the opportunity to observe and analyze a phenomenon that is typical for Dutch companies who want to transfer clean coal technology to China. While a multi-case is preferable, because it provides the basis for generalizing the research findings, this case was the only Dutch example available. This means that the results of this case study cannot be generalized. The research proposal of the project is used as a data source, together with interviews with the Dutch participants. The case study forms an added value to this research because it investigates the phenomenon of knowledge transfer from another perspective, providing new insights. Or, as Saunders describes it: 'The case study will be of particular interest to you if you wish to gain a rich understanding of the context of the research and the processes being enacted.' (Saunders et al. 2007:139)

3.10 DATA ANALYSIS

Instead of only inductively collecting all the data and then analyzing what theory emerges, a hybrid approach is used for this qualitative data research.

Qualitative data refers to 'all non-numerical data or data that have not been quantified' (Saunders et al. 2007:470) A characteristic of qualitative research is that process of analyzing qualitative data is very likely to begin at the same time as data is collected and continuous afterwards. This research involves an established theoretical construct as described in the chapters before, to help make sense of findings. It is clear that the theory for the theoretical framework shapes the conclusions of this research because it is leading for the data collection.

Therefore it is essential to describe why this theory is used and not another theory which may be also appropriate.

The interviews are mainly used to test and verify made assumptions about the choice for future clean coal technologies from the secondary data and are used to determine qualitative weights to the indicators and factors from the theoretical framework. Next to this, the interviews provide a data source of first hand information input for the report.

In order to analyze the data from the interviews, the information in recorded by note taking and then summarized. This summaries can be found in the annexes.

Secondary data that was found during the research was dissected and placed in one of the three folders: macro, meso, micro, in order to keep the overview during the research. In academic literature this method is referred to as 'template analysis'(Saunders et al. 2007:496).

3.11 RESEARCH LIMITATIONS

The sample contains of 11 parties with very different backgrounds (energy producer, governmental organizations, research organization) this limits the generalization of the outcome. Because of the 'snapshot' which is taken of the clean coal technology market, no developments can be measured during the research based on own primary research data. Also the research findings are limited to the Chinese and Dutch borders and cannot be generalized for other countries that are dependent on coal as a primary resource of energy.

3.12 CONCLUSION

Through the study of relevant theories and empirical practices, literature reading and comparisons, a case study and interviews, this explanatory research intends to critically analyze the main opportunities in the field of CCT in China, for Dutch organizations. The theoretical framework functions as a template for gathering research data, and therefore has a very important influence on the research outcomes. This chapter further explains that the non-probability sampling of the Chinese participants in the research has implications for the outcomes of the research. For the meso analysis of one clean coal technology in the Netherlands (carbon sequestration) this chapter explains why the method of selecting actors by membership lists and the snowball method can be used.

4. FINDINGS

CLEAN COAL TECHNOLOGY IN CHINA

This chapter is focused on uncovering the clean coal technology status and the dominant technologies in the future. To understand the drivers behind the promising but complex –CCT market, one needs to first understand 5 key elements of energy production in China and the important role played by coal.

After the key findings this chapter discusses the influence of the macro-environment (political, economic, socio-cultural, technological, environmental and legal factors) on specific clean coal technologies.

Key findings

- China is the third largest country (in square kilometer), the second largest economy measured by purchasing power parity (after the US), the most populated country, as well as the most heavily polluted country, and the second largest energy consumer (after the US). All these statistics prone that China operates on an enormous scale, and has tremendous impact on the global economy, environment and availability of resources.(Bekker et al., 2007)
- China is an industrializing country in transition from a planned economic system to a middle income country, where increasing industrialization and rapid economic development are relying on growing energy usage.(Vallentin and Liu, 2005)
- Energy has been playing a central role in China's economic boom. To keep up with its domestic thirst for energy, China is investing in power plant production – in particular, coal power plants - at a rate of one large power plant (1000 MW) per week. In 2004 alone, the amount by which China increased its generating capacity equaled the entire generating capacity of California or Spain.(International Trade Canada, 2007)
- Because China's energy production is characterized by its striking reliance on coal, now and in the coming four decades (see figure 4.1), China is potentially the biggest market for clean coal technologies.(Kiga, 2008) This market is increasingly attracting international attention from countries that are working/doing research on CCT in cooperation with China for years. In order to benefit from the future growth market in China on CCT, the Netherlands - business and government- should be involved early on.

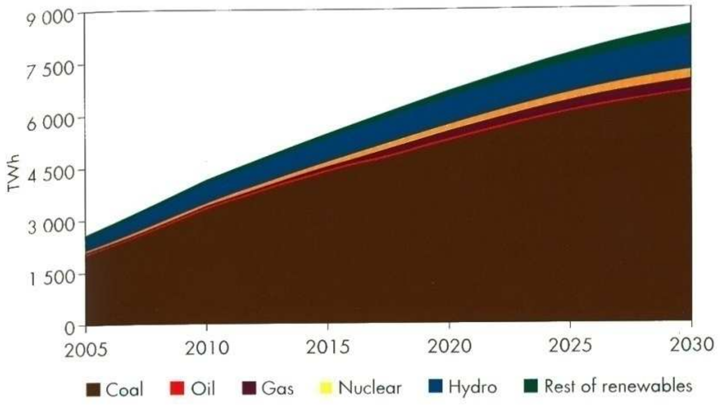


Figure 4.1 Primary Energy Consumption in China (2005-2030)
Source: World Energy Outlook 2007

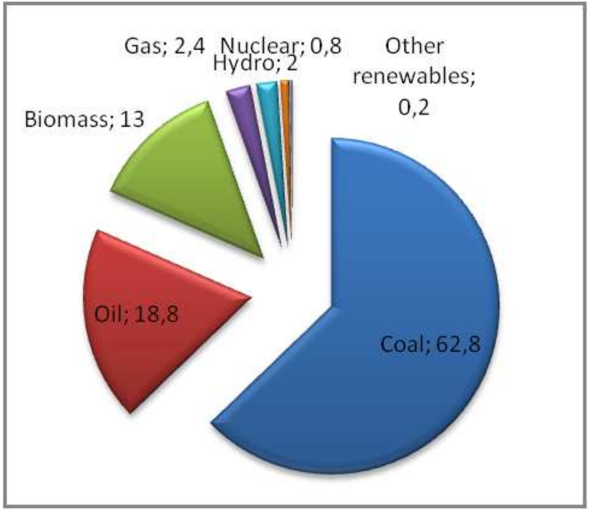
- At present, there is no price linkage mechanism between the costs of coal and electricity in China. Due to government energy policy and related subsidies the price of electricity does not fluctuate along with that of the coal used to generate it. Conclusion: electricity producers get the same price for producing electricity when the coal price rises. Because of this, their profit margins are under pressure.

4.1 ECONOMIC SITUATION

GDP and primary energy demand from coal

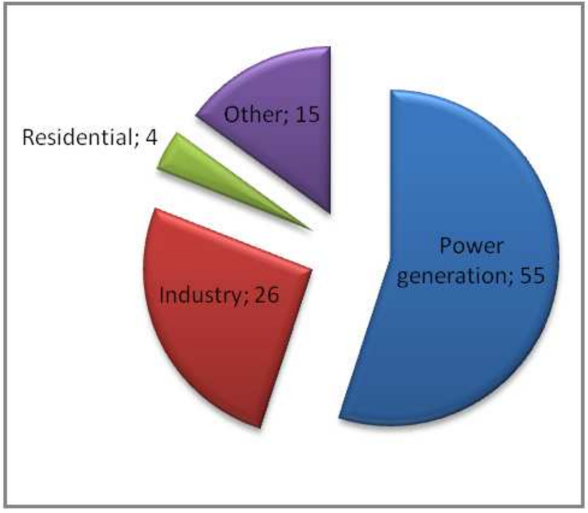
Despite efforts to cool the overheating economy, the officially recorded GDP growth rate was 11.4% in 2007, with a GDP per head of 16,084 RMB (approximately €1600) (Chinability, 2008) With the rapidly increasing of GDP, the electricity sector will continue to expand and play a primary role in China's economic development. Coal accounts for 62.8% of China's energy demand and 55% of its power generation. It is also the largest source of local pollution and CO_2-emissions (see table 4.2).(Energy working group, 2008) China's power sector thus is the largest consumer of the coal industry, as can be seen in figure 4.3 (Vallentin and Liu, 2005). The average coal consumption is 380 gce/kWh (gram coal equivalent weight/kilowatt-hour) (Zhang et al., 2007) in China, about 60–70 gce/kWh higher than that of developed countries (Hu, 2005).

Figure 4.2: Total Primary Energy Demand in China, 2005



Source: World Energy Outlook 2007

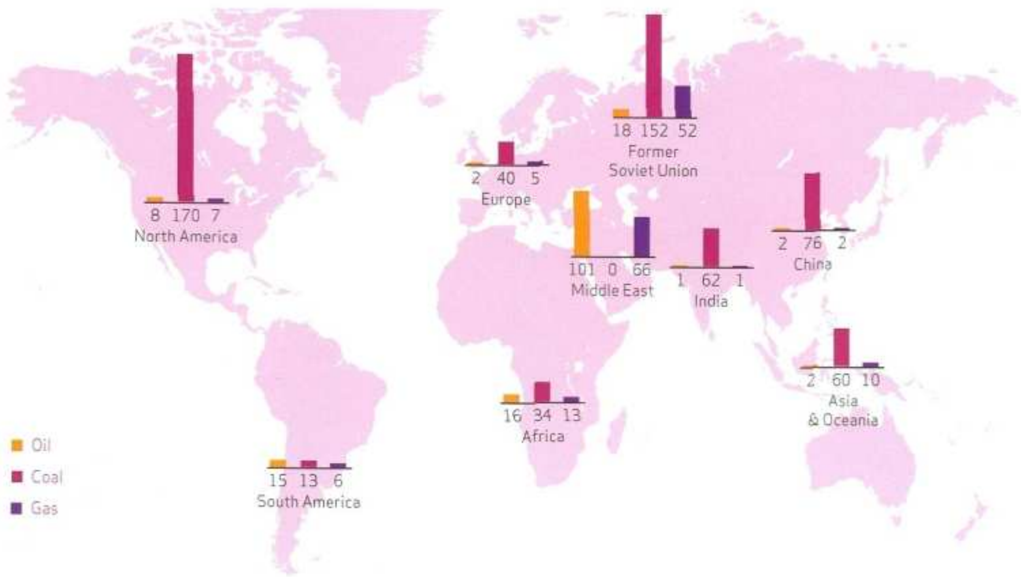
Figure 4.3: Coal usage split up by type of usage, 2005



Source: World Energy Outlook 2007

China mainly relies on itself to increase the supply of energy, and tries to satisfy the rising market demand by way of steadily expanding the domestic supply of reliable energy resources. (China.org.cn, 2007) China is the world's largest producer and consumer of coal. (International energy agency, 2006) In 2005, China's coal production accounted for 44.8% of the world market, which totaled 2.2 billion tons of hard coal, up from 41% in 2004. The vast majority of its production was consumed domestically – China exported only 72 million tons. (International Trade Canada, 2007) This is in stark contrast to the oil sector, in which China became a net importing country in '93. Figure 4.4 below, shows China's relatively low reserves of oil and gas to its relatively high coal reserves.

Fig 4.4: Location of the World's Main Fossil Fuel Reserves (Gigatonnes of oil equivalent)



Source: IPCC, 2005, cited by Metz et al., 2005

Resources restraint and consumption trends

China's relative lack of high-quality energy resources hinders its supply capability. Its imbalanced distribution makes it difficult to secure a continued and steady supply; and the extensive pattern of economic growth, irrational energy structure, unsatisfactory energy technology and relatively poor management have resulted in higher energy consumption per-unit GDP than the average level of the major energy-consuming countries. As such, the energy-supply demand contradiction in China is further intensified. Forecasts indicate that the proportion of coal in Chinese primary energy consumption will decline to slightly 60% in 2020, yet the total amount of coal consumption will rise to above 2000 Mt. The situation of 2002 and a forecast of coal consumption in 2020 are listed in table 4.1. To see this figures in perspective: the U.S. energy consumption of coal in 2002 and 2005 was 1066 Mt and 1125 Mt respectively. (United States Energy Information Administration, 2008)

Table 4.1 Status and projections of coal consumption in China

Year	**Total consumption (Mt)**	**Proportion (%)**				
		Power	Industrial boiler	Coking & injection	Chemicals & fuel oil production	Household use
2002	1315	54.8	~27	9.1	3.0	6.0
2020	2481	68	14-15	8~9	4	5

Source: China's National Energy Strategy and Reform 2003

Table 4.2 Coal-fired electricity generation and CO_2 emissions in China

Reference scenario	**1990**	**2005**	**2015**	**2030**
Generation (TWh)	471	1996	4326	6586
Capacity GW	87	368	814	1259
CO_2 (MT)	598	2424	4328	5997
Emissions Ratio (Mt CO_2/TWh)	1.27	1.21	1.00	0.91

Source: IEA 2007c cited by International Energy Agency, 2008

Distribution of energy sources

A Chinese official whitepaper called China's energy conditions and policies, states that 'The distribution of energy resources is imbalanced. China's energy resources are scattered widely across the country, but the distribution is uneven. Coal is found mainly in the north and the northwest, hydropower in the southwest, and oil and natural gas in the eastern, central and western regions and along the coast. But, the consumers of energy resources are mainly in the southeast coastal areas, where the economy is the most developed. Such a great difference of location between the producers and the consumers has led to the following basic framework of China's energy flow: large-scale transportation over long distances of coal and oil from the north to the south.'(China.org.cn, 2007)

Investments in energy infrastructure

The projected energy supply in China and India, as described together in the reference Scenario of the IEA calls for cumulative infrastructure investment of $5 trillion (in 2006 dollars) over the period 2006-2030, or $200 billion per year. This investment is needed both to expand supply capacity and to replace existing and future supply facilities that are retired during the projected period. China's overall investment needs are three times those of India in total. China accounts for 17% of projected world energy investment. The electricity-supply-industry, covering power generation, transmission and distribution, demands the lion's share of future energy investment. Future investment in the coal-mining industry is relatively modest, at $251 billion (less than 7% of total energy investment) in China. This share however should rise to 40% if coal-fired power stations are included.

The Chinese government strives to gradually establish a market-oriented system for technological innovation, in which enterprises play the leading role and which combines the efforts of enterprises, universities and research institutes.(China.org.cn, 2007) Foreign private investment in the energy sector did not exist until 1990. It was only during the last few years that FDI in energy has grown substantially. This development is mainly brought about by the deregulation of the energy market and incentives provided by state investment policies. (Gan, 1997b) Projections of 2007 (Acquatella, 2007) estimate that the total investments in the energy sector in China will add up to $ 3.7 trillion, with 238 billion dollar in the coal sector, between 2005-2039, which is 18% of the world's total.

4.2 POLITICS AND LEGISLATION ON CLEAN COAL TECHNOLOGIES

National policies

China's dramatic economic growth is literally fuelled by electricity, and demand for energy has outstripped supply since 2002. (International Trade Canada, 2007) Shortages peaked with a 40 million kilowatt shortfall, which resulted in widespread rolling blackouts in 2004 that shut down some factories for days at a time. China's extended economic growth is completely dependent on an abundant energy supply and the number one concern has been to keep the lights on.(Liu, 2007) While China's electricity industry is still regulated, the government has started to introduce more competition into this industry with an eventual goal of full deregulation. More importantly, given the crucial role of electricity in the economy, the power industry always has tremendous political power to influence the decision-making process, and thus is less worried about policy changes.(J.F.K. School of Management, 2004)

Pricing policies and mechanisms

China's pricing mechanism for energy is imbalanced: while coal prices are more or less market-based, the electricity prices are heavily subsidized. China sticks to the policy of reform and opening-up, gives full play to the basic role of the market in allocating resources, encourages the entrance of entities of various ownerships into the energy field, and actively facilitates market-oriented reform related to energy. According to the Energy Working Group (2008), market competition has been already introduced into the production and distribution of coal. The price control of the Chinese Government leads to serious problems: "With rising prices of coal and crude oil and Government's control of prices for electricity and oil products at artificially low levels, both Chinese power producers and oil refiners suffer significant losses. This distortion leads to energy supply insecurity, energy waste, environmental pollution and subsidies to the rich instead of the poor. A stable and predictable market is essential to encourage investment in any sector. For the coal generation sector this is particularly true in terms of the current tariff system. Although coal prices were entirely market based (acknowledged by the Shenhua Group during an interview), both the tariff and the yearly operating hours are still Government regulated. The result of this imbalance is that power producers are being squeezed. This is affecting not only long terms investments but also day-to-day operations. In the absence of financial market mechanisms to hedge the risks (e.g.: futures, forwards or options contracts), this uncertainty makes the game even more difficult for foreign companies. (Energy Working Group, 2008)

According to the Shenhua group, the largest coal producer and seller of China, the so-called squeezing is definitely not the case. The company points at the annual reports of power generating companies, which shows that the margins in power supply have shrunken, but power generating companies are still making profits. (Shenhua Group Corp. 2008)

Analysts say increased contract prices for coal in 2008 indicates that the growing marketization of coal prices have pulled up the spot prices. The average appreciation of China's coal and power prices last year was 10%, and China's major coal enterprises also definitely expressed optimism about the positive trend of coal prices in the future. But the National Development & Reform Commission (NDRC) warns that if coal prices grow too fast or by too high, the department concerned may have to take certain measures to control them. (Chinastakes.com, 2008)

Currently, there is not a so-called coal and electricity price linkage mechanism, that allows the price of power should to fluctuate along with that of the coal used to generate it. This means that using cheaper coal or more efficient use of coal through innovation, for the production of electricity, would generate more money for the electricity companies. Since the price of coal is rising, electricity producers are constantly searching for technologies to increase their electricity producing efficiency. Since several clean coal technologies, like desulfurizing, decrease electricity producing efficiency, the power producing companies implement this technologies because of legislation.

Update on the 20th of June 2008, from the China daily: "The government will raise the electricity tariff to prevent power companies from incurring further losses. The price of coal will be brought under government control temporarily, the NDRC said, because soaring coal price is the main factor behind higher electricity charges." (Zhihong, 2008)

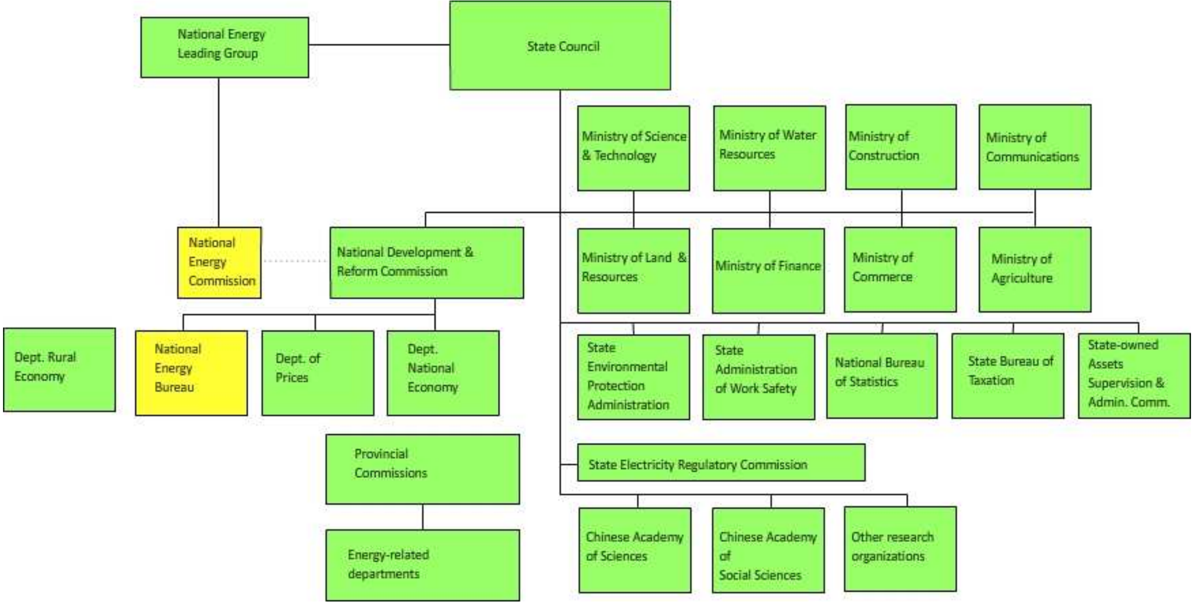
Administrative structure, policies and regulatory frameworks, a decentralized system

Because the governmental role in the power sector is still present, it is important to understand how the administrative structure functions. This is also to understand the coal sector, and ultimately, has impact on the extent to which CCT will be adopted. China's administrative structure is made up of four levels: 1) province level, 2) prefecture level, 3) district level and 4) town level. The authority of a city government depends on a city's status in China's administrative ranking, based on size, population density, and the number of inhabitants. The highest ranked cities, so-called municipalities, include Shanghai, Tianjin, Beijing and Chongqing and their municipal governments have a similar status to provincial level administrations. Municipal governments steer independently their economic, environmental and social development. (Salonen, 2007) Each region should be required to draft realistic local energy development plans and clean coal technology development plans, and develop the technologies suitable for itself according to national environmental goals, local resource availability, and economic ability. Regions should not have national approaches imposed uniformly on all regions. (China development forum, 2003) China's energy policies give high priority to the reduction and rehabilitation of environmental damage and pollution resulting from energy development and utilization. After the 1992 UN Conference on the Environment and Development, China worked out its "21st Century Agenda," and has reinforced environmental protection in an all-round way through legislative and economic means. (China.org.cn, 2007) In order to eliminate overlapping responsibilities and inefficiencies in the government, China restructured the sprawling government into fewer ministries including five new "super ministries " during its National People's Congress in 2008 March. Two new but relatively weak bodies were set up on energy.

A: National Energy Commission: will be responsible for studying and developing national energy strategy and assessing major issues in energy security and development. The NEC is a cross ministries co-ordination and consulting organization which will focus on national energy strategy and policy making of national level. National Energy Commission (NEC) is a successor of the former National Energy Leading Group.

B: National Energy Bureau: A new Energy Bureau will administer the Chinese energy sector under the powerful NDRC.

Figure 4.5 An overview of the organization of Energy Policy Making and Administration in China*
* Note that recent announced changes have already been implemented in the figure. NEC and National Energy Bureau are colored yellow in the figure



Though the new National Energy Bureau is the forerunner of a future energy ministry, currently, NDRC is still the most powerful ministry on Energy administration. (Embassy of the Kingdom of the Netherlands, 2008) The new Energy Law which has been drafted and is currently undergoing revision will have a wide ranging impact on all participants of China's energy market. The draft version of the Energy Law, which was published for public consultation in December 2007, tends to tighten the control by the government, instead of contributing to the creation of an open and competitive energy market. (Energy working group, 2008)

Presence of foreign technology discriminating policies

The Chinese Government has abandoned withholding tax on technology licenses. This effectively means a 10 percent penalty for foreign companies regarding Chinese companies. This form of unannounced price discrimination means that if a Dutch organization and a Chinese organization have exactly the same technology to offer, the Chinese company can offer the technology 10 percent cheaper. An organization can only apply for an Advanced Technology Status (for tax exemption) if it owns the technology. This means that the Chinese company has to own the technology. This would mean that foreign companies would give up their technology completely which is very exceptional.

Structure of the Chinese energy sector

The Chinese Government has been trying hard to privatize many of the former State Owned Enterprises (SOE's) by encouraging them to sell their shares to both domestic and foreign investors. Despite moves toward privatization, much of China's energy sector remains under control of large SOE's, many of which are inefficient and unprofitable. Restructuring of the SOE sector, including the privatization of some enterprises, is one of the government's major priorities. (Bekker, 2007) The State Power Corporation of China (SPCC) was the government's own power utility. The SPCC controlled 90 percent of the country's transmission assets, and accounted for 46 percent of China's total power output. In the year 2000, reforms were carried through to split the plant- from the grid- activities. (International trade Canada, 2007) To encourage more competition, the central Government decided to divide the holdings of the SPCC among 11 different companies. This radical change resulted in two power grid companies, Five electricity producers (referred to as "the big five"), and four energy service companies. (International trade Canada, 2007) The "big five" include: Datang Group, Huaneng Group, China Huadian Group, China Guodian

Group and China Power Investment Corporation. They make up the lion share of energy production in China. Power transmission and distribution is controlled by two regional monopolies: South China Grid Corporation (the five southern provinces) and the State Grid Corporation (covers the remaining provinces including the administration of the Lhasa Power Grid in Tibet.) (International trade Canada, 2007)

Political perspective on clean coal technologies

According to a whitepaper on energy called 'China's energy conditions and policies', China actively develops clean coal technology and encourages the application of coal washing, processing, conversion, clean-burning and smoke-purifying technologies. At the same time, it is expediting the construction of desulfurizing facilities in coal-fired power plants, requiring that newly built coal-fired power plants must install and use desulfurizing facilities according to the permissible emission standards, and such existing plants must speed up their desulfurization upgrading. The Chinese government strictly prohibits the construction of new coal-fired power plants for the sole purpose of power generation in medium and large cities or on their outskirts." (China.org.cn, 2007)

International cooperation

China's development cannot be achieved without co-operation with the rest of the world, and the world economy needs China to prosper as well. With accelerating economic globalization, China has forged increasingly closer ties with the outside world in the field of energy. China's development of energy has not only satisfied its own needs for economic and social progress, but also brought opportunities and tremendous scale for development to the rest of the world. China has observer status at the Energy Charter, and maintains close relations with international organizations
such as the World Energy Agency and the Organization of Petroleum Exporting Countries (OPEC) China is a member of the International Energy Agency (IEA), the energy working group of the Asia-Pacific Economic Cooperation (APEC), Association of Southeast Asian Nations (ASEAN) plus China, Japan and ROK (10+3) Energy Cooperation, International Energy Forum, World Energy Conference, and Asia-Pacific Partnership for Clean Development and Climate. (China.org.cn, 2007) China is also an 'enhanced engagement country' of the OECD. The Chinese Government is active in fulfilling its UNFCCC (United Nations Framework Convention on Climate Change) commitments as evidenced by issuance of China's National Climate Change Program (CNCCP), and in achieving the target to reduce energy consumption per unit GDP by 20% by 2010 against the 2005 level. In spite of the fact that China's energy consumption per unit GDP and GHG emission intensity suggest a decline in general, it would be difficult to reverse the trend of rising energy consumption and total GHG emission in a short period of time. (China's Scientific & Technological Actions on Climate Change, 2007)
Another important institution is the China Council for the Promotion of International Trade (CCPIT). The China Council comprises VIPS, enterprises and organizations representing the economic and trade sectors in China. It is the most important and the largest institution for the promotion of foreign trade in China. The aims of the CCPIT are to operate and promote foreign trade, to use foreign investment, to introduce advanced foreign technologies, to conduct activities of Sino-foreign economic and technological cooperation in various forms, to promote the development of economic and trade relations between China and other countries and regions around the world, and to promote mutual understanding and friendship. (China Council, 2008) Besides the CCPIT there is the China Council for International Cooperation on Environment and Development (CCICED) The China Council for International Cooperation on Environment and Development (CCICED) is a high level, non-profit international advisory body. The main task of CCICED is exchanging and disseminating international
successful experience in the field of environment and development; studying key environment and development issues in China, putting forward policy recommendations to the leaders of the Chinese government and policy makers at all level, which are projecting, strategic and precautionary; supporting and facilitating the implementation of sustainable development

strategy and development of a resource saving and environment-friendly society in China. The CCICED has set up a taskforce on ‘Energy Strategies and Technologies. The China Council has one Dutch member: Hans van der Vlist: Secretary General, Ministry of Housing, Spatial planning & Environment (VROM).

International experiences promoting CCT development

CCT development is generally driven by environmental regulations and policy incentives. First, special laws with strict legal requirements need to be established. The formulation of emission standards is vital for the economic and technical development level. (China development forum, 2003) In contrast to the past, China is opening up to foreign investment in its coal sector, particularly concerning modernization of existing large-scale mines and development of new ones. The China National Coal Import and Export Corporation is the primary Chinese partner for foreign investors in the coal sector. Areas of interest to foreign investment are centered around technologies only recently introduced in China or on environmental benefits, including coal liquefaction, coal bed methane production, and slurry pipeline transport projects.

Table 4.3 contains a list of several research programs on clean coal technologies:
The potential advantages of international energy technology collaboration and transfer for promoting technological change may consist of lowering R&D costs and stimulating other countries to invest in R&D; disadvantages may include free-riding and the inefficiency of having to reach agreement between many actors. (Gallagher, 2006)

Table 4.3 Examples of research programs - Source: World Coal Institute (2007)

Research Programs/Initiatives	**Details**
Asia-Pacific Partnership on Clean Development and Climate (AP6)	AP6 consists of representatives from Australia, China, India, Japan, South Korea and the USA who are working together to develop cleaner, more efficient technologies that will meet climate concerns without negatively effecting economic growth. AP6’s Cleaner Fossil Fuels Taskforce aims to accelerate the development and deployment of technologies through collaborative research and on-going demonstration in order to reduce costs and facilitate the availability of a range of accessible and affordable low-emission technologies.
Carbon Sequestration Leadership Forum (CSLF)	CSLF is an international climate change initiative that is focused on the development of cost-effective technologies for CCS. CSLF aims to make these technologies broadly available internationally and to identify and address wider issues relating to CCS. CSLF is currently comprised of 22 members, including 21 countries and the European Commission.
COAL21 Fund	The Australian coal industry launched the COAL21 Fund in March 2006 to support the financing of near-zero emission coal demonstration projects and associated R&D. The Fund is being raised by an A$0.20 per ton voluntary levy on coal producers that is expected to raise up to A$1 billion over the next ten years. Through the COAL21 Fund, the Australian coal industry will work with governments, electricity generators and researchers to advance knowledge and commercial-readiness of low emissions energy technology.
Cooperative Research Centre for Greenhouse Gas Technologies (CO$_2$ CRC	CO2CRC is a collaborative research organization – involving industry, research parties, international collaborators, and government organizations – focused on the development and application of technologies to more effectively capture and geologically store CO2.
EPRI 66 CoalFleet for Tomorrow	The EPRI 66 CoalFleet for Tomorrow program is tackling the technical and economic/institutional challenges to making advanced, near-zero emission coal power plants a good investment option. This industry-led program provides a vehicle for collaborative RD&D on deployment-related issues for near-term plants.
European Technology Platform on Zero Emission Fossil Fuel Power Plants (ETP ZEP)	The European Commission, European energy industry, research community and NGOs have established a European Technology Platform on Zero Emission Fossil Fuel Power Plants (ETP ZEP). The Platform aims to develop and deploy new competitive options for near-zero emission fossil fuel power plants within the next 15 years.
IEA G8 Gleneagles Program	Under the G8 Gleneagles Plan of Action, the IEA is working with partners around the globe to focus on climate change, clean energy and sustainable development. The IEA's G8 Gleneagles Program is promoting energy-sector innovation, better practice and use of enhanced technology. This includes programs focusing on cleaner fossil fuels and CCS.

4.3 SOCIO-CULTURAL SITUATION

Classification of clean coal technology research in China

Among scientific scholars, CCT are rather broadly defined and correspond to a wide range of polluting procedures. Some like Vallentin and Liu (2005) include coal preparation (e.g. washing

and briquetting), combustion (e.g. fluidized beds and gasification) and emission reduction (e.g. FGD and denitrification) in their definition.
Dr. Zhengang, a leading scientist of the Beijing Research Institute of Coal Chemistry (BRICC) adds another category to this classification that makes the picture more complete for the situation in China (Zhengang, 2007):

Table 4.4: Clean coal technologies in China

Coal processing	**Coal conversion**	**Coal combustion**	**Emission control**
Coal preparation	Coal gasification	CFBC boiler	Flue gas clean-up
Coal water mixture	Coal liquefaction	PC boiler with FGD	Coal-bed methane use
Coal briquetting	Coal pyrolysis	Supercritical boiler	Utilization of fly ash
Coal blending	Chemical synthesis	Ultra-supercritical boiler	Control & use of wastes from coal mining & preparation
Coal up-grading	IGCC and fuel cells	Industrial boilers & kilns	

Chinese universities and research institutes perform research on every clean coal technology. As can be seen In table 5.1 above, according to Dr. Zhengang, CCT in China should cover the whole process from coal mining to the end of coal products. The same author also highlights some specific CCT in China after 2000: 'In the 11th chapter of the China Development Forum (China development forum, 2003), the clean coal technologies and development suitable for the Chinese situation are (also) put forward. Now evaluation and classification is based on four main users of coal, i.e. power sector, industrial boilers, chemical production and fuel oil substitution, and household use.'(China Development Forum, 2003, p.148)

Masculinity index as an indicator that confer high status

During interviews with both clean coal technology buyers and sellers in China, the emphasis was on the fact that Chinese companies want to purchase the most advanced and competitive technology and they are willing to pay for it. It would be interesting if this can be retrieved from the masculinity versus femininity index of China by Hofstede (2008). The assertive pole has been called 'masculine' and the modest, caring pole 'feminine'. A high masculinity score stands for a very assertive and competitive environment. In practice this could mean choosing for a more complex, expensive technology over a cheaper, less complex technology to get international status.
The score for China is 66 (in between masculinity-femininity), with a lowest possible score of 0 and a highest possible score of 125. This means that the practical situation of technology purchasing cannot be retrieved from the masculinity index of Hofstede, because the in-between masculinity index does not clarify the demand for the most advanced and competitive technology.

Long-term orientation as an indicator for choosing more durable, less polluting technologies

The long-term-orientation (LTO) index of Hofstede (2008) deals with values associated with long-term orientation are thrift and perseverance. While values associated with short term orientation are respect for tradition, fulfilling social obligations, and protecting one's 'face'. The score for China is 118, with a lowest possible score of 0 and a highest possible score of 125. This is the highest measure of all 23 countries were this index is measured. (Hofstede, 2008) This high LTO index score is interpreted in this research to predict that China will choose for clean coal technologies that are more durable, less polluting, but also more expensive than other technologies to preserve the environment for future generations.

4.4 ENVIRONMENTAL SITUATION: ENERGY MIX AND ENVIRONMENTAL PROBLEMS

The relatively old-fashioned methods of coal production and consumption have intensified the pressure on environmental protection. Coal consumption has been the main cause of smog pollution in China, as well as the main source of greenhouse gas. As the number of motor vehicles climbs, air pollution in some cities is becoming a mixture of coal smoke and exhaust gas. As this situation continues, the ecological environment will face increasing pressures. (China.org.cn, 2007)

China is the second largest producer of CO_2 emissions in the world, about 3.052 billion ton per year. China, as a developing country, is not required by the Kyoto Protocol to the UN Framework Convention on Climate change to set a quantitative target for CO_2 emission reductions, and it has not done so voluntarily. (Zhao et al., 2008) In the climate debate, China referred to the aggregate amount of China's fossil fuel carbon dioxide emissions that accounted for only 9.3 percent of the world's total in the period 1950-2002 and that the amount of China's per-capita carbon dioxide emissions ranked 92nd in the world (China.org.cn, 2007). Nevertheless, the Chinese Government states that reducing CO_2 is imperative and has set an 10% CO_2 reduction target for 2010. In addition, China features the highest SO_2 (sulfur dioxide) emission in the world. In 2005, China emitted 25.49 million tons of SO_2 (The State Environmental Protection Administration of China, 2005). NOx emissions in China reached around 20 million ton, half of which came from the power industry, while soot emissions totaled 11.825 million ton (SEPA, 2005). The Chinese government has already enacted a series of policies to require the abatement of emission of airborne pollutants and plans to invest 780 million US$ on coal-fired power stations to reduce the emission of SO_2. An annual reduction of SO_2will be required of 15%, based on the emission of 2005. Annual SO_2 emissions from coal fired power plants will be required to be no more than 10 Mt by 2010. (State Environmental Protection Administration of China, 2005)

The enforcement of environmental laws is influenced by various factors. Laws, regulations, and policies lack detailed implementation requirements and enforcement. Some of the emission standards cannot be implemented in practice. Small scale coal fired industrial boilers are currently the country’s second largest pollution source, after the power sector. This large group of polluters has not installed the continuous emission monitors, due to a lack of effective management and monitoring of small-medium users. The level of SO_2 emission fees is still lower than the cost of SO_2 control. The phenomenon of paying emission fees through negotiation still exists. (China development forum, 2003)

Air pollution due to emissions of SO_2, NOx, and soot can lead to health problems amongst the population as well as acid rain. However, global climate change due to greenhouse effects is the most difficult of the problems. High prices and the economic vulnerability associated with oil and natural gas dependence, have motivated interest in coal gasification and liquefaction in many countries, including China. In addition, air pollution, acid rain precipitation, and climate change are increasingly generating interest in cleaner coal technologies, including CO_2 capture and storage. (Zhao, 2007) In 2003, the State Development and Planning Committee together with the Ministry of Finance and the State Environmental Protection Administration of China released managerial rules for levying a fee for emitting pollutants. The rules impose a levy on pollutants emissions. A total of 632 Yuan/ton of SO_2 and NOx, 275 Yuan/ton of particulate matter are levied by the government (State Development and Planning Committee, 2003). Because of the low levy fee, polluters prefer to pay charges for emitting pollutants. Chinese government offers a preferential price for electricity from power plants with a flue gas desulphurization installation (FGD). It’s price is 15 Yuan/MWh higher than the price for electricity from power plants without FGD. Therefore, in China power plants with FGD remain competitive with other power plants. Currently, however, there is no incentive policy to encourage power plants to install NOx control equipment. (Zhao et al. 2008)

The Chinese Academy for Environmental planning (2002) has done extensive research on the internalization of external costs in the energy price, and advise to include the emission taxes in the energy price. For this research, the emission taxes of France are used as an example, to analyze the effect on electricity price when this charges are internalized: €27.40 per ton SO2 and €38.10 per ton of NOx. France is chosen as an example because its emission charges are on an European average level.

An important obstacle for clean coal technologies that need a large amount of water is China's scarce water resources. Coal liquefaction and polygeneration (a plant producing electricity and useful heat) were in fashion in China in 2006-mid 2007, because of the constant price increase of oil. Many projects were started up. In the second half year of 2007, the NDRC restricted permission of coal liquefaction companies because of their excessive use of water. According to the China Coal Information Institute (CCII), only large projects get approval, while the market demand for more projects is high. Authorities approve only projects that produce above a million tons of oil. Two active players in this field are Shenhua and the Yankuang Group; two state-owned enterprises. According to the CCII, coal liquefaction is in an early stage in China. (China coal information institute, 2008)

4.5 TECHNOLOGICAL MEASURES

In recent years, the great demand for new power plants has made manufacturers compete in a highly competitive market. This caused a rapid drop in PC equipment prices.(Zhao, 2007) Players in the Chinese market heavily compete to make their own technology dominant. For instance in gasification technologies, Shell is competing with its Shell Coal Gasification Process (SCGP) with General Electrics' 'GE Clean gasification' technology. This battle has the characteristics of a de facto standard setting process, but since there are no standards in this market) the process for dominance is set by market factors, with a heavy influence on technology choice by governmental institutions like the NDRC that needs to give green light.

4.6 MACRO CONCLUSION: NECESSITY FOR CLEAN COAL TECHNOLOGIES

The environmental situation of energy usage as described above, is not expected to change in the 30 years to come, and causes serious problems. Clean coal technologies can reduce the negative impacts of polluting energy production and usage. They include a series of technologies in the chain of coal exploitation, combustion, conversion and pollution control, all of which offer technical improvements in coal utilization efficiency and environmental pollution reduction. (Vallentin and Liu, 2005) In the near term, advanced coal technologies can significantly improve the energy efficiency of China's industries, especially energy intensive industries and power generation. More importantly, clean coal technologies can bring enormous benefits to the public health and to the environment. Over the longer term, advanced coal technologies could effectively meet, at competitive costs, most of the environmental concerns (including CO_2 emissions, if coupled with carbon capture and storage technologies) associated with burning of coal. (Belfercenter, 2008) China's power sector is the largest consumer of coal domestic industry. Clean coal technologies for coal preparation and coal combustion as well as clean-up technologies will all play a vitally important role in power generation processes. A high percentage of polluting emissions discharged in China are caused by the inefficient combustion of coal in power plants. Therefore, the diffusion of clean coal technologies (CCT) for electricity generating facilities is highly important in order to achieve a sustainable energy development in China. At present, China's electricity demand is well in excess of supply and is continuing to grow at a tremendous rate. There is a trend towards larger, more efficient power plants, which is accompanied by the closure of small, inefficient units. At the same time, ongoing energy sector reforms, increasingly strict air pollution regulations and participation of domestic generation companies and foreign investors are expected to further the diffusion of clean coal technologies. China's government started to introduce and promote clean coal technologies more than ten years ago, but due to China's specific political, economic, social and cultural situation, there is still a long way to go to promote CCT on a large scale. (Vallentin and Liu, 2005) For the deployment of CCT's to occur effectively, it is essential that Chinese companies find ways to improve their skills in the design, manufacture and operation of these technologies. Whilst China could mobilize significant technological and policy drivers to its environmental problems, there is a clear need for additional assistance from international companies and governments. (Watson et al., 2000) At the same time, China provides a platform and the economies of scale needed, to develop expensive clean coal technologies.

4.7 CLEAN COAL TECHNOLOGY PERSPECTIVE ON MICRO-LEVEL

Installed base and future perspective on application of clean coal technology

Key findings

- The dominant installed CCT technology is pulverized coal combustion with a subcritical steam cycle
- The National Development and Reform Commission (NRDC) has recommended advanced supercritical plants for large scale power generation and most recent orders have been for supercritical units
- A recommendation of the China Council for International Cooperation on Environment and Developed made in 2003 to the Chinese government essentially equates coal modernization with polygeneration through gasification.

It is important to notice that China's electricity industry is less interested than the coal industry in adopting more-expensive coal-gasification-based technologies (e.g., IGCC, poly-generation) as a measure to hedge against business risks caused by potential changes in regulatory regimes, especially the possibility that emission of carbon dioxide will eventually be regulated. (Ministry of Science & Technology, 2004)

Table 4.5: clean coal development in China categorized based on specific technology

Technology	Situation in **China**
IGCC	Yantai IGCC project under consideration for past decade. Several power and polygeneration projects being developed by major utilities.
Gasifiers	37 on coal, 13 on petroleum and 1 on gas (25 Shell, 22 GE, 3 Sasol Lurgi, 1 GTI U-Gas) (35 Operating, 16 Planned)
CFBC	Many domestically built 50-200-MW units
CTL/ Polygeneration	First phase of Shenhua's direct liquefaction plant in Inner Mongolia to start operation in 2008, producing 1.08 million tons of liquid products (diesel, LPG, and naphtha). Total production of two phases is 5 million tons. Also, developing two indirect liquefaction plants with Sasol. Polygeneration under study by others, including Hunnan International Technopolis Shenyang (HITS) using coal and waste/garbage and Datang Power (4 plants) using coal.
Supercritical	Several dozen units commissioned
Ultra Supercritical	The first ultra super critical (USC) PC unit went on line in November 2006.

Source: Daniels (2008)

Super critical (SC) and sub-critical pulverized coal (PC) units accounted for 25% (China Electricity Council, 2006). Circulating fluidized bed (CFB) accounted for 17% of the total installed capacity. (Zhao et al. 2008) About 40% of Chinese coal is burned in half a million "industrial boilers" in industry and in district heating systems. Conversely, over 95 % of industrial boilers in China burn coal. The two most important sources of demand for industrial boilers are on the one hand light industry and the textile industry, which require process heat and power; and on the other hand space heating for individual apartment buildings, district residential areas and commercial buildings, particularly in northern Chinese cities. The dominant installed technology is pulverized coal combustion (burning powdered coal) with a subcritical steam cycle. Units range widely in sizes from less than 25 to 660 MW. There are still a large number of these subcritical units under construction. (Philibert and Podkanski, 2005)

Incremental improvements to the performance of existing power stations, industrial boilers and other facilities are perhaps the most important cleaner coal technologies for the short term. Such improvements can lead to a significant reduction in emissions from coal-fired facilities. For example, Chinese fossil-fuel electric power plants have historically had thermal efficiencies that are significantly lower than typical figures for plants in more industrialized countries. The Chinese average is affected by the large number of small power plants in use. In 2005, only 333 of China's 6911 coal-fired units had capacities of at least 300MW. Many of the remainder have capacities of less than 100MW. (Watson et al. 2007) Note that in the run up to the 2008 Olympics in China, many small scale plants have been closed. In addition, China currently imports state-of-the-art control technology for NOx and SO_2 control. (Daniels, 2008) Outside the electric power industry, much larger 'efficiency gaps' have been identified in Chinese industrial facilities. During the late 1990s, it was observed that the average industrial boiler in China was operating at an efficiency of 65% whilst boilers in OECD countries have efficiencies of over 80%. (Watson et al. 2007)

From 2001 to 2003, the proportion of global orders of new coal-fired power plants placed in China has been higher than 80%. China expects its power generation to at least triple in the next twenty years. Currently in China, the power sector chooses USC PC and SC PC for new capacity additions coupled with pollution control technologies, and 300MW circulating fluidized beds (CFB) as a supplement. According to the national industry policy, 600MW SC and 1000MW USC units will become the standard in the coming years. (Zhao et al. 2008) The IEA (2004a) projects a total capacity of 1187 GW in 2030 against 360 GW in 2002. Coal-fired plants would total 776 GW – a decrease due to rapid growth of gas-fired generation and renewables. Ten supercritical units were in operation in 2003 and twenty more units were approved for construction. There will likely be a surge towards 1000 MW power plants with ultra-supercritical steam conditions. (Philibert and Podkanski, 2005) The National Development and Reform Commission (NRDC) has recommended advanced supercritical plants for large scale power generation and most recent orders have been for supercritical units. IEA experts indicate that supercritical plants totaling more than 60 GW of capacity were recently ordered. (Philibert and Podkanski, 2005) Since the 1960s, Chinese engineers have developed their own designs of small fluidized bed combustion equipment independently of early efforts in other countries (Watson and Oldham, 1999). Over 1000 commercial CFB boilers have been put into operation since 1989 and fifteen 300 MWe CFB boilers are in the planning or construction stage (date 2004). (Philibert and Podkanski, 2005) More than 30 GW of co-generation plants are currently in operation, notably in the coldest parts of China. There is considerable knowledge of coal gasification in the chemical industry for production of fertilizer chemicals. This explains why poly-generation has been suggested as a more realistic alternative for China. (Philibert and Podkanski, 2005) Based on coal gasification ("syngas"), poly-generation systems can produce a variety of energy products: clean synthesis gas and electricity, high-value-added chemicals, high-value-added fuels for vehicles, residential and industrial uses, and other possible energy products. Gasification enables conversion of coal, including high-sulphur coal resources, with very low levels of air pollution compared to most existing coal combustion technologies in China. The 2003 CCICED recommendation to the Chinese Government underlines the importance of coal modernization with poly-generation through gasification. From an assessment of the key clean coal technologies by the Energy Working Group of the European Chamber of Commerce In Beijing, it becomes clear that China has "successfully mastered the Super Critical (SC) and Ultra Super Critical (U-SC) technologies for power generation. At the same time, China has been developing technologies for coal liquefaction and coal conversion into methanol and its derivatives (such as coal to olefins). There are a large number of projects that are under construction today in China. A combination of power, liquid and chemical production from coal, under the term of poly-generation, is being encouraged by the government. (Energy working group, 2008)

Entry time – clean coal technology status in China

The China Development Forum gives an overview of the Chinese clean coal technologies based on their status of development.

Table 4.6: Status of main clean coal technologies in China (Table adopted from China Development Forum)

Status in commercial operation	**Status** **under development**	**Status** **mainly imported from abroad and have entered into commercial demonstration**	**Status** **being improved and perfected**
coal washing Blending coal-water mixture (CWM) circulating fluidized beds (CFB)	supercritical units, flue gas desulfurization (FGD) large coal gasification technologies with intellectual property rights	Coal bed methane (CBM) development integrated gasification combined cycle (IGCC) and coal liquefaction (CTL)	Briquette retrofitting of small-medium industrial boilers comprehensive use of coal refuse and fly ash reuse of mine water

Thermal efficiency, and emission of the most environmental harmful waste substances of CO_2-, NOx and CO:

Table 4.7 Power generation Technology Comparison

Parameter	IGCC	Conventional	Supercritical	Ultra-Super Critical
Thermal Efficiency	48%	38%	41%	45%
CO_2 (g/kWh generated)	676	854	790	721
NOx (g/kWh generated)	0.07	2.08	1.93	1.76
CO (g/kWh generated)	0.01	0.13	0.12	0.11

Pricing

When decision-makers are faced with the need for new electricity capacity, several technology types can be considered. One of the tools used by decision-makers is a levelized cost calculation which incorporates all the expenses associated with a project over its lifetime. Levelized cost comparisons give investors a basis for choosing a technology, mostly based on capital costs and Cost Of Electricity (COE). COE is a function of the costs for capital, fuel, consumables, repair, labor, finance, technology, time frame, and site. More stringent environmental regulations often cause plants to add more equipment (e.g., flue gas desulfurization (FGD) systems), lose potential capacity, and lose efficiency. (Zhao et al. 2008)

Table 4.8: Comparison of power plant technologies

Capturing CO_2 with today's technology significantly reduces plant efficiency: Efficiency to electricity, net (HHV			
	Without CO_2 capture	With CO_2 capture	Percentage difference
AVG IGCC	39.5	32.1	-19%
PC-Sub	36.8	24.9	-32%
PC-Super	39.1	27.2	-30%
Cost of electricity comparison: Cents/kWh ($2007) * Coal cost $1.80/106 Btu			
	Without CO_2 capture	With CO_2 capture	Percentage difference
AVG IGCC	7.79	10.63	+36%
PC-Sub	6.40	11.88	+86%
PC-Super	6.33	11.48	+81%

Source: DOE/NETL Report: Cost and Performance Baseline for Fossil Energy Plants, May 2007

The internalized external costs (based on French prizes) for SO2 and NOx are compared to the high costs for CO_2 capture very low: costs per gram of SO_2: 0.0000274, cost per gram of NOx: 0.0000381. This means that in financial terms, the reduced SO_2 and NOx emissions by choosing for a more clean coal technology have a very small or no influence on the technology choice.

4.8 FUTURE PERSPECTIVE ON CLEAN COAL TECHNOLOGY IN CHINA

In the table below, the future developments of clean coal in China are summarized. The situation whereby a technology is potentially interesting is based on various (macro environmental) factors, and technology factors on a micro level, including technological superiority, installed base, pricing and governmental regulations. This list of potentially interesting technologies is based on extensive research of secondary data and expert consultation.

Table 4.9 The future clean coal technologies in China

Short term (one year or less)	**Medium term (2-10 years)**	**Long term (10 or more years)**
• Coal washing • Various efficiency improvements • Small circulating fluidized bed boilers • Flue Gas Desulphurization (FGD) • Coal gasification	• Larger scale fluidized bed boilers • Supercritical boilers for coal fired power plants • IGCC • Coal liquefaction	• Carbon Capture and Storage (CCS)

Below the key findings for the three time categories of future clean coal technologies are summarized, and extensive report with in-depth details can be found in the annexes.

Short term (one year or less)

There is an urgent need for coal blending in China, with a view to the optimization of the coal gasification process. Because more advanced technology is used in the plants, coal sources with better specification are needed. According to Shell, their gasification license holders are interested in coal analysis, especially coal quality measurement. There is a specific need for an online solution.

Medium term (2-10 years)
According to Shell, IGCC is expensive when looking at it standalone. When including Certified Emission Reduction credits (CERs) and CDM's it becomes more economic. (see annex for more details) China is not ready for broad application of IGCC, because of the immaturity of IGCC technology. In addition, higher costs for electricity production, China's failure to implement CO_2 emission reduction policies, difficulties in obtaining financing and inability to sell byproducts of IGCC, like sulfur freely on the market, make that short-term application of IGCC is not feasible. A number of clean coal technologies are being promoted by the Chinese government through environmental regulations. These include larger scale fluidized bed boilers, supercritical boilers for coal fired power plants, flue gas desulphurization (FGD) and coal gasification.

Long term (10 or more years)
Coal-water mixture (CWM) is the first choice for oil substitution technology in the near future. However, it is not economically competitive in the long term. Therefore, development in this area should be moderate and focus should lie on other technologies that are economically viable in the long term. Coal liquefaction technologies are suitable to be developed as strategic technologies and for some fuel oil substitution technologies; this is illustrated by the coal liquefaction centre in Shanghai. Fischer-Tropsch coal-to-liquids technology lends itself to low-cost CO_2 capture (~\$10/t CO_2). Using coal to produce methanol and dimethylenther to substitute for fuel oil is under discussion. China is increasingly active in coal liquefaction due to its abundance of coal and its policy to decrease their dependency on oil imports.

4.9 CLEAN COAL TECHNOLOGY IN THE NETHERLANDS

Electricity production in the Netherlands
The total production output of electricity by all electricity plants in the Netherlands in 2006 equals 67 TWh. This was produced by the five electricity companies Nuon, Essent, Delta, Electrabel and E-on Benelux in 2006. Some 30 TWh was produced by others, mainly industry. Accounting for net electricity consumption by electricity plants and industry, in total around 94 TWh of net electricity was produced. In the case of the Dutch coal fired plants the so-called Coal Covenant requires them to emit less CO_2. The table below shows that the Netherlands is very dependent on gas and oil, while coal, in 2010 only accounts for around 10 percent of total primary energy supply. Even with a rising share in the years to come, the situation in the Netherlands is in sharp contrast with the Chinese situation, were coal accounts for more than 60 percent of total primary energy supply.

Table 4.10: Total primary energy supply (TPES) in The Netherlands and its breakdown by fuel type (all values Mtoe; IEA 2006)

	1973		**1990**		**2003**		**2010**		**2020**		**2030**	
TPES	62.4	%	66.7	%	80.9	%	81.7	%	91.9	%	105	%
Coal	**2.9**	**4.6%**	**8.9**	**13.4%**	**8.8**	**10.9%**	**9.3**	**10.6%**	**11.4**	**12.45%**	**19.0**	**18.1%**
Oil	30.9	49.5%	24.3	36.5%	31.5	39.0%	30.3	38.9%	36.4	39.6%	40.6	38.6%
Gas	28.5	45.6%	30.8	46.2%	36.0	44.5%	36.6	55.7%	36.8	40.1%	42.1	40.1%
Nuclear	0.0		0.9	1.4%	1.0	1.3%	1.0	1.2%	1.0	1.1%	0.5	0.4%
Ren.&Waste	-		0.9	1.4%	1.9	2.4%	2.2	3.3%	3.8	4.1%	1.9	1.8%
Other	-		0.0		0.1	0.2%	0.2	0.2%	2.2	2.4%	1.1	1.0%

Dutch Government general energy policy
Dutch long-term energy policy is focused on sustainable, competitive (in terms of pricing, i.e. affordable, market driven) and secure energy. To realize this, the Dutch government has chosen a transition approach, taking into account that changes are not only necessary but also that they create opportunities for innovation and economic growth. (Energy transition, 2008)

Inland emission of CO_2
Dutch policy on sustainable development seeks to ensure that future generations will have at least as much opportunity as the current generation to make progress and develop, while reducing CO_2 emissions at the same time. This is translated into the objective for Dutch sustainability policy: an absolute decoupling of polluting emissions from economic growth. Dutch policy for achieving sustainable industrial development, energy and air quality relies heavily on a further 'greening' of the tax system, energy saving, sustainable energy and emissions trading for CO_2 and NOx. (CE Delft, 2008) In 2005 the levels of CO_2-emissions in The Netherlands were estimated to be around 180 Mt/year. The total level of all greenhouse emissions (including i.e. CH4, N2O and Fluor containing gases) is around 220 Mt CO_2-equivalent/year. The CO2-emissions have increased 10% from 1990 until 2005 and is still increasing with less than a percentage per year. Considering the objective defined by the new Dutch government to achieve a 30% reduction in greenhouse gas emissions in 2020 (in comparison with 1990), Carbon Capture and Storage (CCS) is steadily emerging as a necessary third option for the Netherlands, alongside energy savings and renewable energy. (Country profile, 2007)

The Netherlands are active in several clean coal technologies, A list is drawn in consultation with VROM, the Dutch ministry of housing, spatial planning and the environment. The Netherlands is active in Carbon Capture and Storage (CSS), Enhanced coal bed methane (ECBM), coal blending, Flue Gas Desulphurization (FGD), NOx-reduction services, Coal gasification and Integrated Gasification Combined Cycle (IGCC). A short description:

Coal washing: In the early nineteen sixties, sales of coal washers started to shrink because the coal mines started to become less and less economic to run. Dutch organizations like Stamicarbon (DSM) shifted its sales markets to Eastern Europe, America and India. Stamicarbon terminated all activities regarding handling of coal.

Various efficiency improvements

Coal Blending: Coal blending is also part of the value chain of coal gasification. In China, plant licensees handle coal blending themselves. A Dutch company that is active on the market of coal blending is KEMA. KEMA provides coal blending know-how to a facility near Shanghai. KEMA determines wich blend of the coals, available from sources in China, Indonesia and elsewhere is best for the individual power plants to be supplied with the object to reduce the sulfur content without compromising the positive combustion properties. (Zurkiewics, 2008) Another Dutch company active in the field of coal blending is EMO. EMO is currently performing research on coal blending and focuses on Shell's IGCC technology. During a meeting with Shell's Eur. Ing Henry K.H. Wang and Mrs. Gu Jing it became clear that there is a urgent need for coal blending in China, with a view to the optimization of the coal gasification process. There is still a large scope for improvement in this field.

NOx-reduction services: Through more than 30 years of working directly with NOx-reduction technologies, KEMA has gained extensive experience with this field as well as a profound insight into both short-term and long-term operational solutions and applications.

Flue Gas Desulphurization (FGD) : Dutch KEMA has a long history in flue gas cleaning and particularly in wet flue gas desulphurization (FGD). This is the result of KEMA's position as the main engineer and R&D consultant of the Dutch Power Generating Companies, as well as the fact that flue gas desulphurization was introduced relatively early in the Netherlands. The first FGD unit at a coal-fired power plant was commissioned in 1985. Based on these experiences, KEMA has developed its services to all kinds of thermal processes for the conversion of fossil fuels, waste and biomass. (Kema, 2008) Since FGD is used for removing sulfur oxide, combined with NOx reduction, this technology is very suitable for China for their combat against acid rain.

Coal gasification: Shell has been developing and using coal gasification technology for over 30 years. Their own gasification technology is called Shell Coal Gasification Process (SCGP). Shell had 85+ gasifiers in operation world-wide. (Shell, 2007) Shell has sold 16 licenses in China for coal gasification and 10 projects are already up and running. The first of which was built by a

50:50 joint venture between Shell and Chinese State oil company Sinopec. (Watson et al., 2007) It entered full operation in 2006. Specific advantages of the Shell coal gasification process is that is 'clean'. None of the constituents in the coal are wasted. The sulphur is recovered as pure sulphur and sold as a feedstock to the chemical industry, and the ash is recovered as clean slag which is used to make ceramic tiles and bricks. Shell's gasification technology has the lowest CO_2 emissions per ton of coal feed, compared to its competitors. The process consumes only a small amount of water, and the waste water can easily be cleaned. This is especially interesting for China because of its water resource problems, especially in its coal producing regions. Another advantage of the Shell coal gasification process is its flexibility, it can operate on a wide range of coal qualities, such as low quality sub-bituminous coal and lignite. (Shell, 2008)

Shell and Sinopec formed a 50:50 joint venture in 2001 to construct and operate the 2,000 ton/day coal gasification plant at Dongting fertiliser plant, Yueyang, Hunan Province. The gas will be used as the feedstock for the fertilizer plant. (Sun, 2008) Shell is the first multinational company with a service center on clean coal technologies. The local service team contains of 28 engineers (90% Chinese) and delivers efficient and timely support. (Shell, 2007)

Dutch IGCC activities potentially suitable for China regarding IGCC

Worldwide, there are five coal-based IGCC demonstration plants (3 in the US, 1 in the Netherlands, and 1 in Spain). The Willem Alexander 250 MW IGCC plant in Buggenum, The Netherlands is operated by Nuon and based on Shell's gasifier technology. (Audus, 2006) The plant in Buggenum already uses 30% of biomass. According to Nuon, this is still unique in the world. During a meeting with Shell for this research, the usage of biomass was explicitly emphasized as a very interesting opportunity for China. Nuon's plans for a new 1200 MW IGCC energy plant were recently brought to a halt because of rising building costs.

Figure 4.6 The IGGC plant in The Netherlands

Carbon Capture and Storage (CCS)

There is a lot of interest in CCS projects based in China. But the Chinese government has not finished creating a regulatory framework for these type of projects yet. This is why market parties are waiting for governmental action on a company level.

The main Dutch activity on R&D regarding ZEP (Zero Emission Fossil Fuel Power Plants) takes place inside the so-called CATO-project. CATO represents a extensive knowledge network in the field of CO_2 Capture and Storage in the Netherlands, assessing and developing new knowledge, technologies and approaches in this field. The aim of CATO is to identify whether and how CCS can contribute to a sustainable energy system in the Netherlands, from an economical, technical, social and ecological point of view and under which conditions this option could be implemented in the energy system. The CATO program is implemented by a strong consortium of Dutch companies, research institutions, universities and environmental organizations, led by the Utrecht Centre for Energy Research (UCE). Given its size of EUR 25.4 million, the CATO program can be regarded as the national research program on CCS in the Netherlands. CATO runs from 2004 to the end of 2008. The successor of CATO will be CATO2, this time led by TNO. TNO has one of the biggest research groups on CCS in Europe. CATO2 will be more market focused and special attention will go to CCS in developing countries, specifically China.

Furthermore Dutch R&D institutes are participating in dedicated Dutch-driven projects such as CAPTECH, but are also participating in EU-projects like Castor/Encap, Recopol, CO2MOVE,

CO2STORE.
In 2007, four large (over 0.5 Mt injected per year) anthropogenic CO_2 projects were in operation around the world. Two of them were in Europe: Sleipner and Snohvit (Norway), Weyburn (Canada-US) and In Salah (Algeria) .(International Energy Agency, 2008) A major project in the Netherlands for the storage of CO_2 is K12b which strips CO_2 from natural gas. CO_2 is injected in a gas field 80 kilometers from the coast of Den Helder. Since 2004, 00.1 Mt per year is stored. Through a European published call for bids, the Dutch government intends to start projects on CO_2 storage in the Netherlands. Proposed projects have a semi-commercial to commercial size and should also incorporate learning by doing regarding technical and non-technical items. The outcome of the projects should have a stimulating effect to follow-on projects. The goal is to have two projects started before 2010 with in total 4Mt of CO_2 stored in geological storage inside a time frame of 10 years. The available budget is EUR 60 million; SenterNovem is the operator of the scheme.
CCS in perspective: The cost of CCS is project specific, depending on the technology of the plant producing the CO_2 and on the adequate storage resources. Overall, the high costs and technical uncertainties of CCS technologies (because of technological immaturity), means that it is unlikely to be considered for new power plants by China's National Development and Reform Commission (NDRC) which is not an active supporter of the CCS technology. However, developed countries such as the UK are hoping to persuade China to build 'capture ready' plants that can have CCS technology added to them relatively easily in the future. (Watson et al. 2007) CO_2 capture technology itself is energy-intensive and requires a substantial share of the electricity generated. Accounting for the corresponding power plant efficiency reduction (up to 30%) by expressing costs in dollars per ton of CO_2 avoided, the costs of CCS in power plants range from \$25 to \$70 per ton of CO_2 avoided. Currently, these cost estimates are dominated by the cost of capture (including compression). If transport distances are less than a few hundred miles, the cost of capture constitutes about 80% of the total costs. (van der Zwaan and Stevens, 2005) Unlike the other power generation technologies, which will become competitive as additional cumulative capacity is added, CCS will always require a carbon price of at least USD 50/t CO_2 to make it cost-efficient. (International energy agency, 2008) Finland enacted a carbon tax in 1990, the first country to do so. The current tax is €18.05 per ton of CO_2 (€66.2 per ton of carbon) or \$24.39 per ton of CO2 (\$89.39 per ton of carbon) in U.S. dollars (using the August 17, 2007 exchange rate of USD 1.00= Euro 0.7405). Sweden enacted a tax on carbon emissions in 1991. Currently, the tax is \$150 per ton of carbon, but no tax is applied to fuels used for electricity generation, and industries are required to pay only 50% of the tax. (Carbon tax center, 2008) CCS is currently awaiting approval as a project activity under the CDM, which is an issue of considerable controversy and diverging political views in the climate negotiations. (Metz and Coninck, 2005)

4.10 COMPETITIVE ACTIVITIES

A potential threat to Dutch activities on the clean coal market are the activities of competitors. Competitors from other countries like the US, Germany and the UK are also working hard on getting foothold in the Chinese clean coal technology market. Some of these competitors already have years of co-research experience and are very keen on placing their domestic clean coal technologies into the Chinese market.(China coal information institute, 2008) Below the clean coal activities in China of several countries will be described, as well as international research programs. It is not the goal of this report to give a complete overview of all the countries and their activities on the clean coal technology market. This overview is meant as an indication of recent activities:
Germany: Germany is developing technological cooperation activities in the coal-fired power sector of China. Germany have set up the Sino-German Technical Cooperation Program EPEI. EPEI stands for Environmental Protection in the Energy Industry. From the German side, the organizer is Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, a non-profit organization that is active in the Chinese Coal- and Power Sector since almost 20 Years. The

focus areas of the technological cooperation activities in China are:
Boiler (Combustion Process) and Auxilliaries, Fluegas Desulphurisation (FGD), DeNOx-Plant and Turbine Sets (though rarely). Provided funds: up to 6 Million EUR from the German Government and up to 90 Million RMB (approx. 9 Million EUR) from the Chinese Government. The period of Implementation is between September 2005 – September 2009. (Moczadlo, 2008)

Canada: Coal remains a key component of Canada's diverse energy supply picture, accounting for as much as 20% of electricity generation. Six of Canada's provinces rely to some degree on coal to supply electrical power, with three (Nova Scotia, Saskatchewan and Alberta) almost fully reliant. It is estimated that Canada has sufficient coal resources for more than 1000 years at current rates of utilization. Given that over the next 25 years Canada will need to replace 18,000 MW of existing coal-fired generation as well as expand its overall generation capacity by roughly 40,000 MW, there is the potential for a strong role for coal in future energy supply. Compared to existing coal power plants, new CCT plants will soon be targeting near-zero emissions as a performance standard, and Canadian researchers, electric utilities and industry are at the forefront of making this happen. Canada is internationally involved in forums, (research)projects, universities, and institutes like the International Energy Agency (IEA). A report from Natural Resources Canada called 'Clean Coal: A compendium of Canada's Participation', describes 31 Canadian companies active in CCT, 5 universities and a long list of involvement international projects, including several projects with China.(National resources Canada, 2008) This makes Canada one of the biggest on the Chinese and worldwide CCT market.

U.S.: The U.S. is a very large and very active player on the Chinese market for clean coal technologies. In a joint workshop (2004) between the United States and China, recommendations were made for CCT development in 2020. Both the Chinese and U.S. governments are funding research in advanced clean-coal technologies such as Integrated Gasification Combined Cycle (IGCC) and poly-generation technologies (co-production of electricity, hydrogen, and chemicals). (Ministry of Science and technology, 2004) General Electric (GE) competes on the Chinese market next to Shell, through their own gasification technology. The GE technology is based on a slurry method (water) and can only use coal with a low ash content. Because China has scarce water resources and the Chinese coal is high on ash content, this technology has disadvantages. Also, the installed GE technology must be replaced several times in a lifetime, while the gasification technology of, for example Shell, lasts during the lifetime of the plant.

United Kingdom: The British government runs a number of specific environmental programs and knowledge transfer projects with China, including projects with the China Coal Information Institute. The British Trade and Investment Ministry co-operates with the China Coal Information institute (CCII) to investigate the emerging demand for clean coal in China. The next step is to investigate how China can make use of British technologies. The results of this study will be public this year and deserve attention as 'technology transfer' is a difficult issue between China and the EU. The British Department of Trade and Investment has been active in assessing and assisting with Coal Bed Methane (CBM) projects through periodical joint Sino-UK project Meetings on CBM. (Bekker et al. 2007)

Norway: Non-EU member Norway already has one CCS plant up and running and is constructing a further two, also both in Norway. The Norwegian Minister of Petroleum and Energy Åslaug Haga and EU Energy Commissioner Andris Piebalgs agreed on 29 May 2008 that Norway's three CCS projects could be defined as part of the 12 projects the EU intends to develop in order to prove the viability of this technology. The announcement was made as part of the energy dialogue between the EU and Norway, which is rich in fossil fuel reserves and is the second largest supplier of oil and gas to the EU. (Eur Activ, 2008)

4.11 FACTORS OF COMPETITIVE ADVANTAGES OF THE NETHERLANDS

Coal blending experience

In the Netherlands only internationally traded coals are utilized for power generation. This means that for more than thirty years different coals from all over the world have been utilized in the Netherlands. The wide ranges of coal quality could only be fired due to blending facilities available for all the power plants in the Netherlands. In close co-operation with the power plants, KEMA has since 1988 performed a large number of studies and experiments to optimize coal blending in relation to power plant operation. Most of these studies have been performed in full scale practice using all seven coal-fired boiler installations in the Netherlands. (Kema, 2008)

Gas handling experience

The Netherlands ranks fairly high with respect to technological knowledge of gasification and separation technology, partly as a result of its very strong focus on natural gas and traditional participation in research programs focusing on these subjects.(Country Profile, 2007) Because its history of gas exploitation, the Netherlands have strong technological, economic and legal knowledge of gas transport and trade, including underground gas storage and monitoring. For geological reasons the Netherlands possesses a relatively large arsenal of potential storage locations in exhausted gas and oil fields. The country is also strategically located for future storage of CO_2 flows, also from industrial centers in neighboring countries, to the considerable storage capacity in various North Sea locations.

Interest in coal gasification is growing in China, because it addresses the increasing need for secure, clean and economical sources of energy. With the help of coal gasification technology, coal is converted into synthetic gas or syngas. Syngas has a direct market value because it can be used to produce a wide range of high-value products such as electricity, fertilizers, transport fuels and chemicals. The applications of syngas as a raw material for producing chemicals are for example ammonia, methanol, acetic and urea fertilizer or can be converted into an ultra-clean transport fuel, known as coal-to-liquids (CTL) fuel. As one of the basic coal conversion technologies, coal gasification is widely used in China, but most installations use outdated designs. In general, these coal gasifiers are small and inefficient and used for industrial processes such as fertilizer and chemical production. For the long term, coal gasification technologies provide not only the feedstock gas of chemical production but also gas sources for multi-product technologies and hydrogen production for fuel cells, so the development should be accelerated.

Reputation and former co-operation with China

In China, The Netherlands has a good reputation in the field of energy efficiency. This is mostly because of its historical background of urbanization, high economic growth and an intensive industrial and agricultural production. China and The Netherlands have experience with multi-year agreements between the government and industry, for instance the Sino-Dutch Sustainable Building Project Management Office: a collaboration between the Chinese Ministry of Construction, Chongqing University and VROM. (Netwerk van het koninkrijk der Nederlanden, 2007)

Time and resources have been invested in a multi-annual, structural and knowledge driven co-operation in areas where the Netherlands have a competitive advantage with respect to other countries. This concerns energy-efficient technology (for industry, mobility, and build environment), and durable energy sources (wind- and solar energy, biomass). Moreover chances may arise for the Netherlands in the gas industry and in the field of energy generation. (Sun, 2008)

Focus on carbon storage

The Netherlands wants to be frontrunner when it comes to the storage of CO_2. This is what Minister Van der Hoeven (Ministry of Economic Affairs) mentioned during a meeting with the ministers of oil producing and consuming countries in Rome on the 18th of March this year (2008). Minister Van der Hoeven and her colleague Minister Cramer (Ministry of Housing, Spatial Planning and the Environment) envision that in 2015, the technology is ready for a large-scale demonstration project. (nu.nl, 2008) In the meantime, Rotterdam is considering importing CO_2 from Antwerp and the German Ruhr-area. The plan is to store it in empty gas fields in the North sea. (Nu.nl, 2008) In March 2008, the 'taskforce Carbon Capture and Storage' officially started. In the taskforce Dutch businesses (i.e. Shell, Gasunie and EnergieNed), environmental organizations and government are working together to create the conditions for large scale and commercial application of CCS by 2020. (Senternovem, 2008) The Dutch government supports its devotion to the carbon storage with subsidizing the industry: at the moment five test projects on CO_2-storage are running in the Netherlands, subsidized with 55 million euro.

While all the elements of CCS have been separately proven and deployed in various fields of commercial activities, a key aim is the successful demonstration of fully integrated large-scale CCS systems and optimization of the various processes. Such large-scale demonstrations would help to lower costs and provide a critical mass of scientific data for proving that operations, monitoring, verification, and mitigation can be carried out in a manner acceptable to regulators and the public. Supporting policy and regulatory environments also have to be developed for these Research, Demonstration & Development (RD&D) activities. (World coal institute, 2007) By 2030, China is anticipated to have significant CCS capacity, and by 2050, China will account for the largest global CCS (under the ACT MAP scenario as described by the IEA). (International energy agency, 2008)
The best geologic options in China, based on current understanding, are enhanced coal bed methane recovery (ECBM), enhanced oil recovery (EOR), depleted oil and gas fields, unmineable coal seams, and saline reservoirs. The largest capacity worldwide is in saline reservoirs. (Zhao, 2007) Interesting academic research work one CO_2 storage is done by Prof. Celia and his research group on subsurface hydrology, from Princeton University. From coal beds, methane gas (also known as 'mine gas') can be harvested, so-called Coal Bed Methane (CBM) production. This is done by drilling a well, lowering pressure in the coal layer and pumping up the methane. Combustion of methane is cleaner, but still large amounts of CO_2 are emitted. When CO_2 is injected into a coal layer, a larger amount of methane can be harvested. This is called Enhanded Coal Bed Methane (ECBM). As the CO_2 is absorbed by the coal, this also leads to effective underground storage of CO_2.
China's coal bed methane (CBM) potential is estimated to be one of the world's largest—between 16,000 and 35,000GNm3 (Zhang and Zhang, 1996). However, the CO_2-ECBM potential is uncertain. Stevens and Kuuskraa (1998) identified the Ordos Basin and the Northeast China Coal Region as regions with the greatest CO_2-ECBM potential. Relatively low-cost CO_2 storage demonstration projects could be carried out at a number of sites in China where low-cost concentrated CO_2 is available.

Dutch Cluster approach

The Dutch Embassy in Beijing has noticed that the Dutch players were very fragmented and there was no comprehensive approach. Also there is a vigorous competition from other countries on the Chinese market. The idea behind a more clustered approach is that by connecting government policy, research, and the market, a more sustained co-operation with China is possible. With a joint approach, complementarities in skills and competences can be achieved. Involved parties are government, universities, knowledge institutions and businesses. The areas of interest of the cluster approach are based on the Dutch Innovation Platform and its key areas flowers & food, high-tech systems and materials, water, the chemicals industry, the creative industry and pensions and social insurance. ICT and energy play an important role as innovation axis in all areas of the economy.
For the activities of the Dutch Embassy in Beijing regarding energy, this effort has been branded the 'Energy Transition Approach'. This approach is based on science, government and business. (Netwerk van het koninkrijk der Nederlanden, 2007) Through the connection of expertise with China, a win-win situation is created. In this way, the Netherlands can help in finding solutions for Chinese issues. The Dutch cluster approach and specific the Energy Transition approach are a required condition in able to get a strong position on the Chinese market.

European approach

As an EU-member state, an integrated EU cluster approach could be a future option for Dutch companies and scientific institutions. In some cases a European approach would allow for a more comprehensive solution to potential clients and improve the overall bargaining position. Besides a more complete offer, synergies could be achieved on R&D spending. Exchanging, processing and synthesizing abundant information on a European scale, may play an even more important role by accelerating diffusion of knowledge and understanding of technologies and their implications.

During a speech at the recent Forum on Climate Change and Science & Technology Innovation in Beijing, the European Science Commissioner Janez Potocnik, highlighted areas where future collaboration has been agreed upon. They include the development and demonstration of advanced zero emissions coal technology by 2020, based on carbon capture and storage and the setting up of a Sino-European clean energy centre, focusing on coal and energy savings in buildings. A speech of Mr. Barosso went deeper into this subject. Mr. Barosso remarked at the joint press conference with Premier Wen Jiabao, in Beijing, on 25th of April 2008 (European Union, 2008), were that the EU has signed a letter of intent for the ICARE project, an EU-China Institute for Clean and Renewable Energy, aiming at training Chinese experts on clean and renewable energy and at developing common technology and research.

About the Sino-European clean energy centre, Mr. Barosso said: “We have carried out constructive and substantive discussions on energy. We agreed to sign, at the next EU-China Summit, a Financing Agreement to set up a "Euro-China Clean Energy Centre" (EC2) in Beijing. And our co-operation on carbon capture and storage should continue and deliver concrete results. With this last line, Mr. Barosso most probably referred to the NZEC partnership, the UK-China Near Zero Emissions Coal project. This flagship project under the Partnership is an agreement to develop a NZEC demonstration plant with carbon capture and storage in China by 2020. The partnership was originally initiated at the 2005 EU-China Summit, where both sides confirmed their commitment to the objectives of the UN Framework Convention on Climate Change and the Kyoto protocol, which aims to strengthen co-operation and dialogue on climate change including clean energy, and to promote sustainable development. In this partnership, clean coal is a key area for technical co-operation. (European Commission, 2008)

The Dutch focus to become a key-player in CCS can be of great future importance and fits perfectly into the European framework, especially in the European strategy for China. This is particularly true for the goal of the European Union of introducing 10-12 comprehensive and varied CCS demo’s. Considering its position, this European objective could also lead to action in The Netherlands. (Lysen, 2007)

4.12 DUTCH CANDIDATE TECHNOLOGIES FOR TRANSFER TO CHINA

Considering its historic and future experience is gas handling and gasification, the highest competitive advantage of the Netherlands, lies in the field of this technologies. By further developing knowledge and technology in the Netherlands regarding IGCC, CCS, ECBM, and other efficiency-based clean coal technologies, possibilities can be expanded to support upcoming coal based economies, like China, with the cleaning of their energy system.

IGCC: According to the China Coal Information Institute (2008), a bottleneck in the development of IGCC in China is the lack of coal gasification technology in China. (China coal information institute, 2008) CCII also states that IGCC is not yet a fully mature technology, even in developed countries, where it delivers electricity at a higher cost of about 20%. (China coal information institute, 2008) The goal of China is to have installed capacity of IGCC to reach 20,000MWe in 2020. (Zhao, 2007) Various factors (law, environmental regulations, efficiency, maturity etc.) that prevent a wide application of IGCC in China are not going to disappear in a few years. While China is already building demonstration plants, IGCC might become interesting in the decennia to come. Since IGCC features the lowest CO_2 capture costs, this technology will become truly interesting when China decides to charge a fee for CO_2 emissions. Yet this scenario is still far away and while this technology is technological superior, without CO_2 capture it is far more expensive than other technologies.

CCS and ECBM: When China does not set emission targets for CO_2 reduction, CCS standalone, is not very advantageous for China. Dutch activities should therefore focus on Enhanced Coal Bed

Methane (ECBM) in China. This technology improves the gas winning by injecting CO_2 into coal beds and pushing the methane gas out. Besides an efficiency improvement of up to 50%, application of ECBM also lowers the pressure on China's scare gas supplies, lowers mining accidents, and lowers environmental pressure of CO2 and methane emissions. Currently the biggest challenge for ECBM is the swelling of the coal when CO_2 is injected what blocks the way out for the methane gas and hinders the injection of CO_2.

4.13 TECHNOLOGY TRANSFER

The gap between China's clean coal technology and foreign advanced technology

From Table 4.11, it becomes clear that the energy intensity (energy consumption per unit GDP), energy consumption per capita and CO_2 emission per capita differ substantially across countries. This indicates that there are differences in energy efficiency and in the use of the same technology among countries. Natural resource endowments, levels of economic development, cultural and social factors contribute to differences in energy consumption. However, the difference in energy efficiency among countries is obviously the important interpretation factor. Take Brazil and Germany for example. In Brazil where carbon free hydropower is rich, CO_2 emission intensity is about 0.49 kg CO_2/US$, similar to that in Germany, about 0.45 kg CO_2/US$; while in terms of energy intensity, 0.31 toe/US$ in Brazil is much higher than 0.18 toe/US$ in Germany.

Table 4.11 Indicators for selected countries in 2003

	TPES**(t/capita)	CO_2/(t /capita)	TPES/GDP (t/thousand US$ 2000)	CO_2/GDP (Kg CO2/ US$2000)
China*	1.10	2.90	0.92	2.43
India	0.52	0.99	1.02	1.93
Brazil	1.09	1.71	0.31	0.49
Africa	0.66	0.90	0.87	1.19
UK	3.91	9.10	0.15	0.35
US	7.84	19.68	0.22	0.55
Germany	4.21	10.35	0.18	0.45
Japan	4.05	9.41	0.11	0.25

** Total Primary Energy Supply
(IEA, 2005). Note: China*—People's Republic of China and Hong Kong China. Source: IEA, 2005

Obviously, the wider the gap between countries on energy technology cost, the larger potential there is to introduce and enforce energy technology. Normally, developed countries enjoy the overwhelming advantage of technology, physical and institutional infrastructures over developing countries. Therefore, the direction flow of technologies would be largely channeled from developed to developing countries. In conclusion, the differences of technologies and their costs among countries provide the foundation for international co-operation on development and diffusion of the affordable technologies for energy efficiency and conservation. (Research center for sustainable development, 2007)

Reasons for the technology gap

The main reason why China is behind, is because of the urgency China has placed on their historic economic transition. China was far behind in development and needed energy fast to boost development and get in pace with the West. Energy efficiency had no priority in this picture. Also local governments had a lot of freedom to deal with their local energy needs. (Bekker, 2008) This resulted in relatively late environmental legislation, and insufficient investment in clean coal technology research. (Jin and Liu, 1999) Despite progress, the implementation of the technologies in China, as described above, still lags behind the situation in OECD countries. Therefore, technology transfer will be important in accelerating their deployment in China in the medium term. (Watson, 2007)

Barriers and threats for technology transfer

International carbon co-operation will contribute significantly to resource saving and production efficiency in the long run through expediting the efficiency promotion of energy and related sectors. However, in the near term there are still some problems in relation to international carbon cooperation with China, which constrain the realization of its full potential. According to Watson (1999), these include:

- Lack of financing;
- High transaction costs with respect to procedures and formalities;
- Tendency to be small in scale in terms of carbon reductions;
- Limited impacts on enhancement of domestic innovation capacity.

The location factors that can hinder technology transfer, namely language barrier, distance, time zone barrier and ease of communication are implicitly analyzed during the interviews and form an important barrier for technology transfer. One respondent answered that there was no interest for China because it is 'too far', regardless of market opportunities.

In contrast with direct import of technologies, patent acquisition allows effective technology transfer but it is a risky strategy. Since the system of intellectual property right protection in China is still in the process of complying with WTO-standards, violations of intellectual property rights often take place in China. Because the enterprise's intellectual property rights cannot be effectively protected, the risk that technology will get stolen is very high. (Watson, 1999) Arguably, however, when technology is been sold it belongs to the acquirer, not to the sellers. What western companies fear most, may be the risk of facing more intense competition on their own domestic markets from developing country exporters when they are not any weaker on technology. This is why they are often reluctant to sell the most advanced technologies. But an important problem with weak protection of IPR may be for developing country acquirers themselves, as is suggested in China's case study by Philibert and Podkanski (2005). Host-enterprises might be reluctant to acquire the technology that their own competitors on their own markets could copy while not having to pay. (Philibert and Podkanski, 2005) Relatively weak protection of intellectual property rights, may be the most important reason for organizations, not to choose for technology transfer to China. Foreign companies are often unwilling to provide free technologies and there may be concerns that future revenues are not protected by intellectual property rights in China. However, small-scale projects often do not require sophisticated technologies. Therefore, the impact of the international co-operation on technology transfer is not as profound as is sometimes highlighted. (Watson, 1999) Philibert and Podkanski (2005) add several factors limiting clean coal technology transfers to China, from weaknesses of the domestic industry to low energy prices and emission charges.

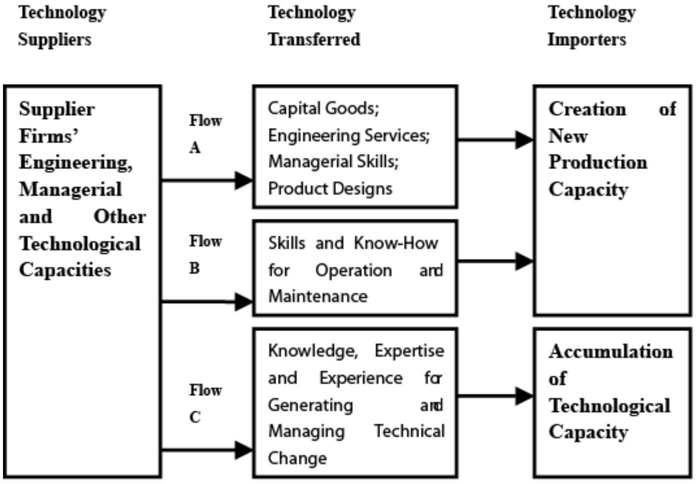
Leapfrogging

One of the most attractive notions in the field of sustainable energy development is the concept of energy-technology 'leapfrogging'. Leapfrogging through international technology transfer can be very problematic because developing countries, like China, often do not have the technological capabilities to produce or integrate the advanced energy technologies themselves. Until they have acquired the capabilities to produce the advanced technologies themselves, most late-industrializing countries buy their new technologies from industrialized countries, usually through licensing or joint-venture arrangements. (Gallagher, 2006)

4.14 CLASSIFICATION OF CLEAN COAL TECHNOLOGY TRANSFER TO CHINA

Figure 4.7 provides a general classification of international technology transfer. It shows that internationally transferred technologies differ widely in their form and function. The question that rises is what kind of technology China can obtain through the international carbon cooperation. (Watson, 1999)

Figure 4.7 the Technological Content of International Technology Transfer



Source: Watson, 1999

The types of technology that China can acquire through cooperation are closely linked to the motives of the international project partner. Usually, foreign CDM investors purchase mitigation equipment from the manufacturers in industrialized countries; then cooperate with a partner in a host country and jointly invest in a mutually agreed-upon and approved CDM project. Obviously, in these kinds of projects China only obtains mitigation equipments or capital goods: flow A technology in Figure 4.X. While technologies in Flow A and technologies in Flow B and Flow C involve transfer of the capacity to manufacture mitigation equipment or improve the ability to manufacture equipment. Transferring such technological capacity will threaten the technological superiority of the partner, thus threatening their potential to sustain commercial profits from their technological competitive advantage.

This is best figured with an example from Shell. During an interview, Shell Global mentions that they do not want to transfer their technology, because they will then lose their most precious assets; their knowledge that gives them a competitive advantage over competitors. Therefore, Shell will only license its technology. Shells' coal to liquid technology is even only used in equity joint ventures and is not licensed. Here it becomes clear that the definition of 'technology transfer' of Shell is giving up their technology, instead of selling the right to use technology. In practive, when a license is sold by Shell, Shell transfers engineering services, product designs, skills and knowhow for operation to the license holder. The need for flow B is emphasized by Valentin and Liu (2005) who underline that besides physical technologies, clean coal technologies include non-hardware measures, which help to improve the overall efficiency of coal usage. These include better maintenance and management of facilities, the usage of more sophisticated control and monitoring systems, comprehensive capacity building etc. In many developing countries, like China, there is a high demand for 'soft' technology improvements in terms of knowledge and skills to apply and diffuse 'hard' technologies, which could encourage the use and improvement of advanced technologies. (Vallentin and Liu, 2005) High level technology transfer such as innovation capacity (Flow C), is seldom transferred. (Watson, 1999) Watson (1999) says there is no real technology transfer in a situation where China acquires most of its clean coal technologies through direct import of technologies. Direct imports of CCT's are profitable for importing companies but do not entail real technology transfer, as buyers are usually the direct end-users of imported equipment rather than manufacturers, and imported equipment will be used entirely as capital goods, it will unlikely enhance overall the status of technology. Buyers of the imported technology will not acquire any knowledge of the design and manufacturing of the equipment. (Watson, 1999) Referring to figure 4.7 this means that flow C is missing, what causes that the importer does not accumulate technological capacity. The Nautilus Institute (1999, cited by Philibert and Podkanski, 2005) underwrites the statement of Watson by illustrating that technology transfer consists of knowledge and is brought about through a

learning process; purchase of machines and blueprints by itself does not constitute technology transfer. When referring back to the definition of Ramanathan (1994) on technology transfer (technology transfer implies the movement of technology from the technology owning entity (the transferor) to a receiver, and if the transfer is successful, the proper understanding and effective use of the technology by the receiving entity (transferee). If the transferee is unable to understand and use the technology effectively, the transfer is considered incomplete.)
I don't agree with the statements of both Watson and the Nautilus Institute, because when for instance a license for Shell's gasification technology is sold to China, the transferor receives enough understanding to use this technology for its purpose, such as power generation. There is no shift of ownership of the technology and Shell does not have the intention to transfer that much knowledge about the technology that transferors can copy or even sell the technology. What I can say is that there are different levels of technology transfer to distinguish. Referring to figure 4.7, transfer of flow A is a low form, while flow C is higher regarding the amount of knowledge transferred to a transferor, to accumulate own knowledge and insight in the technology.
The contemporary advocates of international transfer of technology view the concept to encompass a combination of hardware, services, and knowledge. Philibert and Podkanski (2005) propose the term "technology cooperation" as a replacement for technology transfer, because the latter does not satisfactorily represents the two-way relationships involved in the matter. In a second paper (Philibert 2004a) considers the potential advantages and disadvantages of international energy technology collaboration and transfer for promoting technological change. The advantages of collaboration may consist of lowering R&D costs and stimulating other countries to invest in R&D; disadvantages may include free-riding and the inefficiency of reaching agreement between many actors. According to Philibert and Podkanski the strategies of multinationals are to export only equipment, not technology; to transfer only outdated technology once new technology has been developed; and to make transfer conditions extremely hard to meet, so that Chinese enterprises find them hard to accept. (Philibert and Podkanski, 2005) According the theory of Madu (1989) this means that multinationals are not transferring appropriate technology, one of the critical factors for successful technology transfer. The findings of (Philibert and Podkanski, 2005) state that technology is not exported, what means that there is no option for innovation and technology modification, because the transferee does not have a full understanding of the technology. This is a second critical factor of Madu (1989), falling under the denominator of education, training, research and development, that is lacking. When referring to the initial components of technology as defined by Ramanathan (1994) is becomes clear that hardware (equipment and instruments), software (drawings, manuals etc.) and humanware are transferred to China, but that the orgaware component is not transferred.

The rather negative view on transfer of clean coal technologies from secondary literature sources, is in sharp contrast with the observations of a case that is studied for this research. This case, that focuses on recent Dutch enhanced coal bed methane (ECBM) activities, involves Dutch organizations TNO, Shell and Procede that have successfully applied for a financial support grant of the Asia Facility. The applied together with the following Chinese partners: State Key Laboratory of Coal Conversion, Institute of Coal Chemistry, Chinese Academy of Sciences (SKLCC), China United Coal Bed Methane Co. Ltd. and PetroChina. The most important goal of the project is setting up a knowledge centre on ECBM at the State Key Laboratory of Coal Conversion, in Taiyuan, Shanxi. This knowledge center includes: training of Chinese research professionals, a joint R&D program and a joint Knowledge Centre. This project fits perfectly with the preference of most Chinese enterprises, for absorbing technologies through foreign direct investments (FDI) and cooperation: foreign parties bring capital, technology which are necessary for China to develop its clean coal technology, have demonstration effects, stimulate competition and indirectly accelerate technology transfer. (Watson, 1999) This case could form an example of 'real' transfer of knowledge from the Dutch organizations to the host country of China, but since the actual technology transfer is not started yet, this is still unsure.

4.15 STRATEGY CHOICE

This report has analyzed the Chinese and Dutch situation regarding clean coal technologies (CCT's). After this analysis specific gaps of the Chinese situation were compared to (potential) competitive advantages of the Netherlands. This resulted in a short and non-exclusive list of CCT's that could translate into opportunities for Dutch businesses and organizations.

Treacy and Wiersema (1993) identify three paths (value disciplines) that can serve as the basis for strategy: operational excellence, customer intimacy, and product leadership. The operational excellences strategy is focused on leading in the production and delivery of products and services, based on price and convenience. Treacy and Wiersema explain that when you excel in one value discipline, it is necessary to provide industry standards in the other two value disciplines. From the case study on international energy technology collaboration and climate mitigation, as described by Philibert and Podkanski (2005) can be learned that Chinese manufacturers that have obtained a license for the production of a part for a clean coal technology (mostly a boiler) are able to produce this product far below the price of an imported boiler from Europe. A strategic choice for operational excellence would therefore, not be a good one. The second option as explained by Treacy and Wiersema is the customer intimacy strategy that focused on tailoring and shaping products and services to fit an increasingly fine definition of the customer. Hereby the objective is long-term customer loyalty and long-term profitability. Since it is not possible to tailor or shape clean coal technologies specifically for the a market, this strategy option is not suitable for this situation. Still, it is important to focus on long-term customer loyalty, because contracts, for example for a new power plant, are closed for long terms (more than twenty five years) and include maintenance and service. Because China is the biggest market for clean coal technologies, it is also a very suitable location to test technologies, for example enhanced coal bed methane (ECBM) because of China's appropriate geology and huge potential for storing CO2 in coal beds. Therefore the example of the case where Shell, Procede and TNO transfer their ECBM technology to China is a very good one, but is not focused on tailoring and shaping technologies and services to fit the Chinese customer. The third strategy options, product leadership is focused on producing a continuous stream of state-of-the-art products and services. With the product leadership strategy, a strategic fit, based on optimization of activities, is created because this is where the strengths of the Netherlands lies. According to the China Coal Information Institute (CCII, 2008), the clean coal situation and activities of the Netherlands are not well understood in China. Chinese research institutes and business organizations do not have enough knowledge about specific activities and expertise about CCT of Dutch organizations. Also the competition is fierce in market that demands the latest technology. According to the CCII, the first step in starting co-operation in CCT must be research. A spokesman of the CCII described China as the 'mainboard' of clean coal technology: the most advanced technologies are being explored by China. China collects and absorbs technologies, and then develops them further. The Netherlands can tag along with these developments by putting more effort in knowledge and expertise transfer with China, for instance with joint training and R&D programs and exchange of employees (engineers) and students (MSc, PhD.). Therefore, the Netherlands should focus on specific clean coal technologies in which it can become a renowned key player, instead of covering a wide range of CCT. Here the focus must lie on these technologies were the Dutch competitive advantage lies, that is in the field of coal blending, gas handling and gasification: coal blending, IGCC, CCS and ECBM, and are based on historic experience, running and future cooperation & research tracks, its domestic supporting policy and appealing financial aids. Because most Dutch organizations are relatively small next to giants like General Electric, they should form combined groups like CATO (carbon capture and storage research group), in order to focus on one specific clean coal technology and conquer a niche position on the Chinese market. These forms of collaboration are not necessarily tied to the Dutch border, as co-operating together with other European organizations could lead to an even stronger attempt to benefit from the future Chinese market in CCT. Therefore the Netherlands should focus its attention toward China by offering the latest, state-of-the-art solutions and intensify its research and collaboration effort towards China for this specific CCT's.

5. DISCUSSION OF THE RESULTS: WHAT DOES THIS MEAN?

In search for a dominant design of a clean coal technology, it turns out that there will not be one dominant design, but that several technologies will shape the market in China. This means that the opportunities and threats also lie in different technologies.

Proven technologies can be brought directly to the end-user and can be sold under license as equipment, used as capital goods. When studying the content of technology transfer to China, it turns out that according to some scholar, there is no real technology transfer in a situation where China acquires most of its clean coal technologies through direct import of technologies. According to this scholars, direct imports of clean coal technologies are profitable for importing companies but do not entail real technology transfer, as buyers are usually the direct end-users of imported equipment rather than manufacturers, and imported equipment will be used entirely as capital goods, it will unlikely enhance overall the status of technology. This does not have to be a problem since the source company (for instance Shell) wants to protect its technology and only licenses the use of its technology. The importing company receives a technology that generates electricity at a higher efficiency rate and has lower emission values. But, this also means that buyers of the imported technology will not acquire any knowledge of the design and manufacturing of the equipment. While the technology is moved geographically, it does not leave the technology owning entity.

For technologies with a low market acceptance or technologies that are not proven yet, technology transfer is needed. This technologies are in a more early stage and move vertically from a lab, into different development stages, into commercialization. In China, the development stages are
(co-)accomplished by research institutes and organizations that in turn advise policy makers (for instance the National Development and Research Commission) on environmental regulations, policy incentives and choice for future technologies.
This means that the hardware, software and humanware need to be transferred to China. This implies the movement of technology from the technology owning entity (the transferor) to another entity, and if the transfer is successful, the proper understanding and effective use of the technology by the receiving entity (transferee). If the transferee is unable to understand and use the technology effectively, the transfer is considered incomplete. This causes that the research institutes and universities will not give a positive advise to policy makers about this technology: when they don't understand it, they won't buy it. Therefore technology transfer of Dutch technologies and research cooperation with China, are necessary to get a grip on coming technologies. In the development stages, China provides a platform and the economies of scale needed, to develop expensive clean coal technologies like enhanced coal bed methane (ECBM), which cannot be developed on such a scale in the Netherlands.

5.1 IMPLICATIONS FOR ORGANIZATIONS

The results indicate that when organizations in the Netherlands wants to transfer clean coal technology to China, it has to focus on the technologies that China demands in the (short) future and simultaneously focus on the transfer of the technologies that the Netherlands have a competitive advantage on in China. Competitive advantages lie in the technologies of coal blending, integrated gasification combined cycle (IGCC), carbon capture and storage (CSS) and enhanced coal bed methane (ECBM). The best strategy for transfer clean coal technology is by choosing for the product leadership strategy by joining efforts with other Dutch and European organizations, and producing a continuous stream of state-of-the-art products and services. Dutch organizations should know that China is not interested in old technology but demands that latest technologies on the market. Since the most advanced technologies are being explored by China, the Netherlands can tag along with these developments by putting more effort in knowledge and expertise transfer with China, for instance with joint training and R&D programs and exchange of employees (engineers) and students.

5.2 ADDITIONS TO THE LITERATURE AND IMPLICATIONS FOR FUTURE RESEARCH

The results of the study of Srinivasan et al. (2006) show that a dominant design is more likely to emerge with weak network effects, low product radicalness, and high R&D (research and development) intensity. This situation is in conflict with the findings for IGCC development in China of this research. In China, investment costs decrease because of an increase of utilization of IGCC for power generation. As the number increases, the initial investment costs for power generators decreases, because of economies of scale (network effect). In this situation it improves the emergence of the technology, even if it does not becomes dominant in the market. This findings place question marks at the theory of Srinivasan.

Recalling to the initial components of technology as defined by Ramanathan (1994) it becomes clear that hardware (equipment and instruments), software (drawings, manuals etc.) and humanware are transferred to China, but that the orgaware component (or management as Steenhuis and de Bruijn (2001) call it, is not transferred. While it is correct that the four components are complementary to one another and are interrelated and that they are required simultaneously in an operation and no transformation can take place in the complete absence of any of the four components, technology can be transferred in individual components. According to this research there is technology transfer, even when not all four components are transferred. This finding does not directly falsify the theory/definition of Ramanathan, but can be seen as an addition. It is possible to define clean coal technology transfer in such a way that it measures the magnitude of the technology and does not involve concepts that are not transferred. The development of the definition was obtained through the study of former clean coal technology transfer cases. The result is a definition that excludes the orgaware component. While management is required in order to achieve that the technology is utilized productively, it is not transferred. To make sure the theory is falsifiable, new research must be capable of generating more tests of the theory with more data that will put the theory at risk of being falsified or make it possible to collect data so as to build strong evidence for the theory.

This research adds an overview of the future clean coal technologies in China to the literary base, based on extensive structural research of macro environmental factors and technological factors on a micro level. Also the findings of the interviews give insight into the Chinese clean coal developments that could not be found in any secondary source. This overview is not only useful for the Netherlands, but for any country or organizations that wants to supply clean coal technology to China or want to learn from the Chinese energy situation.

This research gives an overview of what indicators are important when screening a clean coal technology market for competitive activities and provides indicators for sources of national competitive advantage in the technological field. Also this research explicitly discusses what technology characteristics are important for choosing a candidate technology for the Chinese market. This research advises to combine a product leadership strategy with a focus strategy, where the focus is on a small range of technologies in the broad field of clean coal technologies.

MEASUREMENT QUALITY

5.3 ENDOGENEITY

Since this research is not experimental, there is no opportunity to manipulate the explanatory variables, they are just observed. One consequence of this lack of control is endogeneity, which means that the values the independent variables take on are sometimes a consequence, rather than a cause of the dependent variable.

The independent variables in this research are for example the macro environmental measures which affect the dependent variables; the choice for certain clean coal technologies. But it is possible (this is not researched) that the previous choice for certain clean coal technologies affects the macro environmental measures, such as emission policies. In the absence of investigator control over the values of the explanatory variables, the direction of causality (if there is any) is always a difficult issue. This research does not seek for co-variation, time order and alternative explicating factors to determine if there is causality between independent and dependent variables. But seeks for correlation between variables. For example government policy for use of more clean technologies correlates with the introduction of more clean coal technologies at power plants. Correlation on itself does not constitute a causal relationship between two variables, but is one criterion of causality.

5.4 RELIABILITY

Reliability is about applying the same procedure in the same way will produce the same measure. As explained in chapter 3, for selecting the samples, the non-probability sampling technique is used. This means that the probability of each case being selected from the total population is not known and it is impossible to answer research questions or to address objectives that require to make statistical inferences about the characteristics of the population. This causes that choosing for this method of selecting respondents could pose a bias to the reliability. It is still possible to generalise from the non-probability sample about the population, but not on statistical grounds. The companies in China are selected on the judgement of the Embassy (so called purposive sampling). This means that the researcher had no input in selecting this respondents. When this research is repeated by another researcher, with other interview respondents, it might be possible that the focus can lie on other clean coal technologies but, since the measures will yield the same results on other occasions this is only a focus issue. This is more true because all the secondary data sources can be retrieved from the references and notes from the interviews can be found in the annexes. This also improves the transparency of how conclusions are drawn from the raw data. A possible threat to the reliability is subjectivity: since every interviewer has its own attitude and demeanors, this can lead to different answers from respondents. The choice for a not strictly codified list of interview questions and only open questions threatens the reliability of the research but gives a great amount of information that would not have been found when the questions were strictly codified. Here, a trade-off between reliability and validity is made, in favor of the validity.

One possible bias which is important to mention is the ‘subject or participant bias’ which might form a threat to the validity. In China it is not unusual to say what your boss wants you to say. This means that when interviews were conducted during this research with two or more respondents from a Chinese organization, this threat to reliability might occur. This is a particular problem in organizations that are characterized by an authoritarian management style or when there is a threat on employment insecurity. There can also be an observer bias. When an interview was conducted with Chinese speaking participants, the questions of the researcher were formulated in English, and then interpreted and translated into Chinese by a translator. The Chinese answer was then interpreted, summarized and translated into English by the translator again. This situation could lead to a threat of both reliability and validity: when the same interview was performed by a Chinese speaking interviewer, the outcome of the interview could be different. A common form of raising the reliability level was executed during this interview: a similar question was asked in another way, to test if the interpretation was correct. The validity could be threaded because the situation offers a great chance of misinterpreting of both questions and answers. This might lead to a situation where something else is measures than originally intended.

A practical example of a threat to reliability in this research is a threat that originated by the etiquette of the Chinese culture. When discussing a list of clean coal technologies found in the secondary data during an interview with a research institute, there were two technologies in the list that did not fall under clean coal technologies, but under clean forms of energy. The problem was that this was not corrected, because the employee of the research organization did not want to let the interviewer ‘lose its face’. This is also the reason why it took so long to find the categories of clean coal technologies; made assumption were not corrected. This can lead to measuring with a bias, that would not be present in other researches and simultaneously threatens the validity because something else is measured than originally intended.

5.5 VALIDITY

Validity is about measuring what you think you are measuring. Or put differently: validity is a measure that accurately reflects the concept it intended to measure. The choice for respondents of every type of involved party in the process of technology dominance, including governmental organizations, businesses (both buyers and sellers), independent research institutes and universities, combined with a response rate of 100% provides a high rate of validity, since the information is not limited to one perspective. Since the technology dominance process can be measured in different macro environmental ways, the highest form of validity is reached by measuring them all.

It must be said that Chinese newspapers are under the supervision of the Government, which means that there can be a political bias on the news these sources bring. This can lead to false assumptions.

A possible threat to the validity is the problem of 'testing'. When a Chinese company is asked in several ways what measures it takes against environmental pollution this may influence the response: if the company believes that the results of the research may disadvantage them in some way, then this is likely to affect the given answers and thereby the results.

A short note on the statistics used within this report is that most of the data used has been derived, directly and indirectly from: China's National Bureau of Statistics, university publications, publications of governmental institutions, research organizations, market reports of commercial organizations, journals, interviews and presentations. Upon researching the data, it became clear that some disparities occur between the statistics produced by the various sources. These discrepancies can be explained from the fact that different methods of data gathering have been employed, with different goals, which therefore leads to other results. Despite these discrepancies, the statistics do provide a good basis for drawing of conclusions that can be applied for the general Chinese situation and individual circumstances. All this sources of data, combined with the interview data, provide a high level of external validity. Yet it should be noted that the numbers found in this report may deviate to some extend from reality and should therefore not be used as the single source of information for decision-making.

The long-term orientation index of Hofstede, is not necessarily a good index to predict that China will choose for clean coal technologies that are more durable, less polluting, but also more expensive than other technologies to preserve the environment for future generations. This is because this choice has a direct effect on the pace of economic growth that has its effect on the long term performance of the whole Chinese economy. In fact, the long-term orientation index, possibly measures another construct, that is long term economic performance whereby the environmental situation is excluded. This means that there can be a threat to the criterion related validity, because the degree to which the measure relates to some external criterion is too low.

The quality of the indicators of the macro environment, seem to be reasonable measures of the variables (politics, economics, socio-cultural, technological, environmental and legal) what indicates that the face validity is not threaded. But, the content validity might be in danger because the degree to which the used measures cover the range of meanings included within the concept, is too low. An example: when measuring the political dimension, several measures are used including national policies, structure of government, presence of foreign technology discriminating policies etc. But this is not a complete description of the political dimension. In this research this is done by intention, because only the most important political measures are used that have an influence on the technological dominance process.

This is in contrast with the definition of technology as part of technology transfer. This definition suffers from content invalidity because the definition is too wide for the actual content of the technology transfer process. The standard setting as a technological measure suffers from construct invalidity because the standard setting methods that could predict the speed of technological dominance are absent in the Chinese situation. Including this irrelevant measure would lead to inefficiency, therefore this is indicated in the research findings and not taken along in the research.

'In qualitative research, the decision as to which observations to select is crucial for the outcome of the research and the degree to which it can produce determinate and reliable results.' (King, Keohane and Verba, 1994) As described, randomness is not appropriate in this research, but abandoning randomness opens the door to many sources of bias. The most obvious example is when, knowing what outcome is desirable, subtly or not subtly selecting observations on the basis of combinations of variables that support the desired conclusion. Suppose that all the respondents for this research were board members of electricity companies, than the list of clean coal technologies would be a lot shorter since for application of most clean coal technologies causes a negative reward for the electricity company: higher costs but absence of increased income.

5.6 SUGGESTIONS FOR FUTURE RESEARCH

More research is needed on all technical aspects of carbon sequestration, fundamental processes (e.g., pore behavior), leakage rates and safety, storage capacities, and measurement-monitoring-verification, as well as on policy aspects including permitting and liability. Also the Dutch competence on CO_2 sequestration needs to be analyzed further. Therefore, this research presents an analytical framework that can be used. A list of potential respondents can be found in the annexes.

Further research is also needed for the competition on the Chinese clean coal technology market since this research is restricted to basic competitive screening. This would be very useful to get a deeper insight into advantages and weaknesses of competitors and the price levels on competitive products on the Chinese market.

6. CONCLUSIONS

In order to analyze the central question of this research: ‘What strategy does the Netherlands has to apply regarding the transfer of its clean coal technology to China?’, this report analyses the Chinese and Dutch situation regarding clean coal technologies (CCT’s).

To fulfill the first research objective, specific technology gaps of the Chinese situation were compared to (potential) competitive advantages of the Netherlands. This resulted in the second research objective, the draft of a short and non-exclusive list of CCT’s that could translate into opportunities for Dutch businesses and organizations. The options for research collaboration, knowledge transfer and hardware transfer have been categorized in short-term, medium-term and long-term. This has been research in order to answer the research question, In the short term, advanced coal blending (mixing of coal for a better composition) could be interesting, because Chinese power plants are increasingly using more advanced technology which can benefit from a better composition of the coal input to come to highly efficient gasification or combustion. The factors (law, environmental regulations, efficiency, maturity etc.) that block the wide application of Integrated Gasification Combined Cycle (IGCC) in China are not going to disappear in a few years. While China is already building demonstration plants, IGCC might become economically interesting in the decennia to come. Because IGCC brings the lowest CO_2 capture costs, IGCC will become truly interesting when China decides to capture their CO_2 emissions. But this scenario is still far away.
Gasification, which is also a part of the IGCC production chain, is already deployed in China by for instance Royal Dutch Shell that is selling its licenses throughout China.
When China does not set emission targets for CO_2 reduction, Carbon Capture and Storage on its own, is not very interesting for China. Potential Dutch activities should therefore focus on Enhanced Coal Bed Methane (ECBM) in China, which improves the gas winning by injecting CO_2 that pushes the methane gas out. Besides an efficiency improvement of up to 50%, this technology also lowers the pressure on China’s gas shortage. Future competition on the Chinese market for clean coal technologies will be fierce. On the one side, there is competition from giants like Japan, the US, Canada and Australia who are investing billions in Sino-research programs to push their technologies on the Chinese market. On the other side, China is developing clean coal technologies very rapidly itself. Even though the market for clean coal technologies is huge, this competition creates a very difficult situation to compete in for Dutch organizations. Because most Dutch organizations are relatively small next to giants like General Electric, they should form combined groups like CATO, in order to focus on one specific clean coal technology and conquer a niche position on the Chinese market. These forms of collaboration are not necessarily tied to the Dutch border, as co-operating together with other European organizations could lead to an even stronger attempt to benefit from the future Chinese market in CCT.

Based on the findings of this research, including China’s future demand, and Dutch competitive activities, A strategy advise is given to the Netherlands to focus its strategy on product leadership. This strategy is directed at producing a continuous stream of state-of-the-art products and services to become visible on the Chinese market with a select number of technologies. Proven technologies can be sold directly to China, while non-proven technologies can go through the development stages by transferring technology to China and cooperating in the research and development process. China collects and absorbs technologies, and then develops them further at a very high pace. The Netherlands can tag along with these developments by putting more effort in knowledge and expertise transfer with China, for instance with joint training and R&D programs and exchange of employees (engineers) and students (MSc, PhD.). China is also a very suitable location to test technologies, for example enhanced coal bed methane (ECBM) because of China’s appropriate geology and huge potential for storing CO_2 in coal beds.
A strategic focus on leading in the production and delivery of products and services, based on price and convenience is not a wise decision because Chinese domestic competitors can easily

outrun you, based on economies of scale and low labor costs. A strategy where the focus lies on tailoring technologies specifically for the a market, is not suitable for this type of situation.

The strategic focus on product leadership, implies to provide industry standards on operational excellence and customer intimacy. This means that it is still important to focus on long-term customer loyalty, because contracts, for example for a new power plant, are closed for long terms (25+years) and include maintenance and service. Because China will at least triple its power generation capacity in the next twenty years and is potentially the biggest market for clean coal technologies, the Netherlands should be involved early, in order to benefit from the future growth market.

Limitations of this research are the sample that is limited to 11 players with very different backgrounds (energy producer, governmental organizations, research organization) this limits the generalization of the outcome. Because of the ‘snapshot’ that is taken of the clean coal technology market, no developments can be measured during the research based on own primary research data. Also the research findings are limited to the Chinese and Dutch borders and cannot be generalized for other countries that are dependent on coal as a primary resource of energy. Considering the duration of implementing CCT through co-operation and research trajectories, this research is limited to look for strategic opportunities in the short term, medium term and long term (respectively: one year or less, 2 till 10 years, 10 or more years).

As a third research objective, this report present the bare bones of an analytical framework for measuring the economic competence of CO_2 sequestration technology of the Netherlands.

As a result of reading this report and implementing the strategic advice, Dutch organizations will be better positioned to exploit chances for co-operation and exchange of knowledge and technology in the field of clean coal technologies to China.

7. REFLECTION

7.1 PROBLEMS ENCOUNTERED

The language barrier created a problem, because the researcher does not speak Mandarin. Although a lot of information written in Chinese language is translated by members of the Embassy, it hampered the daily work. Websites of many Chinese organizations, companies or State agencies are only in Chinese language or contain a very limited English section. This problem greatly increased the amount of time needed to collect relevant data.

7.2 EVALUATION OF THE RESEARCH PROCESS

Although the research work in China was performed under strong time pressure, it ran quite smoothly. With just two weeks of preparation I dove into research reports about clean coal technologies using search words as 'clean coal technology', 'carbon capture and storage' and 'clean energy in China'. I arrived in Beijing with a notion what the subject was about.

In the 3 months at the Dutch Embassy I dove into the literature about clean coal technologies to learn more about the subject and spoke with lots of players in the field by phone, face to face and by e-mail. After about three weeks, a framework was developed to study and describe the market in such a way that opportunities and threats for Dutch organizations could be found, based on Chinese needs and Dutch strengths. This resulted in an extensive report and presentation about the clean coal technology market in China and specific opportunities for the Netherlands. Back in the Netherlands the formulation of the academic report was so time consuming that further research of Dutch strengths in carbon sequestration was not possible. That is why the third objective of this report is formulated as the formation of the bare bones of an analytical framework to make this analysis. Also potential respondents are already found and are listed in the annexes.

My personal objective before starting with this research was, independently writing a thesis about something I do not know anything about in an environment that is not familiar to me. This would force me to use and develop academic skills but mostly personal and social skills. Because I want to add extra value to the current work of the Embassy, the report for the Embassy should contain specific suggestions for future policymaking. This means that the recommendations have to be based on grounded research, performed in a short period of time. Writing two separated reports (one for the university and one for the Embassy) lies some extra pressure on the aim to finalize my graduation work in about six months. During the presentation of the research report at the Embassy in turns out that the research findings connected with already formed presumptions of embassy members and lay the foundations for future policy making.

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ANNEX I: WORKPLAN IN CHINA

Week:	Activities:	Completion of:
13,14,15	Research in the Netherlands: Gathering information about clean coal technologies in the Chinese and Dutch market. First part of literature research aimed at exchanging knowledge and technology between international partners. First part of literature research on competitive advantages First part of literature research on forms of cooperation in the energy sector.	Interim report
16,17	Start research in Beijing	Orientation on sources for data collection
19, begin 20	Writing Chapter: Clean Coal Technologies	Definitive work plan Basic chapter about CCT with focus on China
20	<u>Interviewing general industry experts:</u> William Sun – Energy Assistant Economic Department NL Embassy Bert Bekker – Manager Natural Gas EU Energy and Development Partnership	Choosing relevant CCT (‘s) for further research Formulating research topics
21, 22, 23	ECN (via Eric van Kooij) Senternovem KEMA – Clean Coal Operations China Coal Information Institute (CCII) Jane Chen, Corporate Strategy & Planning Manager - Shell China University of Mining & Technology (CUMT-Beijing) – discussion scope CCT Research, coal industry development, possible cooperation Shenhua Group discussion topics: - Clean Coal Technology Utilization - Chinese Coal Industry development - Coal Liquefaction & Chemical - Possible co-operation Multi Purpose Industries? NL Org. – Ton Koens	Formulating additional research topics for interviews during site visits

24, 25, 26, 27	Visiting traditional- and clean coal energy plants in China LOCATIONS: - JV Shell Ningxia province: coalbed methane Maybe? Visiting of recently approved power projects of the World Bank: New coal-fired power plants. - 1200MW Tuketuo plant in Inner Mongolia, -1800MW Waigaoqiao phase II project in Shanghai (using boilers from Alstom Power) - Hunan Power Development project which includes a 600MW power plant at Leiyang. (Watson 2000) Carbon Capture and Storage locations? IGCC demonstration plants?		
28	Present results during a meeting with principal Improving report based on comments received		
29	Submit market exploration report to principal in pdf		

ANNEX II

THE CLEAN DEVELOPMENT MECHANISM (CDM)

The Clean Development Mechanism (CDM) is an arrangement under the Kyoto Protocol allowing industrialized countries with a greenhouse gas reduction commitment (including the Netherlands) to invest in projects that reduce emissions in developing countries like China, as an alternative to more expensive emission reductions in their own country. A crucial feature of an approved CDM carbon project is that it has established that the planned reductions would not occur without the additional incentive provided by emission reductions credits, a concept known as "additionality". By looking at the distribution of CDM emission reductions by country, it turns out that China receives 51.45% of the total distribution sum[1].

The purpose of the CDM was defined in the Kyoto Protocol. Apart from helping developed countries comply with their emission reduction commitments, it must assist developing countries in achieving sustainable development, while also contributing to stabilization of greenhouse gas concentrations in the atmosphere. The CDM is supervised by the CDM Executive Board (CDM EB) and is under the guidance of the Conference of the Parties (COP/MOP) of the United Nations Framework Convention on Climate Change (UNFCCC).

The Energy Working group is the organization under the European Union Chamber of commerce in China that focuses on electric power generation, the supply of equipment for the electricity industry and the provision of municipal utilities including water, district heating and gas. The energy working group seeks greater market access and improved operating conditions for European companies in China. The Energy Working Group expressed its displeasure about the requirement of 51% Chinese majority control for CDM eligibility. The current restriction on the eligibility of project companies to apply for CDM only where they are owned/controlled by Chinese shareholders, is discouraging international developers and investors from transferring valuable technology and know-how into the Chinese market, As a result, China misses out on an opportunity to accelerate the government's objective of promoting renewable energy, energy efficiency and waste and water recycling. Expanding the eligibility for CDM to foreign controlled project companies will encourage more foreign investors to enter the Chinese market and invest in the development of new clean energy solutions.[2]

ANNEX III: ANALYSIS OF CHINA'S ACQUISITION OF CLEAN COAL TECHNOLOGY

Key findings

- The Chinese government is encouraging foreign investments in specific industries regarding clean coal technologies. But not every encouraged investment area is equally attractive to invest in.
- Most of China's new power plants were financed with loans from commercial or development banks, or both.
- Chinese customers want the best products and technologies, not second best, and they are increasingly willing to pay for it.
- The market for clean coal technologies in China is becoming increasingly competitive due to both foreign technologies as well as China's own activities on development of clean coal technologies.

6.1 Investing

In the 'Catalogue for the Guidance of Foreign Investment Industries' the Chinese Government outlines in what industries foreign investment is encouraged. Investment areas are formulated rather broadly. In 2006 the following industries were explicitly promoted regarding clean coal technologies:

For the Coal Industry:
1 . Design and manufacture of coal mining, conveyance and concentration equipment
2. Coal mining and ore-dressing by washing. The Chinese party will be the holding party or play a leading role in the mining and ore-dressing by washing of special and rare kinds of coal
3 . Production of water-coal and liquefied coal
4. Comprehensive development and utilization of coal
5 . Exploration and development of coal bed gas

For the Power Industry the Catalogue prescribes:
1. Construction and management of power stations with the technology of clean coal-burning[3]

In a whitepaper of the Chinese government's official website, this information is further elaborated. China encourages foreign investment in the production and supply of electric power and gas, as well as in the construction and operation of thermal power plants with a single-generator capacity of 600,000-kw and above, power stations burning clean coal, power stations featuring heat and power cogeneration, hydropower stations mainly for electricity production, nuclear power stations in which the Chinese side holds the dominant share, as well as power stations with renewable energy or new energy resources.[4]

In 2008, various European companies represented in the Energy Working Group, published a position paper.

In this document, they expressed their displeasure of the fact that annually, thousands of bid documents are issued for the purchasing of the main components of the power projects. However, the basis for deciding which auctions are open to foreign companies is unclear and the bid documents do not always contain clear evaluation principles. Many companies are willing to provide advanced technology and make strong bids on projects; however, crucial to this is encouraging a transparent legal framework at all stages of the bidding process.[5]

6.2 Financing

Most of China's new power plants were financed with loans from commercial or development banks, or both. The share of equity investment usually is at the lowest level that is allowed by regulation, which is 20 percent. While this practice stimulates the expansion of electricity industry due to the resulting cost of capital, it is commercial and development banks, which are state-owned, that ultimately bear most of the financial risks.

- It is important to note that government cofunding is used to assist industry in advancing the technology. The government, generally, does not acquire or take ownership of the facility. The government has a stake in completing the mutually agreed work scope, and can step in if the industry partner walks away . Also the government can provide other incentives like e.g. tax credits, loan guarantees. [6]

The World Bank is working on an Investment Framework for Clean Energy and Development. This framework will catalyze investments from public and private sources to increase access to energy in developing countries, while using cleaner technologies that protect the environment.[7]
Below a list of supporting financial instruments available to Dutch businesses and organizations, is listed.

Table 6.1 Dutch Supporting Financial instruments

Tender EOS (New Energy Research)	The new tender for compensation on Energy research. Till the 21th of August 2008 proposals can be submitted. Total budget: 700.000 euro. Proposals for feasibility studies can be submitted till 31th of October.
AF (Asia Facility)	The Asia-Facility for China is directed at projects that focus on knowledge transfer with Chinese partners. Target groups are: educational-, training and research organizations, businesses, NGO's, foundations or other social organizations and (semi)governmental organizations. The maximum compensation from the AF is 454,000 euro, or a maximum of 80 percent of the total project costs.
Subsidieregeling Opkomende Markten (SOM)	The aim of this compensation is to encourage cooperation between Dutch Businesses and foreign parties in upcoming markets. Compensation is possible for cooperation projects in the field of industrial research, experimental development or a combination. The compensation contains: • For Industrial research: 35 percent of the project costs and a maximum of 500,000 euro. • For experimental development: 25 percent of the project with a maximum of 500,000 euro.
PESP	PSEP is not a compensation programme but an assignment programme. PSEP pays 50 percent of the costs of a study till a maximum of 133,000 euro.

Table 6.2 European Supporting Financial instruments

Call for Proposals - Environment and sustainable management of natural resources including energy (http://ec.europa.eu/europeaid/cgi/frame12.pl reference 126201)	This was the first call under this programme - the actual call is now closed, however the background information and application forms could still be useful for a future call

ANNEX IV: FUTURE APPLICATION OF CLEAN COAL TECHNOLOGY IN CHINA

It is important to notice that China's electricity industry is less interested than the coal industry in adopting more-expensive coal-gasification-based technologies (e.g., IGCC, poly-generation) as a measure to hedge against business risks caused by potential changes in regulatory regimes, especially the possibility that emission of carbon dioxide will eventually be regulated.[8]

Key findings

- The dominant installed CCT technology is pulverized coal combustion with a subcritical steam cycle

- The National Development and Reform Commission (NRDC) has recommended advanced supercritical plants for large scale power generation and most recent orders have been for supercritical units
- A recommendation of the China Council for International Cooperation on Environment and Developed made in 2003 to the Chinese government essentially equates coal modernization with polygeneration through gasification.

Table 5.3: clean coal development in China categorized based on specific technology

Technology	Situation in **China**
IGCC	Yantai IGCC project under consideration for past decade. Several power and polygeneration projects being developed by major utilities.
Gasifiers	37 on coal, 13 on petroleum and 1 on gas (25 Shell, 22 GE, 3 Sasol Lurgi, 1 GTI U-Gas) (35 Operating, 16 Planned)
CFBC	Many domestically built 50-200-MW units
CTL/ Polygeneration	First phase of Shenhua's direct liquefaction plant in Inner Mongolia to start operation in 2008, producing 1.08 million tons of liquid products (diesel, LPG, and naphtha). Total production of two phases is 5 million tons. Also, developing two indirect liquefaction plants with Sasol. Polygeneration under study by others, including Hunnan International Technopolis Shenyang (HITS) using coal and waste/garbage and Datang Power (4 plants) using coal.
Supercritical	Several dozen units commissioned
Ultra Supercritical	The first ultra super critical (USC) PC unit went on line in November 2006.[9]

Source: Daniels (2008)[10]

Super critical (SC) and sub-critical pulverized coal (PC) units accounted for 25% (China Electricity Council, 2006). Circulating fluidized bed (CFB) accounted for 17% of the total installed capacity.[11]
About 40% of Chinese coal is burnt in a half million "industrial boilers" in industry and in district heating systems. Conversely, over 95 % of industrial boilers in China burn coal. The two most important sources of demand for industrial boilers are on the one hand light industry and the textile industry, which require process heat and power; and on the other hand space heating for individual apartment buildings, district residential areas and commercial buildings, particularly in northern Chinese cities. The dominant installed technology is pulverized coal combustion (burning powdered coal) with a subcritical steam cycle. Units range widely in sizes from less than 25 to 660 MW. There are still a large number of these subcritical units under construction.[12]

Incremental improvements to the performance of existing power stations, industrial boilers and other facilities are perhaps the most important cleaner coal technologies for the short term. Such improvements can lead to a significant reduction in emissions from coal-fired facilities. For example, Chinese fossil-fuel electric power plants have historically had thermal efficiencies that are significantly lower than typical figures for plants in more industrialized countries. The Chinese average is affected by the large number of small power plants in use. In 2005, only 333 of China's 6911 coal-fired units had capacities of at least 300MW. Many of the remainder have capacities of less than 100MW [13].
Note that in the run up to the 2008 Olympics in China, many small scale plants have been closed. In addition, China currently imports state-of-the-art control technology for NOx and SO_2 control.[14] Outside the electric power industry, much larger 'efficiency gaps' have been identified in Chinese industrial facilities. During the late 1990s, it was observed that the average industrial boiler in China was operating at an efficiency of 65% whilst boilers in OECD countries have efficiencies of over 80% [15].

From 2001 to 2003, the proportion of global orders of new coal-fired power plants placed in China has been higher than 80%. China expects its power generation to at least triple in the next twenty years. Currently in China, the power sector chooses USC PC and SC PC for new capacity additions coupled with pollution control technologies, and 300MW circulating fluidized beds (CFB) as a supplement. According to the national industry policy, 600MW SC and 1000MW USC units will become the standard in the coming years.[16] The IEA[17] projects a total capacity of 1187 GW in 2030 against 360 GW in 2002. Coal-fired plants would total 776 GW – a decrease due to rapid growth of gas-fired generation and renewables. Ten supercritical units were in operation in 2003 and twenty more units were approved for construction. There will likely be a surge towards 1000 MW power plants with ultra-supercritical steam conditions[18]. The National Development and Reform Commission (NRDC) has recommended advanced supercritical plants for large scale power generation and most recent orders have been for supercritical units. IEA experts indicate that supercritical plants totaling more than 60 GW of capacity were recently ordered.[19] Since the 1960s, Chinese engineers have developed their own designs of small fluidized bed combustion equipment independently of early efforts in other countries[20]. Over 1000 commercial CFB boilers have been put into operation since 1989 and fifteen 300 MWe CFB boilers are in the planning or construction stage (date 2004)[21]. More than 30 GW of cogeneration plants are currently in operation, notably in the coldest parts of China.

There is considerable knowledge of coal gasification in the chemical industry for production of fertilizer chemicals. This explains why poly-generation has been suggested as a more realistic alternative for China[22]. Based on coal gasification ("syngas"), poly-generation systems can produce a variety of energy products: clean synthesis gas and electricity, high-value-added chemicals, high-value-added fuels for vehicles, residential and industrial uses, and other possible energy products. Gasification enables conversion of coal, including high-sulphur coal resources, with very low levels of air pollution compared to most existing coal combustion technologies in China The 2003 CCICED recommendation to the Chinese Government underlines the importance of coal modernization with poly-generation through gasification. From an assessment of the key clean coal technologies by the Energy Working Group of the European Chamber of Commerce In Beijing, it becomes clear that China has "successfully mastered the Super Critical (SC) and Ultra Super Critical (U-SC) technologies for power generation. At the same time, China has been developing technologies for coal liquefaction and coal conversion into methanol and its derivatives (such as coal to olefins).

There are a large number of projects that are under construction today in China. A combination of power, liquid and chemical production from coal, under the term of poly-generation, is being encouraged by the government."[23]

When decision-makers are faced with the need for new electricity capacity, several technology types can be considered. One of the tools used by decision-makers is a levelized cost calculation which incorporates all the expenses associated with a project over its lifetime. Levelized cost comparisons give investors one basis for choosing a technology, mostly based on capital costs and Cost Of Electricity (COE). Cost of electricity (COE) is a function of the costs for capital, fuel, consumables, repair, labor, finance, technology, time frame, and site. More stringent environmental regulations often cause plants to add more equipment (e.g., flue gas desulfurization (FGD) systems), lose potential capacity, and lose efficiency.[24]

The choice for CCT therefore must not be made by profit driven companies but by the Chinese Government.

5.3 Clean Coal Technologies in China on the short term (one year or less)

- Coal processing technologies (including coal washing and coal blending)
- Small circulating fluidized bed boilers (CFB)
- Flue gas desulphurization (FGD)
- Coal gasification

Key findings:

- There is an urgent need for coal blending in China, with a view to the optimization of the coal gasification process.
- Because more advanced technology is used in the plants, coal sources with better specification are needed. According to Shell, their gasification license holders are interested in coal analysis, especially coal quality measurement. There is a need for an online solution.
- Shell is selling its licenses for their gasification technology through China. Since Shell is not a manufacturer, important manufacturing orders could go to Dutch companies that provide solutions In the line with Shell's high standards. Here lies an important opportunity for Dutch organizations.

In the short term, Chinese firms have the capacity to build on existing competencies in a number of cleaner coal technologies including coal processing technologies like coal washing (chemically washing minerals and impurities from the coal) and coal blending, but also various efficiency improvements and small circulating fluidized bed boilers. Many of these technologies are now well established and commercialized in China, though some do not have a direct impact on carbon emissions[25].

One of the simplest and best-known techniques for reducing emissions is the washing of coal.[26] Basic coal washing technologies are well established in China. In 1997, there were over 1500 coal preparation plants in operation with enough capacity to wash a third of China's coal output[27]. A 2007 report of the World Coal Institute underlines that although coal preparation is standard practice in many countries, greater uptake in developing countries is needed as low-cost method to improve the environmental performance of coal. The report claims that only 11% of thermal coal in China is currently washed.[28] Consequently, ash contents will tend to be 25% on average in China. There has been some consideration of coal washing to lower sulphur contents but this has not been thought cost effective under the current environmental requirements. However, there is some evidence that companies are starting to recognize the benefits of coal blending but are hampered through the State driven coal supply procedures and the imbalance between supply and demand for coal.[29] This related technique will be dealt with later in the paragraph.

In 2005, EUCHINA did a research (2005) called " International cooperation to improve efficiency and reduce environmental impact for fossil fuel fired power plants within China". The EU-China team identified two boiler configurations that typify Chinese boiler stock. The research report identifies low-cost equipment upgrades and high-cost upgrades and improvements. One of the most important low-cost upgrades with very positive expected impacts is the introduction of a coal quality management system and the establishment of a management information system to optimize overall performance. These low cost measures, produce economic benefits through efficiency increase and also improve the overall management of resources that normally leads to cost reduction. A high cost upgrade that must be considered within the context of the government policies for environmental improvements in the coal fired power is the installation of FGD combined with the necessary improvements in the electrostatic precipitators. This is mandatory since the government is forcing the utilities to introduce FGD. As such it has to be viewed as an unavoidable cost that has considerable environmental benefits. That said, the potential market for introduction of FGD is enormous. [The full report (public) of the findings can be found on the website of EUCHINA].[30]

Interest in coal gasification is growing because it addresses the increasing need for secure, clean and economical sources of energy. With the help of coal gasification technology, coal is converted into systhesic gas or syngas. Syngas has a direct market value because it can be used to produce a wide range of high-value products such as electricity, fertilizers, transport fuels and chemicals. The applications of syngas as a raw material for producing chemicals are for example ammonia, methanol, acetic and urea fertilizer or can be converted into an ultra-clean transport fuel, known as coal-to-liquids (CTL) fuel.
As one of the basic coal conversion technologies, coal gasification is widely used in China, but most installations use outdated designs. In general, these coal gasifiers are small and inefficient and used for industrial processes such as fertilizer and chemical production. For the long term, coal gasification technologies provide not only the feedstock gas of chemical production but also gas sources for multi-product technologies and hydrogen production for fuel cells, so the development should be accelerated. The suitable technologies for China are advanced pressurized fixed bed technologies, pressurized entrained-flow technology, and pressurized fluidized bed technology.[31] Cleaner and more advanced gasifier designs have been introduced to China by foreign firms such as Shell [32]. These are sometimes installed as retrofits to existing gasification facilities to reduce emissions through increases in efficiency.

Dutch activities potentially suitable for China
- Coal washing
In the early nineteen sixties, sales of coal washers started to shrink because the coal mines started to become less and less economic to run. Dutch organizations like Stamicarbon (DSM) shifted its sales markets to Eastern Europe, America and India. Stamicarbon terminated all activities regarding handling of coal.

- Various efficiency improvements
Coal Blending
Coal blending is also part of the value chain of coal gasification. In China, plant licensees handle coal blending themselves.[33] A Dutch company that is active on the market of coal blending is KEMA. KEMA provides coal blending know-how to a facility near Shanghai. KEMA determines what blend of the coals, available from sources in China, Indonesia and elsewhere is best for the individual power plants to be supplied with the object to reduce the sulfur content without compromising the positive combustion properties.[34]
Another Dutch company active in the field of coal blending is EMO. EMO is currently performing research on coal blending and focuses on Shell's IGCC technology.

In the Netherlands only internationally traded coals are utilized for power generation. This means that for more than thirty years different coals from all over the world have been utilized in the Netherlands. The wide ranges of coal quality could only be fired due to blending facilities available for all the power plants in the Netherlands. In close co-operation with the power plants KEMA has since 1988 performed a large number of studies and experiments to optimize coal blending in relation to power plant operation. Most

of these studies have been performed in full scale practice using all seven coal-fired boiler installations in the Netherlands.[35]
During a meeting with Shell's Eur. Ing Henry K.H. Wang and Mrs. Gu Jing it became clear that there is a urgent need for coal blending in China, with a view to the optimization of the coal gasification process. There is still a large scope for improvement in this field.

NOx-reduction services
Through more than 30 years of working directly with NOx-reduction technologies, KEMA has gained extensive experience with this field as well as a profound insight into both short-term and long-term operational solutions and applications.

- Flue Gas Desulphurization (FGD)
Dutch KEMA has a long history in flue gas cleaning and particularly in wet flue gas desulphurization (FGD). This is the result of KEMA's position as the main engineer and R&D consultant of the Dutch Power Generating Companies, as well as the fact that flue gas desulphurization was introduced relatively early in the Netherlands. The first FGD unit at a coal-fired power plant was commissioned in 1985. Based on these experiences, KEMA has developed its services to all kinds of thermal processes for the conversion of fossil fuels, waste and biomass. [36] Since FGD is used for removing sulfur oxide, combined with NOx reduction, this technology is very suitable for China for their combat against acid rain.

- Coal gasification
Shell has been developing and using coal gasification technology for over 30 years. Their own gasification technology is called Shell Coal Gasification Process (SCGP). Shell had 85+ gasifiers in operation world-wide.[37] Shell has sold 16 licenses in China for coal gasification and 10 projects are already up and running. The first of which was built by a 50:50 joint venture between Shell and Chinese State oil company Sinopec [38]. It entered full operation in 2006. Specific advantages of the Shell coal gasification process is that is 'clean'. None of the constituents in the coal are wasted. The sulphur is recovered as pure sulphur and sold as a feedstock to the chemical industry, and the ash is recovered as clean slag which is used to make ceramic tiles and bricks. Shell's gasification technology has the lowest CO_2 emissions per ton of coal feed, compared to its competitors. The process consumes only a small amount of water, and the waste water can easily be cleaned. This is especially interesting for China because of its water resource problems, especially in its coal producing regions.
Another advantage of the Shell coal gasification process is its flexibility, it can operate on a wide range of coal qualities, such as low quality sub-bituminous coal and lignite.[39]
Shell and Sinopec formed a 50:50 joint venture in 2001 to construct and operate the 2,000 ton/day coal gasification plant at Dongting fertiliser plant, Yueyang, Hunan Province. The gas will be used as the feedstock for the fertilizer plant.[40] Shell is the first multinational company with a service center on clean coal technologies. The local service team contains of 28 engineers (90% Chinese) and delivers efficient and timely support.[41]

5.4 Clean Coal Technologies on the medium term (2-10 years)

- Larger scale fluidized bed boilers
- Supercritical boilers for coal fired power plants
- IGCC
- Coal liquefaction

Key findings:

- Because The Netherlands already has one of the world's first IGCC power plants in Buggenum, there is an opportunity for further technology and experience sharing with China.
- According to Shell, IGCC is expensive when looking at it standalone. When including Certified Emission Reduction credits (CERs) and CDM's it becomes more economic.
- China is not ready for broad application of IGCC, because of the immaturity of IGCC technology. In addition, higher costs for electricity production, China's failure to implement CO_2 emission reduction policies, difficulties in obtaining financing and inability to sell byproducts of IGCC, like sulfur, freely on the market, make that short-term application of IGCC not feasible.
- A number of clean coal technologies are being promoted by the Chinese government through environmental regulations. These include larger scale fluidized bed boilers, supercritical boilers for

coal fired power plants, flue gas desulphurization (FGD) and coal gasification.

One of the objectives during the 11th Five-year Plan period (2006-2010) is "To advance research on key technologies for climate change mitigation and to launch pilot projects at local level and in industrial sectors." The 11th years plan specifically underlines clean and efficient coal technologies for further development, including integrated gasification and combined cycle (IGCC), high steam condition supercritical (ultra-supercritical) units, and large-scale supercritical circulating fluidized bed; to develop technologies of coal liquefaction with poly-generation system; to develop conversion technologies of coal liquefaction, gasification and coal chemical industry; (...) Also the 11th year plan prescribes the exploration and development of coal bed methane resources and CO_2 capture, utilization and storage technologies.[42] More advanced clean coal technologies such as Integrated Gasification Combined Cycle (IGCC), coal liquefaction and carbon capture and storage (CCS) are still relatively immature even in OECD countries. In need of significant improvements, these technologies have long term prospects in China.[43]

A number of clean coal technologies are being promoted by the Chinese government through environmental regulations. These include larger scale fluidized bed boilers, supercritical boilers for coal fired power plants, flue gas desulphurization (FGD) and coal gasification. The China development forum and the Development Research Center of the State Council, for instance, advise that Supercritical and ultra supercritical units (with FGD) as the main-force units with supplementary CFBC units should be extended in the power sector. The FGD technologies should be extended overall for large coal users in power and non-power sectors.[44] Currently, China's equipment vendors, and the electricity industry as a whole, focus their innovation efforts on ultra-supercritical technology because of its high thermal efficiency and large single-unit capacity. China does not have many sites that are suitable for large-scale coal-fired power plants. Ultra-supercritical technology, whose single-unit capacity (600-1,000 MW) is much larger than that of sub-critical and supercritical units (600 MW or smaller), allows power generation companies who are vigorously competing with each other to occupy the sites while rapidly expanding their total capacity. [45]

Despite progress, the implementation of the technologies in China, as described above, still lags behind the situation in OECD countries. Therefore, technology transfer will be important in accelerating their deployment in China in the medium term.[46]

Supercritical boilers use higher steam temperatures and pressures to increase the thermal efficiency of coal-fired power plants. Despite early unreliable experiences, the designs have been largely improved. Supercritical boilers are regularly installed in new power stations in China to replace the outdated small conventional coal-fired power plants. Some experts argue that supercritical and ultra supercritical boilers will be the most important option for power generation for China [47] for the foreseeable future.
End of pipe technologies to remove particulates, SO2 and NOx are becoming standard for new-build power plants in China, though implementation of these measures is still unsatisfactory. Many of the boilers in power plants have low NOx combustors. The new large power plants are equipped with electrostatic precipitators to remove soot from the flue gas [48]. After years of upgrading, 86% of Chinese power plants had installed electrostatic precipitators in 2001, compared with 60% in 1996[49]. Low NOx combustors are now compulsory for new power plants larger than 300MW. The existing power plants without it will be upgraded or replaced gradually. Unlike these measures, FGD has not yet been widely deployed in China. In 2000, only 3% of Chinese coal fired power plants (6.95 GW) had installed FGD [50]. FGD is compulsory in China for all the new power plants using coal with more than 1% sulphur content. Power plants larger than 300MW will tend to use Wet FGD (limestone-gypsum) or more advanced FGD technologies, while cheaper options such as rotary spraying or in-bed calcium injection is allowed for smaller power plants. Existing large power plants are also required to add FGD equipment. However, the enforcement of these regulations remains patchy at best. Even when FGD projects under construction are completed, only 5% of China's coal-fired plants will include this technology[51].

The Chinese government wishes to see large power stations equipped with FGD burn high sulphur coal and leave low sulphur coal for smaller boilers without FGD. China has mandated FGD for all the new plants and has created incentives to encourage companies to retrofit existing plants with FGD. The application of FGD has contributed to the gradual reduction of $S0_2$ emissions in China. In early 2007, China for the first time in history witnessed a decrease in total absolute SO_2 emissions.
The current situation in practice shows a somewhat different picture: to fulfill the more severe standards on large boilers low sulphur coal is burnt in large power plants while smaller boilers only have access to

high sulphur coals. Despite the government policy emphasizing the construction of larger, more efficient units of 300 to 600 MW power plants, the main increase in generating capacities consisted of hundreds of smaller units just a few years ago. In 2000, units smaller than 200 MW still represented 65% of a total capacity 237 GW, emitting 60% more CO_2 per kWh than larger units[52]. In 1999 the Nautilus Institute already expressed concern that many of the new plants being built by the local governments are in unit sizes of 50 MW or less. The main reason is that these small units are easier to finance. [53]
The improvement of existing power plants is encouraged by the NDRC; small power plants have to close because they are not efficient enough:
In 2010: power plants that produce less than 100 MW have to close down.
In 2020: power plants that produce less than 200 MW have to close down.
In 2030: power plants that produce less than 300 MW have to close down.[54]
In conclusion, more efficient designs of CCT can only be fully competitive, as lower fuel costs compensate for higher initial capital costs; however, the lack of up-front capital can still be a barrier. End-of-pipe techniques, such as FGD, always entail positive costs, and can only be disseminated thanks to environmental regulations.[55]

5.4.1 Integrated Gasification Combined Cycle (IGCC)

According to the China Coal Information Institute, China is at the same IGCC-stage as the rest of the world. Also most research capacity of foreign countries is in the area of IGCC.[56] The goal of China is to have installed capacity of IGCC to reach 20,000MWe in 2020.[57] IGCC offers similar efficiency to Ultra-Super-Critical Pulverized Coal (USCPC) plants. USCPC is cheaper, but IGCC offers better control of conventional pollutants, has a lower water demand, reduces solid waste, provides the possibility of H2 co-production, and offers lower cost to add CO_2 capture (to a new plant).

Table 5.4 Power generation Technology Comparison

Parameter	IGCC	Conventional	Supercritical	Ultra-Super Critical
Thermal Efficiency	48%	38%	41%	45%
CO2 (g/kWh generated)	676	854	790	721
NOx (g/kWh generated)	0.07	2.08	1.93	1.76
CO (g/kWh generated)	0.01	0.13	0.12	0.11

With current technology, cost of electricity from IGCC with carbon capture appears to be less than from pulverized coal with carbon capture (comparing new plants built from outset to do this). Cost per ton of avoided CO_2 emission is likewise lower for IGCC with Carbon Capture and Storage (CCS). [58]

Table 5.5: Comparison of power plant technologies

Capturing CO_2 with today's technology significantly reduces plant efficiency: Efficiency to electricity, net (HHV			
	Without CO_2 capture	**With CO_2 capture**	**Percentage difference**
AVG IGCC	39.5	32.1	-19%
PC-Sub	36.8	24.9	-32%
PC-Super	39.1	27.2	-30%
Cost of electricity comparison: Cents/kWh ($2007) * Coal cost $1.80/106 Btu			
	Without CO_2 capture	**With CO_2 capture**	**Percentage difference**
AVG IGCC	7.79	10.63	+36%
PC-Sub	6.40	11.88	+86%
PC-Super	6.33	11.48	+81%

Source: DOE/NETL Report: "Cost and Performance Baseline for Fossil Energy Plants", May 2007

According to the CCII, a bottleneck in the development of IGCC in China is the lack of coal gasification technology in China.[59] CCII also states that IGCC is not yet a fully mature technology, even in developed countries, where it delivers electricity at a higher cost of about 20%. The main risk factors include capital cost over-run (higher expenses than expected), construction delay, and shortfalls in plant availability and performance. The cost and the risk disadvantages are substantially higher in China, where the average cost of power generation from an IGCC plant would be 32% higher than power from a PC plant; the overall risk factor would be 23% greater, according to the Nautilus Institute[60]. In recent years, the great demand for new power plants has made manufacturers compete in a highly competitive market. This caused a rapid drop in PC equipment prices. But IGCC technology is still in a testing and demonstration phase and as a result the prices of IGCC equipment are relatively high. Also because some components need to be imported. Therefore, currently IGCC has no ability to compete on price with other advanced coal power technologies in the Chinese market. Even though IGCC technology cannot compete with conventional coal-fired power generation technologies, it has the potential to show its advantage and market competitiveness once the goal of CO_2 emission reduction is set in the country.[61]

A report of the United States Department of Energy elaborates further on the reasons for higher cost of IGCC over conventional PC: IGCC is less mature than PC, absence of warranties on IGCC hardware, lack of industry confidence, difficulties in obtaining financing, high cost of CCS. Cost reductions for IGCC will result from improved gasifier designs (more reliable and maintainable), cheaper air separation technologies (e.g. membranes), improved gas clean-up technologies, and utilization of advanced low-emission hydrogen turbines, and reduction in CCS costs and energy penalties.[62]

Nonetheless, China is becoming active in the development of IGCC technology, with several demonstration projects under construction or in planning, including:

- China approved the first IGCC demonstration project to be constructed in Yantai in 1999. When finished, it will have a capacity of 300-400MW. Expected to be completed in 2010.
- China Hua Neng Group started working on another 250MW IGCC demonstration project in Tianjin using a design developed by the Thermal Power Research Institute (TPRI).[63]
- China Huadian Corporation will build a 200MWe IGCC power plant in Hangzhou
- Dongguan Electricity and Chemicals Industry Co., Ltd. will build a 200MWe IGCC power plant and retrofit a 120MWe combined cycle power plant into IGCC.[64]
- The coal-based company Shenhua, employing 150,000 people, and largest coal producer of China is currently waiting for approval for building two IGCC power plants.
- The GreenGen Co., founded in 2005, with the important shareholders from the five largest power companies, two biggest coal companies and one important investment company, has the objective to design, build and operate the first IGCC power plant in China in 2009 and coal-based, near-zero-emission GreenGen power plant in China with independent intellectual property rights. The feasibility study report of GreenGen's 250MW generator set IGCC Project in Tianjin passed the examination successfully. The bidding of main equipments of GreenGen's IGCC Project in Tianjin is in process.[65] GreenGen intends to draw experts from all over China to establish a powerful technology support system. The website of GreenGen Co. says that GreenGen welcomes international cooperation, but what specific cooperation cannot be discovered.

5.4.2 Coal liquefaction

China has recently started to build coal liquefaction plants. As a result it is worthwhile to further analyze this development and discuss potential opportunities in the short as well as in the medium term.

Key Findings

- Coal-water mixture (CWM) is the first choice for oil substitution technology in the near future. However, it is not economically competitive in the long term. Therefore, development in this area should be moderate and focus should lie on other technologies that are economicly viable in the long term.
- Coal liquefaction technologies are suitable to be developed as strategic technologies and for some fuel oil substitution technologies; this is illustrated by the coal liquefaction centre in Shanghai.
- Fischer-Tropsch coal-to-liquids technology lends itself to low-cost CO_2 capture (~\$10/t CO_2)[66]
- Using coal to produce methanol and dimethylenther to substitute for fuel oil is under discussion. The technology development for the long term still needs comprehensive and comparative argumentation;[67]
- China is increasingly active in coal liquefaction due to its abundance of coal and its policy to decrease their dependency of oil imports.

Owing to soaring crude oil prices in 2008, China has to pay much more for its oil imports. Last year the country imported 163 million tons of crude, around 47 percent of total consumption. The gap between the high oil price abroad and the relatively low price of refined oil products at home (set by the government) is creating unsustainable losses for the country's oil refineries. The retail price for 93-octane gasoline in Beijing is for instance just 5.3 yuan (€0.46)(jun 2008) per liter. Any further rise in oil prices could push up the already high rate of inflation. And because energy-intensive industries still drive in China's rapid economic development, an additional rise in oil product prices might negatively affect GDP growth.
High oil prices have forced Chinese companies to invest in alternative energy sources to fuel the country's development. Analysts say China's coal industry will be able to produce 50 million tons of oil products in every year by 2020, which could help the country reduce its oil imports.[68]

Coal liquefaction and polygeneration (a plant producing electricity and useful heat) were in fashion in

China in 2006-mid 2007, because of the constant price increase of oil. Many projects were started up. In the second half year of 2007, the NDRC restricted permission of coal liquefaction companies because of their excessive use of water. According to the China Coal Information Institute (CCII), only large projects get approval, while the market demand for more projects is available. Authorities approve only projects that produce above a million tons of oil. Two active players in this field are Shenhua and the Yankuang Group; two state-owned enterprises. According to the CCII, coal liquefaction is in an early stage in China.[69] The 2008 report of the Energy Working Group of the European Chamber concludes that "Chinese policymakers focus on building the plant itself instead of streamlining the development conditions across its value chain. This means that they often do not implement the latest available technology. Also, as much of the attention is paid to develop advanced clean coal technologies such as IGCC, China should not ignore the "low hanging fruit" i.e. the huge potential of improving the existing thermal power plants. This is a relatively easy job to do for energy saving and pollution reduction. For instance, wider use of 'dry cooling technologies' (Air Cooled Condenser(ACC)) could also significantly reduce the amount of water used in coal-fired power plants."

China is pursuing research in both direct and indirect liquefaction of coal because of its interest in pursuing greater energy independence. An interesting fact is that in the US, government-sponsored research in direct liquefaction was halted during the late 1990s because the government decided there were too many disadvantages to the technology.
Poly-generation technology is favored by China's traditional coal-mining companies for several reasons. First, it offers an excellent opportunity to these companies to move into more profitable businesses including chemical production and power generation. Most of China's major coal mines are located in less-developed regions. Recent reforms that transferred their ownership from the central government to local governments have motivated the latter to adopt strategies that can generate more profit from their coal resources. The central government also adopted policies to encourage small coal-mining companies to merge into large firms so that they can survive in a competitive market. Aggregation also enables the newly formed large companies to adopt complex technology such as poly-generation technology. Methanol from coal-based poly-generation plants, however, encounters many barriers upon entrance in the automobile-fuel market in China, which is controlled by a few large, vertically-integrated firms.[70]

The Shenhua liquefaction project
Shenhua Group is leading in the field of activities on coal-to-liquid and coal to chemical. Shenhua is building a coal-to-liquid plant located in Erdos, in Inner Mongolia which is scheduled to be completely active in September 2008.
Shenhua teholdslls that the plant is a direct liquefaction plant with its own developed technology. The plant uses a license of Shell for gasification, which is part of the liquefaction process.[71] The plant is expected to convert 3.5 million tons coal per year into 1 million tons of oil products such as diesel.[72] Shenhua is investigating indirect liquefaction based on the Fisscher Tropsch method together with Sasol, Shell and BP. Shenhua is also investigating the option of building a new liquefaction plant with Shell in Ningxia. At the moment unacceptably high costs of building the plant form the most important burden for Shenhua. This is why the building of the plant has not been started yet. Shenhua evaluates the increasing building costs of potential projects, with the increasing oil price. As long as the oil price keeps rising, this offsets the increased building costs. At an oil price of $50 a barrel, a coal-to-liquid plant turns break-even, regarding current manufacturing and building costs at Shenhua.[73]

Coal liquefaction centre in Shanghai
China has set up its first coal liquefaction research centre in Shanghai, a strategic move to safeguard the nation's increasing oil supply shortage. Three energy and industrial companies, Shenhua Group, Shanghai Huayuan Group and Shanghai Electric Group, jointly invested more than 100 million yuan (EUR 10 million) in the centre. Shenhua has taken an 80 per cent stake in the research centre. Local industrial companies Shanghai Huayuan Group and Shanghai Electric Group have taken 10 per cent each. The centre mainly explores and develops direct and indirect coal liquefaction technologies. China is now the second-largest oil consumer in the world after the United States. It is widely expected it will import half of its oil consumption by 2010.[74]

5.5 Clean Coal Technologies in the long term (10 or more years)

- Carbon capture and storage (CCS) (5.5.2)

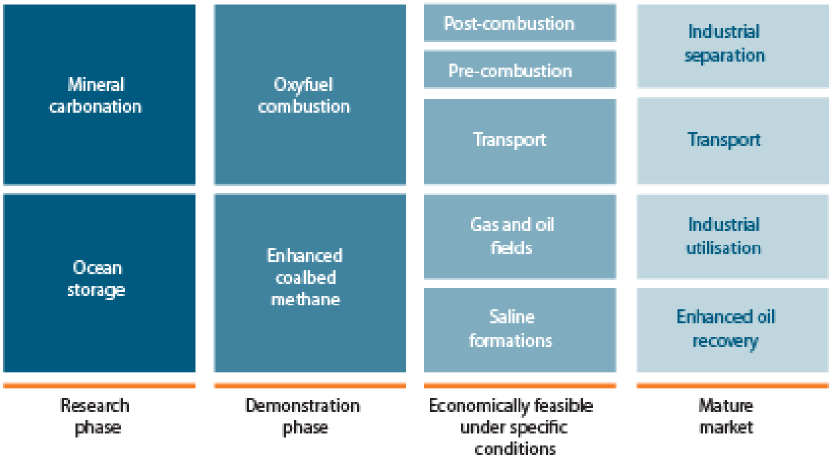
Key findings:

- Post-combustion CCS technologies are most appropriate for China's existing power station stock and most stations that will be build in the next 10-15 years, as most of them will not be based on IGCC technology.
  Pre-combustion capture is most efficient and therefore cheapest technology but can only be applied
  when coal gasification technology is employed, such as present in integrated gasification combined-cycle coal-fired power plants.
- While the prospects for CCS in China are very good, the market is still underdeveloped. This particularly concerns the demonstration, regulation, cost perspective, transportation and storage options. This is why China's powerful National Development and Reform Commission (NDRC) is not an active supporter of this technology.
- CCS is currently awaiting approval as an endorsed project activity under the CDM, which is an issue of considerable controversy and diverging political views in the international climate negotiations.

5.5.1 Carbon Capture and Storage

There is a growing recognition that technology developments have to be part of the solution to climate change. The greatest potential is offered by carbon capture and storage (CCS) which can reduce CO_2 emissions to the atmosphere by 80-90%.[75] But, because political discussions are still ongoing and the technology is still partly in its infancy, it represents a CCT which might be feasible only in the long term. (See figure 5.2)

Figure 5.2 Maturity of CCS Technology

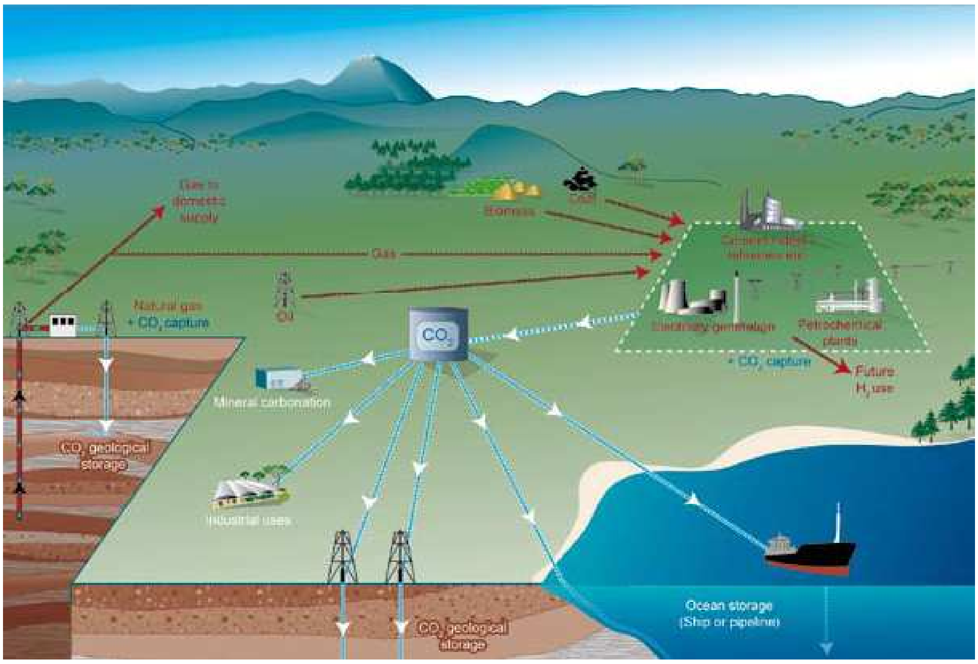


Source IPCC 2005 cited by World Coal Institute (2007)[76]

While all the elements of CCS have been separately proven and deployed in various fields of commercial activities, a key aim is the successful demonstration of fully integrated large-scale CCS systems and optimization of the various processes. Such large-scale demonstrations would help to lower costs and provide a critical mass of scientific data for proving that operations, monitoring, verification, and mitigation can be carried out in a manner acceptable to regulators and the public. Supporting policy and regulatory environments also have to be developed for these Research, Demonstration & Development (RD&D) activities.[77] By 2030, China is anticipated to have significant CCS capacity, and by 2050, China will account for the largest global CCS (under the ACT MAP scenario as described by the IEA).[78]
CO_2 capture technology is already widely used in ammonia production and other industrial manufacturing processes, as well as oil refining and gas processing. CO_2 gas is being transported through pipelines and injected underground for decades, most notably in west Texas, where it is used to enhance oil recovery from wells in which production is declining (the injection of CO_2 facilitates the recovery of oil).

CO_2 Capture; pre-combustion capture most efficient and cheapest

CO_2 capture technologies can be divided into three categories: post-combustion or "end-of-pipe" CO_2 capture, relying on chemical or physical absorption of CO_2;pre-combustion CO_2 capture technologies that separate $CO_2$from a syngas fuel (produced from coal, oil, or natural gas) before the fuel is burned; and oxyfuel combustion, in which oxygen instead of air is introduced during the combustion process to produce a relatively pure stream of CO_2emissions. Of these options, pre-combustion capture is currently the most efficient and therefore the cheapest. In the case of coal-fired power plants, however, pre-combustion capture can be applied only when coal gasification technology is employed, such as in integrated gasification combined-cycle coal-fired power plants. [79] Post combustion CCS technologies are most appropriate for China's existing power station stock and most stations that will be build in the next 10-15 years, as most of them will not be IGCC.



The technology CO_2capture and storage (CCS), may come at the right time, making it possible, in principle, to continue using coal, while drastically reducing its emissions. But the technology still needs to be applied at large scale, is not cheap and has risks that need to be controlled. Point sources need to be large to make it economically attractive to capture CO_2. Examples of such sources include power plants and natural gas production wells. Capture can occur by separating $CO_2$from flue gases or natural gas, eg through chemical absorption or membrane technology. The capture step is by far the most costly component of CCS and research is underway to find more efficient capture processes. Although there are no full scale power plants with CO_2 capture facilities yet, several are planned and no major technological challenges are expected. [80]

China is rapidly becoming one of the main suppliers of modern 'supercritical' coal-fired power plants. It is already building such plants in large numbers and is moving to the most advanced technology: integrated coal gasification systems. This technology has much lower air pollutant emissions and is the cheapest when it comes to adding CCS, possibly even through retrofitting. China could, with appropriate additional investment made available, eg through cooperation such as the zero carbon power consortium of China, the EU and the UK, become a leader in coal gasification-based CCS power plants, in conjunction with major international corporations.[81]

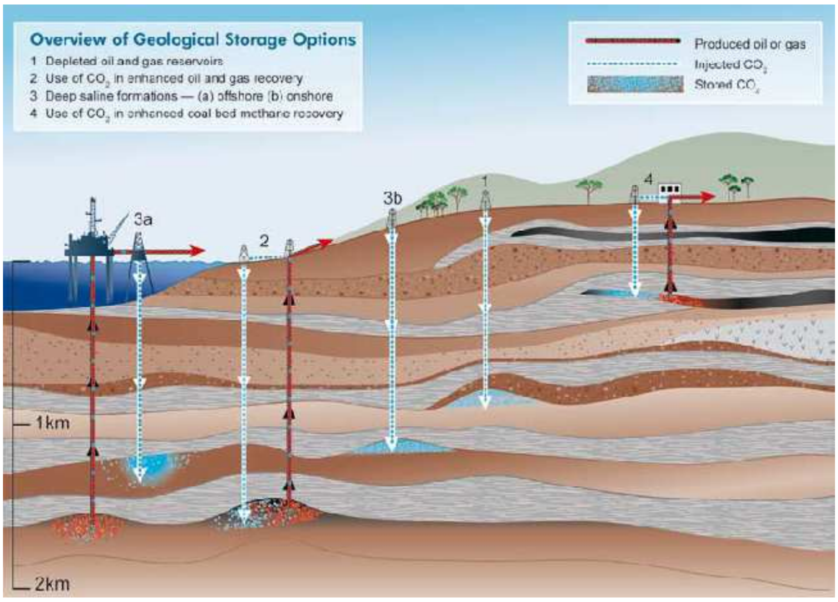
CO_2 Transportation

Figure 5.3 Schematic diagram of possible CCS Systems
Source: Intergovernmental Panel on Climate Change [82]

CO_2 is largely inert and easily handled and is already transported in high pressure pipelines. The technology for CO_2 transportation and its environmental safety are well-established because it is already used in the gas industry.[83] CO_2 can be best transported by pipeline or ship. Ships are cost-effective only if the CO_2 must be moved more than 1,000 miles.[84]

Storing CO_2

Figure 5.4 Methods for storing CO_2 in deep underground geological formations
Source: Intergovernmental Panel on Climate Change [85]



Three alternative approaches to storing CO_2 in a reservoir other than the atmosphere have been proposed: geological storage, storage in the ocean, or aboveground land storage. Geologic storage is currently the most promising approach. It involves direct injection of CO_2 into underground geologic formations. (see figure 5.4)

More research is needed on all technical aspects of sequestration, fundamental processes (e.g., pore behavior), leakage rates and safety, storage capacities, and measurement-monitoring-verification, as well as on policy aspects including permitting and liability.[86] The best geologic options, based on current understanding, are enhanced coal bed methane recovery (ECBM), enhanced oil recovery (EOR), depleted oil and gas fields, unmineable coal seams, and saline reservoirs. The largest capacity worldwide is in saline reservoirs.[87] Interesting academic research work one CO_2 storage is done by Prof. Celia and his research group on subsurface hydrology, from Princeton University.

The map below is showing rock formations categorized as highly feasible for CO_2 storage.

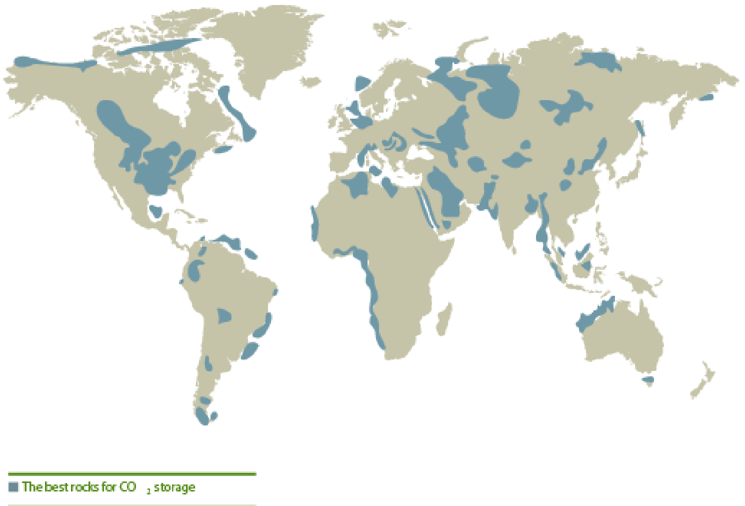


Figure 5.5 Rocks categorized as highly prospective for CO_2 storage

Source IPCC (2005)[88]

The figure 5.5 below shows the location of sites worldwide where geological storage of CO_2 and CO_2 enhanced oil and gas recovery takes place.

CCS technology is integrated into the National Medium- and Long-term Science and Technology Development Plan towards 2020. Theoretically, there is capacity for storage of large quantities of carbon dioxide in saline (dissolved salts) aquifers or depleted hydrocarbon fields in China. However, many of these are remote, and are not close to the majority of large point sources such as power plants[89]. A feasibility analysis of the potential and scope for accessible carbon storage is still needed before the extent of CCS is known with any certainty.

Figure 5.6 Location of sites where geological storage of CO_2 and CO_2 enhanced oil and gas recovery takes place

Source IPCC (2005)[90]

Nevertheless, several Enhanced Oil Recovery (EOR) projects have already been implemented in Chinese oil fields. These are being pursued for economic reasons rather than any strategy to explore CO_2 storage for climate change mitigation. In addition to this, there are several other early signs of Chinese interest in CCS technologies. China and several other developing countries are involved in the work of the Carbon Sequestration Leadership Forum (CSLF).[91]

Another international effort to accelerate the deployment of CCS is the IEA Greenhouse Gas R&D Programme (IEA GHG). European initiatives are: The Zero Emission Technology Platform, The Carbon Capture and Storage Associations, Competency networks including CO2NET and CO2GeoNet. Germany's own R&D programme is called COORTEC. China related initiatives are GreenGen, nZEC (the UK-China Near Zero Emissions Coal project) and MoveCBM.

Enhanced recovery of oil and gas as well as enhanced coal-bed methane production bring economic benefits that offset sequestration costs. As a result, these applications are particularly attractive for early implementation. But, unlike technology transfer, "geology can't be transferred"; thus geologic assessments of sequestration potential must be done for every region with large CO_2 sources. These assessments are large tasks and for most regions have barely begun.[92] The feasibility of CO_2 storage in coal beds, with or without the recovery of coal bed methane, depends strongly on the permeability of the reservoir.[93]

CCS in perspective

The cost of CCS is project specific, depending on the technology of the plant producing the CO_2 and on the adequate storage resources. Overall, the high costs and technical uncertainties of CCS technologies because of technological immaturity, mean that it is unlikely to be considered for new power plants by China's National Development and Reform Commission (NDRC) which is not an active supporter of the CCS technology. However, developed countries such as the UK are hoping to persuade China to build 'capture ready' plants that can have CCS technology added to them relatively easily in the future.[94]

CO_2 capture technology itself is energy-intensive and requires a substantial share of the electricity generated. Accounting for the corresponding power plant efficiency reduction (up to 30%) by expressing costs in dollars per ton of CO_2 avoided, the costs of CCS in power plants range from \$25 to \$70 per ton of CO_2 avoided.

Currently, these cost estimates are dominated by the cost of capture (including compression). If transport distances are less than a few hundred miles, the cost of capture constitutes about 80% of the total costs.[95] Unlike the other power generation technologies, which will become competitive as additional cumulative capacity is added, CCS will always require a carbon price of at least USD 50/t CO_2 to make it cost-efficient.[96]

Finland enacted a carbon tax in 1990, the first country to do so. The current tax is €18.05 per tonne of CO2 (€66.2 per tonne of carbon) or \$24.39 per tonne of CO2 (\$89.39 per tonne of carbon) in U.S. dollars (using the August 17, 2007 exchange rate of USD 1.00= Euro 0.7405). Sweden enacted a tax on carbon emissions in 1991. Currently, the tax is \$150 per ton of carbon, but no tax is applied to fuels used for electricity generation, and industries are required to pay only 50% of the tax. [97]

CCS is currently awaiting approval as a project activity under the CDM, which is an issue of considerable controversy and diverging political views in the climate negotiations.[98]

Current CCS projects

Perhaps the most concrete move towards demonstration of CCS in China so far is the near-Zero Emissions Coal (nZEC) project, which is part of the EU-China Partnership on Climate Change announced at the EU-China Summit in September 2005. The project is planned in three phases following agreements signed by the Chinese Ministry of Science and Technology, the UK Government, and the European Commission. The UK government is leading the first phase with £3.5m of funding, which is a three year feasibility study. This study will examine various technological options to capture CO_2 emissions from power generation and explore the potential for geological storage in China. The ultimate target is to demonstrate near zero emission coal fired power generation at commercial scale by 2020. Progress in implementing the first phase is slow so far, whilst details of funding for the second and third phases have yet to be revealed.[99] In contradiction to this ambitious goal, the IEA assumes that carbon capture and storage will not be commercially attractive by 2030 in China[100].

Another demo project is that of the Huaneng Group that signed an agreement with the Beijing Municipality in August 2007, to construct a demo CCS project on Huaneng Beijing Cogeneration Plant.[101] This is a Sino-Australia co-operation project. Currently, the plant produces 10% of the total energy power of Beijing, 30% of the total needed heat of Beijing and 70% of the needed steam of Beijing.[102]

The capture of CO_2 has already started. The designed CO_2 capture percentage is 85%, and annual capture capacity is 3000 tons. After the processing, the captured CO_2 will be used for food industry.

Figure 5.7 Huaneng Beijing Cogeneration Plant

Coal giant Shenhua Group is collaborating on CCS with the US Government, Shell, BP and Sasol and two Universities: the China Mining University and the China Technology University.

Some European companies have already developed pilot projects of CCS to capture and sequestrate CO_2

under the maturing oil field and enhance oil recovery rate at the same time. China could encourage the adoption of such advanced technologies by teaming up with those European companies in a few selected pilot projects.

Although China is closely following the R&D activities being performed in the world to better understand the mechanism of CO_2absorption and sequestration, more active engagement is needed, according to the Energy Working Group. More demonstration programs such as the Chinese GreenGen program, mentioned above, and cooperation projects such the European program COACH are needed.[103]

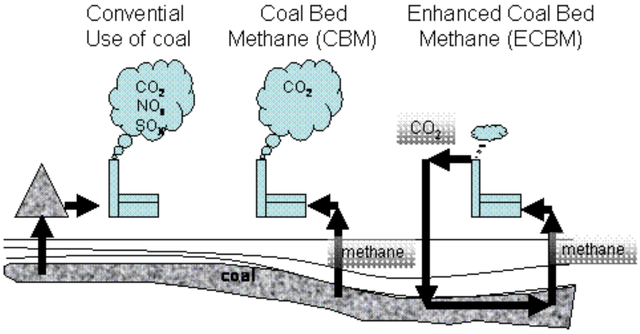
General barriers to large/scale deployment of CCS

- **Legal and regulatory barriers:** legal guidelines regarding the injection of CO_2 and long-term liabilities must be established, a regulatory framework must be defined, and risk-management procedures that include monitoring and remediation must be developed.
- **Commercial and financial barriers:** a global market that can value CO_2 must be created. In addition, governments need to create a framework and an infrastructure for enabling efficiencies.
- **International mechanisms:** economic incentives for CCS need to be developed and agreed on.
- **Technical barriers:** Research, Demonstration and Development (RD&D) must be accelerated, with the objective of improving reliability and reducing costs. Potential leakage routes and long-term isolation procedures need to be identified.
- **Public awareness:** education and outreach to all stakeholders are crucial.[104]

5.5. Enhanced Coal Bed Methane

From coal beds, methane gas (also known as 'mine gas') can be harvested, so-called Coal Bed Methane (CBM) production. This is done by drilling a well, lowering pressure in the coal layer and pumping up the methane. Combustion of methane is cleaner, but still large amounts of CO_2 are emitted. When CO_2 is injected into a coal layer, a larger amount of methane can be harvested. This is called Enhanded Coal Bed Methane (ECBM). As the CO_2 is absorbed by the coal, this also leads to effective underground storage of CO_2. See the figure below for a schematic overview.

Fig 5.8: Coal exploration options



Source: Condensed project proposal – Asia Facility for China

According to the CCII, Coalbed Methane (CBM) is a technology which makes the use of coal(gas) less polluting and dangerous. CBM can be an important resource for China, because China possesses few domestic gas resources. Therefore the government is developing more favorable government policies for CBM.[105] Apart from natural gas deposits, China also has large deposits of coal bed methane. Coal Bed Methane (CBM) is natural gas associated with coal resources and absorbed in coal seams. It consists of more than 95% of methane, making CBM potentially the most likely successor of conventional natural gas resources. Once an economically viable breakthrough in CBM production is achieved, CBM development projects could play an extremely important role in China's energy consumption pattern. Although the potential certainly exists, there are doubts whether CBM production will ever become well established, partly because there are problems related to this kind of production (such as the release quantities of saline water) and partly because Chinese CBM deposits have a very low porosity, making it costly and possibly uneconomic to produce it. Substantial efforts from domestic and foreign investors have thus far been undertaken to produce CBM, amounting to investments of some US$ 76 million into international CBM projects by the end of 2000 and more than 250 wells drilled. However, no commercial CBM schemes have been established in China for several reasons so far, despite the fact that the government has identified coal seal gas as an energy resource of strategic dimension.[106]

China's coal bed methane (CBM) potential is estimated to be one of the world's largest—between 16,000 and 35,000GNm3 (Zhang and Zhang, 1996). However, the CO_2-ECBM potential is uncertain. Stevens and Kuuskraa (1998) identified the Ordos Basin and the Northeast China Coal Region as regions with the greatest CO_2-ECBM potential. Relatively low-cost CO_2 storage demonstration projects could be carried out at a number of sites in China where low-cost concentrated CO_2 is available. This particularly applies to coal-fed ammonia plants that are located near underground sites where CO_2 might be stored. Nine currently operating or planned ammonia plants were identified where the streams of essentially pure CO_2 are available at annual flow rates between 570 and 1070 kt of CO_2 per year. Based on these CO_2 sources, four possible CO_2 storage demonstration projects for storage in deep saline aquifers were identified. The costs for compressing, transporting and storing the CO_2 for these projects ranged from \$15 to \$21/t of CO_2, the corresponding total project costs range from \$15 million to \$18 million dollars per year, and the investment required per project ranges from \$56 million to \$71 million.

Funding for CO_2 storage demonstration projects in China would most likely come from some mix of government, multinational agency, and private company sources, with most of the funding needed coming from sources outside of China. Successful CO_2 capture and storage demonstrations in China and elsewhere could help pave the way for eventual widespread deployment of these technologies, both in China and the rest of the world.[107]

China United Coal bed Methane Corp. (CUCBM) is a state-owned company in China. Until several years ago CUCBM had the exclusive rights to explore, develop and produce coal bed methane in co-operation with overseas companies. Now an increasing number of Chinese gas firms are allowed to co-operate with foreign companies as China seeks to boost clean energy use by encouraging funds and technology from abroad. Since its foundation, CUCBM has drilled CBM wells which amount to 85% of the national total and acquired the proven CBM resources which have been approved by the government.[108]

Noteworthy Coal bed Methane projects

In December 2007 Shell has joined in a Chinese coal bed methane project. Shell China Exploration and Production Company Limited acquired a 55% equity interest in a coal bed methane venture in Shanxi Province and will take over as operator. In addition, China's Ministry of Commerce recently approved an agreement for Shell to acquire Verona Development Corporation's majority equity position in a 30-year production sharing contract covering the North Shilou block, an area of 1,015 square kilometers in the eastern part of the Ordos Basin. Verona maintains a 5% interest in the venture with China United Coal Bed Methane Company (CUCBM) holding the remaining 40% equity.

Noteworthy CBM projects in China are listed in the figure below.

Table 5.7 CBM projects in China

Area	Project Title	Outline
CMM to power	Jincheng	2,900,000 CERs per year, 10 year crediting period, follow the methodology of Hegang CBM for power project.
CMM to power	Nanshan 1.8MW	62,400 CERs per year, 10 Year Crediting period, New Methodology, NM0066
CMM to Furnace	Yangquan (1)	>600,000 CERs per year, 10 year crediting period, requires new methodology
CMM to power& flared excess	Panshan 4MW, Huainan	278,000 CERs per year, 10 Year Crediting period, New Methodology, Aim to submit to28th October Methodology Panel round

ANNEX V: DESCRIPTION OF THE CRITICAL FACTORS OF MADU (1989)

- **Needs and objectives** The active participants will identify needs and objectives. They identify the problems and the ability to satisfy and solve these problems.

- **Capabilities** The capabilities identified can be in terms of human resources, capital, natural resources, land and others. Some of these capabilities will enhance the growth of particular industries and make it cheaper to transfer certain forms of technology.
- **Education, Training, Research and Development** In order to be able to modify and improve technology, the recipient of the technology must be sufficiently capable of maintaining an introduced production system. Innovation and technology modification can only exist if those concerned have a full understanding of the technology.
- **Identification and Implementation of Appropriate Technology** According to Ladman (1977 cited by Madu, 1989) This issue has received great attention; as has often happened, the MNCs are blamed for transferring inappropriate technology. This is because the technology is often capital intensive and ill-suited to the local production needs.' The success or failure of technology transfer also depends on the ability of the receiving nation to identify the right technology for its needs.
- **Managerial effectiveness** In order for the implementation of new technology to be effective, managers must be innovation-oriented. Managers need to be both sensitive to their environment and committed to the new technology. Since this construct is on a company-level and not on a national level, this construct will not be researched.
- **Stable governments and political systems** Governments view technology transfer as part of the foreign policy arena. Governments can therefore have a significant impact on promoting or hindering the transfer process.

Appraisal of the above described factors helps to identify future obstacles in technology transfer.

ANNEX VI: INTERVIEWS

1. Email contact with Annemarieke Grinwis – VROM – Language Dutch
2. Extra minutes Shell
3. Question list Ilse Pauwels – VROM – Language Dutch
4. Interview with TNO Geosciences
5. Minutes Lecture of Michael Celia (Princeton) @ Peking University
6. Minutes conversation Dutch Embassy and The China Coal Information Institute (CCII)
7. Visit to China University of Mining & Technology (Beijing)
8. Visit to Shenhua Group
9. Interview with Bert Bekker, EEP

Email contact with Annemarieke Grinwis – VROM – Language Dutch

Annemarieke Grinwis

Beste Ilse

Hierbij stuur ik je mijn antwoorden op de vragen van Rik van den Berge . Ik vertrouw er op dat jij ze naar hem zal door geleiden.

1. Nederland is vooral actief op het gebied van IGCC en CCS zowel qua onderzoek als bij de toepassing in installaties (IGCC full scale, CCS op pilot schaal met plannen om dit jaar naar middelgrote schaa l op te

scalen en in 2015 naar frote demonstratie/full scale). ECBM is met name een onderwerp dat in de onderzoekswereld aan de orde is. Voor zover ik weet is coal blending en kwaliteit van kolen een onderwerp dat in het verleden veel aandacht had, maar dat is nu minder het geval.

Wat nu de 'competitive advantages' van NL precies zijn is de vraag die m.i. in dit onderzoek beantwoord moet worden. Daartoe moet de situatie in NL en China met elkaar vergeleken worden en beoordeeld worden wat NL China kan bieden en wat dat voor NL oplevert.

2. Er wordt momenteel samengewerkt door NL'se kennisinstellingen met China op het gebied van kennisuitwisseling over CCS, ECBM, dus dat is haalbaar en levensvatbaar. Ik heb geen zicht op samenwerkingen tussen NL'se technologieleveranciers, zware industrie zoals electriciteitsbedrijven, raffinaderijenen Chinese partners.

3. Voor coal blending zou ook TNO Built Environment en Geocience in Utrecht benaderd kunnen worden (contactpersoon H. Pagnier).

4. VROM werkt aan aan het programma Schoon en Zuinig; op het gebied van CCT wordt vooral gewerkt aan CCS gericht op de energiesector en halvering van het gebruik van fossiele grondstogffen in de chemische industrie.

Vriendelijke groet,

Annemarieke Grinwis

Geachte ,
De Nederlandse Ambassade in Peking is op dit moment bezig met een onderzoek voor Nederlandse organisaties. Het onderzoek richt zich op de Chinese markt voor Clean Coal Technologies en de specifieke marktkansen voor Nederlandse organisaties. Voor het onderzoek ben ik ook opzoek naar specifieke Nederlandse organisaties die zich bezighouden met coal blending, IGCC, CSS en ECBM.
Wat zijn volgens u de 'competitive advantages' van Nederland op het gebied van schone kolen technologie en bent u het eens met mijn gedachte dat Nederland vooral actief is/wordt in coal blending, IGCC, CSS en ECBM?
Is er met deze competitive advantages op een specifiek kennisterrein, kennissamenwerking met Nederlandse organisaties haalbaar en levensvatbaar?
En wat zijn mogelijk factoren voor het beoordelen van het samenwerkingspotentieel/Verkooppotentieel van kennis en technologie richting China.
Via internet heb ik enkele organisatie gevonden en benaderd, maar het aantal organisaties actief op het gebied van coal blending welke ik heb kunnen vinden, valt me tegen: KEMA en EMO. Mogelijk weet u of er meer zijn?
Graag wil ik bij u informeren wat VROM precies doet op het gebied van CCT binnen het Schoon en Zuinig programma en of dit mogelijk iets kan bijdragen in China.
Aangehecht vind u een versie van het market report in wording. <<Management

Summary.pdf>> Ik ben benieuwd naar uw mening.
Ik hoop dat u mijn vragen kunt beantwoorden.
Kind regards / met vriendelijke groet,
Rik van den Berge

2. Meeting with Shell @ South Beauty 11.00
Henry Wang
Gu Jing

Clean Coal Technologies in China on the short term (one year or less)

- Coal washing
- Various efficiency improvements
- Small circulating fluidized bed boilers

Clean Coal Technologies on the medium term (2-10 years)

- Larger scale fluidized bed boilers
- Supercritical boilers for coal fired power plants
- Flue gas desulphurisation (FGD)
- Coal gasification

Clean Coal Technologies on the long term (10 or more years)

- Integrated Gasification Combined Cycle (IGCC)
- Carbon capture and storage (CCS)
- Coal liquefaction

Do you agree on this list?

Does Shell have activities regarding coal washing or other efficiency improving Technologies?
Does coal washing for European countries is performed in the coal producing countries and then shipped or first shipped and then washed etc.?

30 Years of experience in coal gasification
By the end of 2007, Shell has so far licensed its coal gasification technology to 16 projects in China.
Is this information still correct?

IGCC Power Plant in Buggenum, The Netherlands
Is Shell already active in selling buildup know-how of this plant to China? Or cooperation with Shenhua

Coal Liquefaction
Mr. Lu Bing, GM Dept. of International Cooperation.
What are the activities regarding the CTL plant in Ningdongin in relation to the MoU of Nov 2004?

Carbon Capture and Storage
The Netherlands have got a relatively big empty gas field where CO2 can be stored and the North Sea.
What are the activities of Shell regarding CCS in China?
What are the best CO2 storage options in China? geological storage, storage in the ocean, or aboveground land storage. How do you see the possibilities of enhanced coal bed methane or CO2 storage in depleted coal beds?
Are there enough suitable storage locations near to CO2 point sources?

Do you agree on the sentence that China is potentially the largest market for clean coal Technologies?

On what Clean Coal Technologies is Shell going to focus in the short, medium, long term?

CCII states that China wants clean coal technologies for free from Western companies. How do you see this?
Biggest barriers for clean coal technology to China?
- lack of governmental funding
- technology transfer lacking (because of IP-rights or poor design and implementation)
-strategy of multinationals: exporting only equipment, not technology and transferring outdated technology to China or asking to high costs.
- No direct technology transfer to power plants but to equipment manufacturers. How does Shell handles this?
Does Shell encounters problems in practice, when transferring technology from Europe to China?
Technology leapfrogging?

What kind of technology transfer does Shell supports looking at specific problems like IP-rights protection. Which flows?
A: capital goods, engineering services, managerial skills, product designs
B: Skills and know-how for operation and maintenance
C: Knowledge, expertise and experience for generating and managing technical change.

Shell's gasification technology has the lowest CO_2 emissions per ton of coal feed, compared to its competitors.

Source: Shell Gas & Power – Clean coal energy (2007) Royal Dutch Shell, The Hague, The Netherlands

Shell is not transferring technology: only license.
CTL only equity joint ventures, no license.
Supports to licensee also include
- document review

- technical training

- On-site commissioning and start-upm support
- performance test support

- Overall operational support:

  - Accumulated gasification operation experience

  - Shell's technological advantages world wide

Shell is new in China and has to prove
Engineers from NL are to expensive
Service Center with 28 engineers → 90% Chinese
First Multinational company with a service center on clean coal technologies

IGCC is expensive looking at it standalone. Looking at life-cycle costs, it's more cheaper, because of more CER's and CDM's it's more profitable.

3. Question list Ilse Pauwels – VROM – Language Dutch

Gesprek met Ilse Pauwels
donderdag 22 mei ’08
Tijd ~11.30

Wat doet VROM precies op het gebied van CCT?
Schoon en zuinig programma in China
Activiteiten Vrom in Clean Coal werkgroep ChinaCouncil
Dutch competitive advantages in CCT?
Aansluiting vraag naar- en aanbod van kennis en technologie op het gebied van CCT in China.
Nederland moet een bijdragen gaan leveren aan de oplossing voor energie inefficiëntie en vervuilingsproblematiek
door schoner en zuiniger met energie om te gaan: consumenten, bedrijfsleven en overheid
Factoren voor het beoordelen van het samenwerkingspotentieel/Verkooppotentieel van kennis en technologie richting China
Hoe beoordeelt u de toegankelijkheid van de Chinese vraagmarkt voor samenwerking met Nederlandse organisaties/clusters?
Op welk kennisterrein lijkt kennissamenwerking met Nederlandse organisaties u het meest haalbaar en levensvatbaar?
Welke eventuele benaderingsstrategie zou u aan Nederlandse organisaties voorstellen?

4. Interview with TNO Geosciences

9-5-2008

Eric van Kooij
Frank van Bergen
Henk Pagnier

CO2 Storage in Coallayers
Capture of CO2
1 Post-combustion **TNO**-MEP
2 Pre-combustion ECN
3 Oxy-combustion process → **<u>Denitrogenated conversion TNO-MEP</u>**

The electricity sector is one of the leading candidates for CO_2 capture,

representing 52 to 89 percent of total CO_2 capture, for the different scenarios analysed, in the period 2020-2040.

Questions
What are the research needs and gaps for carbon capture technologies in China?

What are the remaining IGCC and co-production technical challenges?

What are the top priorities for carbon capture technology development?

Carbon Storage Mapping in coal layers China?

Notulen gesprek NL Ambassade en TNO Built Environment and Geosciences		
Datum / begin- en eindtijd	vrijdag 9 mei 2008 /15.00-17.00	
Locatie	NL Ambassade Peking	
Aanwezig	**H. (Henk) J.M. Pagnier** Manager CO2 Storage TNO Built Environment and Geosciences Geological Survey of the Netherlands Princetonlaan 6 P.O. Box 80015 3508 TA Utrecht T +31 30 256 46 06 M +31 6 533 378 28 F+31 30 256 46 05 henk.pagnier@tno.nl	**Frank van Bergen** Geologist/Geochemist TNO Built Environment and Geosciences NITG/Geological Survey Princetonlaan 6 P.O. Box 80015 3508 TA Utrecht T +31 30 256 46 22 F+31 30 256 46 05 frank.vanbergen@tno.nl
	Eric van Kooij NL Ambassade	Rik van den Berge NL Ambassade

Besproken	
1.	Heren van TNO hebben een gesprek gehad met PetroChina en China United Coal Be Methane om te praten over de locatie van een CBM injectiesite. De insteek investeri 50-50, waarbij Europa de ene helft betaald en China de andere helft. De praktijk is m anders.
2.	Eric heeft clusteraanpak ambassade uiteengezet

3.	TNO heren hebben het unique selling point van TNO: het multidisciplinair systeem denken uiteengezet.
4.	De activiteiten van TNO met betrekking tot CBM zijn besproken, waarbij CO2 wordt geïnjecteerd in kolenlagen waardoor methaangas uit de mijn gepompt kan worden. TNO heeft een van de grootste Carbon Capture and Storage (CCS) groepen in Europa.
4.	TNO geeft aan ondersteuning te willen van de ambassade wat betreft hun project voorstel Azië faciliteit. Hierbij ligt de nadruk op het om het opzetten van een Enhanced Carbon Capture and Storage (ECBM) kenniscentrum bij het State Key Laboratory of Coal Conversion, in Taiyuan, Shanxi. TNO vraagt expliciet of de NL Ambassade bij de EVD wil polsen hoe de project aanvraag ervoor staat. Ook geeft TNO aan mee te willen tenderen bij het Europees programma voor een CCS site in China.
5.	CATO is gericht op het creëren van een netwerk en kennisinfrastructuur in Nederland om complexe lange termijn processen mbt Clean Fossil Fuel (CFF) systemen beter te begrijpen en ondersteunen. Het CATO project wordt eind 2008 opgevolgd door CATO2, met een 100 miljoen onderzoeksprogramma. CATO2 wordt getrokken door TNO. Het 8e werkpakket, als onderdeel van CATO2, wordt kennisuitwisseling met emerging economies, waaronder China.

5. Minutes Lecture of Michael Celia (Princeton) @ Peking University
24-6-2008 14.30

Introduction
Introduction of CO2 emission problem.
Current emission worldwide 30 Gt/year
2058: 60 Gt/year

To fight CO2 emissions, CCS has to be implemented at 800 large-scale power plants.
Rate of building power plants in China 1-2 per week
Information about storage capacity can be found in an IPCC publication of 2005
(I checked this. This are worldwide estimates not specifically focused on countries or regions)

Celia states that at the moment countries get huge problems like water pollution and agricultural productivity lowers, they will implement CCS out of itself and not because of international pressure.
"Climate change will make countries act when they get problems"
Celia thinks that China could even act before the US. Prime movers can make serious money.
CCS must be done commercially: someone has to make money of it.

An increase of the electricity price (even an 100% increase) is not per se a negative thing. Because you should not be allowed to use resources as a waste dump. You have to pay to clean things up.

The rest of the talk was about CO2 injection in Brine fields and leakage simulation models. Possible simplifications of leakage simulations, fast numerical models, Monte Carlo simulations etc.

Interesting facts

- Celia and a student of his has made a publication on early CO2 storage opportunities at an ammonia plant in China.
- Celia cites a McKinsey report on the economics of low-carbon economy at essentially zero-costs.
- Norway will build two commercial CSS projects in the coming 5 years.

6. Minutes conversation Dutch Embassy and The China Coal Information Institute (CCII)

Datum / begin- en eindtijd	Dinsdag 20 mei ’08	
Locatie	CCII 35 Shaoyaoju Chaoyang District, Beijing	
Aanwezig	Li Hongjun Ph.D. International division for energy and safety lhj@pku.org.cn	Jinyan Wu Master (mineral processing Clean energy & Environme Centre Energy & Safety Division sailing_wu@163.com
	William Sun NL Ambassade	Rik van den Berge NL Ambassade

Review of main topics	
1.	William explained the way of working of the Dutch Embassy and explained the Ener transition model.

	The CCII points out that they are very interested in this way of working. This way of working can be very helpful to China because successful experience from the Dutch side can be brought to China.
2.	**Former projects of the CCII** The British government has some specific environmental programs and knowledge transfer projects. The British Trade and Investment Ministry cooperates with CCII to investigate the emerging demand for clean coal in China. Then they investigated how they can make use of British technologies. The results of this study will be public this year. We need to make sure we obtain them timely. Another working experience of CCII is a joint research program with the International Energy Agency (IEA): A strategic research program on clean coal usage. In this research, nearly all Chinese clean coal experts participated. This research has not yet been finished. Also the CCII has a 10 year cooperation with the American Environmental Protection Ministry and the Australian Scientific and Technology Ministry. The CCII is also executive researcher on CBM exploration, evaluation and industrial development. The CCII cooperates in commercial research programmes of the Asian Development Bank (ADB) and the World Bank. Internally, the CCII advises the Chinese government on policy making. Externally, the CCII tries to show the outside world what developments China is making in clean coal.
3.	It must be said that other countries already have a clear role in clean coal technologies in China. (France, US, Great Britain, Germany etc.) To the CCII the clean coal situation in The Netherlands is yet unclear. What about Shell and Ningxi province? According to Mr. Li, The Netherlands has to focus on specific techniques and technologies in the range of clean coal technologies to become a more familiar key-role player in the field. This is the way how The Netherlands should put itself on the map regarding clean coal technologies. Mr. Li states that when exploring market opportunities for Dutch organizations, the real advantages of Dutch organizations must be clear and design a strategy focussed on the emergent needs of China. The first step in starting co-operation in Clean Coal Technologies must be research.
4.	As we know, the energy mix in China is dominated by coal. In other countries this domination of coal is not the case, this is why they are less interested in coal while China is the biggest market for clean coal technologies. The developments in clean coal technologies are also taking place at a very high pace in China.
5.	The main reason why China has (had) a backwardness in clean coal is because of its history: China started later with clean coal as caused by limitations of the market (ie not yet a developed market economy that financially rewards private investment in

	innovation). Now plenty of researchers and technicians fuel rapid development. Also worldwide research capacity is coming to China. China is as far as, or even further than foreign countries in coal washing and coal selection. So how is KEMA making money with coal selection in Shanghai region?
6.	IGCC (Integrated Gasification Combined Cycle) is gradually and on a large scale beijng used around the world. There is no commercial production yet, but the first test project will open soon. [is this technique that Shell has sold through 16 licences to China? On IGCC, China is at the same stage as the rest of the world. Also most research capacity of foreign countries is in the area of IGCC. A bottleneck in the development of IGCC in China is the lack of coal gasification technology in China. GEBRUIKT [because they do not want to pay for the technology – vide Shell
7.	The following three clean coal Technologies are highly encouraged by the Chinese government: - IGCC-technology - Coal Liquefaction and coal conversion into methanol and its derivatives and – Polygeneration. The improving of existing power plants is encouraged by the NDRC → small power plants have to close because they are not efficient enough: In 2010: power plants that produce less than 100 MW have to close down In 2020: power plants that produce less than 200 MW have to close down In 2030: power plants that produce less than 300 MW have to close down GEBRUIKT
8.	Coal liquefaction and polygeneration were very hot in 2006-mid 2007 because of the constant price increase of oil. Many projects were started up. In the second half year of 2007, the NDRC restricts permission of coal liquefaction companies because of their excessive water-use. Is CL still economically viable if you internalise the real cost of water? Only large projects get approval, while the market demand for more projects is there. Is that true, if yes what is the evidence? Authorities approve only projects that produce above a million tons of oil. Two active players in this field are Shenhua and the Yankuang Group; two state-owned enterprises. According to the CCII, coal liquefaction is in an early stage in China. We will meet with Shenhua shortly. GEBRUIKT
9.	According to the CCII, Coalbed Methane (CBM) is much cleaner than other technologies (such as…) and is therefore considered as a clean coal technology. CBM will also be an important resource for China, because China possesses few domestic gas resources. Therefore the government is developing more favorite government policies for CBM. GEBRIUIKT In the conversation about CBM, Rik has told about the activities of TNO in cooperation with PetroChina and China United Coalbed Methane. This interested CCII a lot. In China, carbon dioxide capture and storage (CCS) is according to the CCII, still in the conceptual research state. Apparrently, the NDRC has been rather critical of CCS very recently.
10.	In some area's China is further developed than other countries. Especially the situation in large sized industry companies while the private middle/small

	sized companies still need to be upgraded. On the area of coal power plants, other countries use water for cooling, while China now already uses air. Also China is ahead in coal washing. Mr. Li Hongjun describes China as the mainboard of clean coal technology: the most advanced technologies are adopted by China. China collects everything and absorbs technologies and develops them further.
11.	Barriers in CCT development in China China is potentially the largest market for clean coal technologies in the world. The Government must keep the balance with market demand which is the most important driver in adoption of technology and know-how. The Government has to consider long-term development by using their restrictions. The Chinese economy is not 100% open for free development.
12.	CCII releases a research report called China Coal Outlook, every year. Also CCII has a large database with market information.

7. Visit to China University of Mining & Technology (Beijing)
Date:

Future development of Clean Coal Technologies in China

Short term (one year or less)

- Coal washing
- Various efficiency improvements
- Small circulating fluidized bed boilers
- Flue gas desulphurisation (FGD)
- Coal gasification

Medium term (2-10 years)

- Larger scale fluidized bed boilers
- Supercritical boilers for coal fired power plants
- IGCC
- Coal liquefaction

Long term (10 or more years)

- Carbon capture and storage (CCS)

- Do you agree on this list?
I think that Dutch parties can help develop in the areas of Coal blending, IGCC, CCS en ECBM.

- On what CCT Research area's is CUMT working? On what areas is CUMT looking for cooperation/input from foreign partners?
- How big is the Chinese market for coal blending?

Carbon Capture and Storage
The Netherlands have got a relatively big empty gas field where CO2 can be stored and the North Sea.
- What are the best CO2 storage options in China? geological storage, storage in the ocean, or

aboveground land storage. Is CO2 storage an option in China with current carbon prices?
- How do you see the possibilities of enhanced coal bed methane or CO2 storage in depleted coal beds?
- Are there enough suitable storage locations near to CO2 point sources?
- Does the CUMT has information about suitable storage locations in coal beds?

- Do you agree on the sentence that China is potentially the largest market for clean coal Technologies?

Coal industry development
- The price of coal will be brought under government control temporarily, the NDRC said, because soaring coal price is the main factor behind higher electricity charges. What are the consequences of this act for the development of CCT's?

IGCC cases emit the least CO2 per kWh. It is clear that compared with the other coal-fired plants, IGCC has the best environmental performance. As China's pollution-control standards become more stringent, some technologies will become less attractive and others relatively more competitive. Concerning economic estimates, from the results calculated it is clearly indicated that the levy charge for pollution has a small

impact on COE. Only levying charges for emitting pollutants are not enough to encourage power plants to install pollution control equipment. Because of the low levy fee, polluters prefer to pay charges for emitting pollutants.
If China plans to deploy IGCC based on successful demonstration during the Eleventh Five Year Plan, major economic hurdles will have to be overcome. Incentive policies are needed to deploy IGCC in China, such as tax credit, loan guarantee, direct finance from the government, and a preferential price for electricity from IGCC plants.
- How likely is this? And on what term?

What are the emission fees on SO2, NOx and in the future CO2 in China?
How do you think this is developing?

For my research I am developing a model to look at the internalization of external cost in the power generation sector for different power generation technologies. This in order to explore future interesting power generation technologies when the environmens is more taken in consideration.

For instance:

Conventional Pulverized Coal
Fluidized Bed Combustion
IGCC

On what scale are external costs internalized when making investment decisions regarding new power plants?
This modeling approach imposes additional charges on electricity generation, which reflect the costs of environmental and health damages from:

- local pollutants (SO_2, NO_x) Sulvur Dioxide , Nitrogen
- climate change (CO_2) Carbon Dioxide
- wastes
- occupational health

- risk of accidents
- noise and other burdens

8. Visit to Shenhua Group
3-6-2008 - 14.30 leave 14.00

Overview:
Presently, the Group has controlling stakes in 6 operating power plants, with a total installed capacity of 5.16 million kW and total asset worth of close to RMB 30 billion Yuan, to which are added controlling stakes in power plants that are under construction, which will have a combined capacity of 7.20 million kW. In addition, the Group has non-controlling stakes in 2 operating power plants with a combined installed capacity of 424,000 kW, as well as in 3 power plants that are under construction with a combined capacity of 3.72 million
kW. By 2005 or thereabouts, the total installed capacity will reach 8 million kW, generating a coal market of some 20 million tons for Shenhua.

Technical status Clean Coal Technologies in NL
The main Dutch activity on R&D regarding ZEP (Zero Emission Fossil Fuel Power Plants) takes place inside the so-called CATO-project. CATO represents a strong knowledge network in the field of CO_2 Capture and Storage in the Netherlands, assessing and developing new knowledge, technologies and approaches in this field.
In Cato scientific institutions and market organizations that work on CCS are gathered.

Specific competitive advantages regarding Carbon Capture and Storage:

- The Netherlands ranks fairly high with respect to technological knowledge of gases, gasification and separation technology, partly as a result of its very strong focus on natural gas and traditional participation in research programmes focusing on these subjects.
- This also applies to technological, economic and legal knowledge of gas transport and trade, including underground gas storage and the monitoring thereof.
- For geological reasons the Netherlands possesses a relatively large arsenal of potential storage locations in the gas and oil fields. The country is also strategically located for possible future discharge of CO2 flows, also from industrial centers in neighboring countries, to the considerable storage capacity in various North Sea locations.

<u>Questions</u>
On what clean coal technologies and technology area's is Shenhua Group focusing in the coming years?
- Integrated Gasification Combined Cycle (IGCC) technology
- Coal Liquefaction and coal conversion into methanol and its derivatives
- Polygeneration
- improving the existing thermal power plants)

What is the perspective of Shenhua on CO2 capture and storage (in coal seams, gas fields etc)?
Is Shenhua active/planning activities in this area?

What are the main factors for implementing CCT's? Pure Regulation

Is there a need for international cooperation for the domestic production?
For what forms of international cooperation is Shenhua looking?

On what ground does Shenhua assesses potential for a cooperation agreement or buying potential? For what factors in Shenhua looking? Price/quality/innovativeness/absolute novelty

On what knowledge field does knowledge transfer/cooperation with a Dutch organization sounds

most logic or viable to you?
What approaching strategy would you suggest for a Dutch organization?

What is the status of the Coal to liquid project in Inner Mongolia?
This facility should be on line in 2007 and is using the Headwaters Direct Coal Liquefaction (DCL) process. China is also interested in building two more CTL using Sasol technology (the indirect coal liquefaction process). The economics of CTL are compelling; when crude oil is greater than $35 to $40/bbl, then the conversion of coal to diesel makes economic sense.
Is this build in association with Shell, Sasol or another foreign company?
Inner Mongolia - China Shenhua Coal Liquefaction Corporation 2x2,000 t/d plant to supply hydrogen for coal liquefaction process with licence from Shell since 2004.
The project is designed to produce 5 million tons of product oils annually, with the first production line going into trial run by 2006, producing 1 million tons of product oils annually.

How does the Shenhua Group handles both coal and energy generation activities while the price of Electricity is set and price of coal is rising? Is Shenhua compensated for this?

I understand that the electricity price is set by the Government and that the coal price is more or less market based. Is the coal price already completely set by the market or is there a Government Institutions controlling/regulating the price?

9. Interview with Bert Bekker, EEP
EU Manager Energy Efficiency & Natural Gas EU-China Energy and Environment Programme
11.00 @ Kempinsky Beijing

Aantekeningen nav het gesprek:
China heeft geen behoefte aan buitenlandse investering voor de bouw van energie centrales
De elektriciteitsprijs is laag
De kolenprijs is relatief vrij, en daardoor hoog
Energiecentrales en raffinaderijen zijn hierdoor in gevaar en draaien met verlies
CNPC, ChinaPec e.a. betalen geen belasting
Wanneer je buitenlandse bedrijven wil aantrekken zal deze regelgeving veranderd moeten worden.
Energy Bureau = Energy Administration geworden, waardoor het belang is gestegen
Kleinere NL bedrijven kunnen zich op de Chinese marjt begeven via een partnerschap met chinezen en moeten voorzichtig zijn met knowhow.
Of ze kunnen contact zoeken met de grote bedrijven die ergens mee bezig zijn en daarmee samenwerken.
De Chinezen willen graag leren → voorwaarde is innovatie: het moet innovatief zijn.
Richard Ridord/Ridart/ridort   Britse ambassade CCT.
Er is een rol weggelegd voor universiteiten mits zij komen met innovatieve oplossingen.
Bij het onderzoeken van CCT's voor de Chinese markt moet gekeken worden naar wat de Chinezen zelf willen en het kosten perspectief.
CDM regel is 51% van de onderneming in Chinese handen. De CDM zorgt er vaak net voor dat een project winstgevend wordt. Bedrijven zijn terughoudend met het hebben van een minderheidsbelang ten opzichte van de Chinezen.
Chinezen zijn slecht in maintenance. Mogelijk zijn ze meer gefocust op het snel terug verdienen van de investering dan te kijken naar de mogelijk meer winstgenererende lange termijn.
Clean Energy Center

De *Energy Working Group, European Chamber-- Energy Working Group Meeting*

Tuesday, 15th April 2008, 2pm European Chamber Office, Beijing
Benoemen de belangrijkste CCT´s voor China
- Integrated Gasification Combined Cycle (IGCC) technology
- Coal Liquefaction and coal conversion into methanol and its derivatives
- Polygeneration

"Also, as much of the attention is paid to develop advanced clean coal technologies such as IGCC, China should not ignore the huge potential of **improving the existing thermal power plants.** This is a relatively easy job to do for energy saving and pollution reduction. Wider use of 'dry cooling technologies'(Air Cooled Condenser(ACC)) could also significantly reduce the amount of water used in coal-fired power plants. "

Is deze lijst volledig?
Op welke technologieën/onderdelen moeten Nederlandse organisaties zich richten?
- Commerciële partijen zoals Shell, TNO, ECN, KEMA
Is er een rol weggelegd voor universiteiten?
Wat is een goede tijdshorizon om aan te houden voor projecten om te onderzoeken?

Welke CCTs vallen af voor dit onderzoek? CO2 capture out of coal and storage (in coal layers)
Reasons for falling behind in clean coal technology? Bron uit '99:

- Overall deficiency in national strength
- Lag of legislation
- Disjunction between R&D and production

In hoeverre is dit nog correct?

Wat zijn projecten/locaties die zeker onderzocht/bezocht dienen te worden?
Hoe worden buitenlandse investeringen voor grote CCT projecten aangetrokken?
Tenders/jv opties/anders
Markt benaderingsstrategie voor NL SME's gespecialiseerd in CCT?
Hoe staat het ervoor met Coal to liquid projecten? Bijvoorbeeld Ningxia province
In een marktanalyse van de Canadese ambassade heb ik gelezen dat de nieuw geïnstalleerde elektriciteitscentrales state-of-the-art zijn, vergelijkbaar met Canadese elektriciteitscentrales. Kunt u dit bevestigen?
Hoe verloopt de knowledge & skill transfer naar China?

ANNEX VII: LOGBOEK THESIS ACTIVITIES

Datum	Activiteiten	uren
20-03-2008	Informatie biosgas opzoeken Informatie Clean Coal Tech opzoeken, beginnen met schrijven TOR	4,5
26/3/2008	informatie opzoeken via Web of Science: zoekterm 'clean coal' mbt China	4,5
27/3/2008	Schrijven TOR	2,5

27/3/2008	Afspraak Dhr. Stienstra	1
28/3/2008	Correspondentie met Albert van Pabst en schrijven Interim Report	7
31/3/2008	Zoeken theorie voor theoretisch kader Macro-meso	5
31/3/2008	Zoeken theorie voor theoretisch kader Macro-meso	1
1-4-2008	zoeken kapstok model sectoranalyse	6
2-4-2008	formuleren deelvragen mbv theorie	5,5
3-4-2008	Aanpassen theoretisch kader adh van Saunders	4
4-4-2008	Toevoegen theorie aan theoretisch kader	6
8-4-2008	Schrijven Interim Report	7,5
8-4-2008	Schrijven Interim Report	1
9-4-2008	Schrijven 'Categories of CCT'	3,5
9-4-2008	Afspraak met Dhr. Stienstra	0,5
10-4-2008	Scannen boek: porter: The Competitive advantage of Nations	4
11-4-2008	Scannen boek: porter: The Competitive advantage of Nations	2
16/4/2008	energierapporten doornemen	3
16/4/2008	energierapporten doornemen	2
17/4/2008	Doornemen:	7
	Energierapport CBM in China doornemen	
18/4/2008	Introduction of CCT in Japan, voltooid	8
	Life cycle analysis of UK fired power plants	
	Gebruiken en verwerken Energierapport CBM in China doornemen	
	Zoeken Sciencedirect: China, CCT	
	Zoeken Sciencedirect: Clean Coal Technologies, categories	8
21/4/2008	http://www.harvardir.org/articles/1295/2/	8
	http://www.efchina.org/csepupfiles/report/2006102695218629.4783588424742.pdf/LCDP_Project_Updates_Jun2005.pdf	
22/4/200	China development forum	8

8		
	artikelen zoeken over industry and market analysis	
	coal and sustainable energy supply challenges and barriers	
	external costs from electricity generation of China up to 2030	
	Artikelen Stienstra vn over energy models	
23/4/2008	Chapter 11 - China development forum	8
	A fresh look at industry and market analysis	
	opzoeken events	
	Aanpassen onderzoeksopzet adhv Van Alsem e.a.	
24/4/2008	artikelen over Innovation Systems lezen	8
	Innovations systems: analytical and methodological issues	
	The diffusion of renewable energy technology: an analytical framework and key issues for research	
	Analyzing the functional dynamics of technological innovation systems: A scheme for analysis	
28/4/2008	Onderzoeken ontwikkelingen NL: cato, senternovem	8
	beleidsrapportage schoonfossiel	
	presentatie CATO dag 15jun07	
	World Energy Outlook 2007 begin maken in...	
	China Environment Series (teksten en interessante dingen gebruiken)	
	Energy in China	
	Overzicht maken van huidige voortgang	
29/4/2008	Doorgaan met Energy in China	4
	World Energy Outlook 2007	
	Uitwerken stukje China Environment Series	
	http://www.epa.gov/ies/china/china_factsheet.htm	
	http://www.iea.org/Textbase/country/n_country.asp?COUNTRY_CODE=CN&Submit=Submit	

	Lunch met Albert van Pabst	
6-5-2008	Verwerken notitities Energy Working Group - European Chamber Schrijven tijdsplanning tot 15/7/2008 Opzoeken Clean Energy Centers andere ambassades CANANDA GEVONDEN	8
7-5-2008		8
8-5-2008		8
9-5-2008	Gesprek met TNO @ Ambassade	8,5
13/5/2008	Schrijven hst 1 en 2	
14/5/2008	Gesprek William Sun	8
	Schrijven indeling eindrapport	
	Opzoeken informatie overheid en regelgeving	
15/5/2008	Afspraak met Bert Bekker @ Kempinsky	8
16/5/2008		8
19/5/2008		8
20/5/2008	Afspraak met China Coal Information Institute	8
	O.a. bronnen nagezocht en notulen uitgewerkt	
21/5/2008	Gewerkt aan onderzoeksopzet Boek Saunders uitgelezen	8
	gezocht met andere zoektermen, waaronder: China clean coal latest developments (ZEER SUCCESVOL!)	
22/5/2008	working on market report	8
23/5/2008	working on market report	8
24/5/2008	working on market report	8
25/5/2008	working on market report	8
26/5/2008	working on market report	8
27/5/2008	interim report version send to Mr. Stienstra	8
28/5/200	Starting to finalize first draft version market report	8

8		
29/5/2008	Sick day	
30/5/2008	Sick day	
2-6-2008	Sending first draft market report to Mr. Van Pabst	8
		282
3-6-2008		8
4-6-2008		8
5-6-2008		8
6-6-2008		8
9-6-2008	off-day Chinese boat day	
10-6-2008	working on interim market report v2	8
	reader stuff world coal institute	
11-6-2008	working on interim report v2	8
	reading Energy Technology Perspectives- OECD	
12-6-2008	Researching European activities on CCT	8
	writing chapter on Analysis of China's acquisition of clean coal technology	
13/6/2008		8
16/6/2008		8
17/6/2008	Shell meeting	8
18/6/2008	called Un. Utrecht emailed report v2 to Jaap, Freek and William	8
19/6/2008	making calls updating documents	8
20/6/2008	Nederlandse organisaties bellen, Hilux5 etc	8
23/6/2008	Nederlandse organisaties bellen Procede, ECN	8
24/6/2008		8

25/6/2008		
26/6/2008	VRIJ	
27/6/2008	VRIJ	
30/6/2008		8
1-7-2008		8
2-7-2008	visit CUMT	8
3-7-2008		8
4-7-2008		8
7-7-2008		8
8-7-2008		8
9-7-2008		8
10-7-2008		8
11-7-2008		8
14/7/2008		8
15/7/2008		8
16/7/2008		8
17/7/2008		8
18/7/2008		8
21/7/2008		8
22/7/2008		8
23/7/2008		8
24/7/2008		8
25/7/2008		8

25/8/2008	Theorie NIS TIS	8
26/8/2008	Theorie NIS TIS	8
27/8/2008	Theorie NIS TIS / verwerken aanpassingen Albert van Pabst	8
16/09/2008	Werken aan theoretisch kader	6
17/09/2008	Werken aan theoretisch kader - contact leggen met CCS partijen	4
18/09/2008	Werken aan hst 1	6
19/09/2008	werken aan hst 1	6
22/09/2008		5
23/09/2008		4
24/09/2008	verhuizen	
25/09/2008		8
26/09/2008	analytical framework theorien aanvullen	8
29/09/2008	analytical framework theorien aanvullen	
1-10-2008	hst 2 - Shell	
2-10-2008		6
3-10-2008		4
6-10-2008		5
7-10-2008		4
8-10-2008		7
9-10-2008		3
10-10-2008		4
13/10/2008	hst 3	5

14/10/2008	hst3	5
15/10/2008	hst 3	6
16/10/2008	hst 3 + voorbereiden CCS competentie meting	6
17/10/2008	afspraak Dhr Groeneveld Enschede	3
22/10/2008	doorwerken boeken	4
23/10/2008	doorwerken boeken verwerken innovatie verhaal	5
24/10/2008		2
25/10/2008		5
26/10/2008	in elkaar zetten tussenverslag	7
29/10/2008	verwerken hst 6 China	6
30/10/2008	Afspraak met Dhr. Stienstra	3
31/10/2008	verwerken op- en aanmerkingen Stienstra	6
3-11-2008		8
4-11-2008		6
5-11-2008		7
6-11-2008		5
7-11-2008		6
10-11-2008		5
11-11-2008		8
12-11-2008		4
13/11/2008		6
14-11-2008	carrieredagen Rai -	
15-11-	hst 3,4	6

2008		
16-11-2008	hst 3,4	8
17-11-2008	hst 3,4	8
18-11-2008	hst 3,4	8
19-11-2008	hst 3,4	8
20-11-2008	hst 3,4	8
21-11-2008	hst 3,4	4
22-11-2008	`~	
23-11-2008	opzet hst 7	
24-11-2008	hst 7	
25-11-2008	referenties, doorlezen verslag aanpassen	10
26-11-2008	aanpassen, hst 5 schrijven, hst 6	8
27-11-2008	discussie en conclusie, aanpassen man. Sum	4
28-11-2008	afmaken verslag, verzending, printen	10
	total worked hours	866
	Target	700

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