Nordic Institute of Asian Studies

Nordic Collaboration with China in Energy Research and Development

Jørgen DELMAN and Yong CHEN

November 2008

Nordic Collaboration with China
in
Energy Research and Development

Jørgen DELMAN and Yong CHEN

A study commissioned by Nordic Energy Research

November 2008

First published in 2008
by NIAS Nordic Institute of Asian Studies
Leifsgade 33, DK-2300 Copenhagen S, Denmark
tel: (+45) 3532 9500 • fax: (+45) 3532 9549
email: sec@nias.ku.dk • website: www.nias.dk

ISBN: 978-87-7694-051-9

EXECUTIVE SUMMARY

Purpose

In a situation where China is eager to exploit the opportunities in the world energy and energy technology markets, the purpose of this study is to highlight opportunities for Nordic research and development (R&D) institutions and companies working with energy research, technology, and innovations to collaborate with Chinese stakeholders and actors in energy R&D to address the key issues associated with China's energy production and consumption. The study puts forward a series of strategic and specific recommendations on how Nordic collaboration can engage with the Nordic countries, i.e. their government agencies, their organizations, and their companies, as well as with Chinese partners to promote a clean energy R&D agenda in China.

China's energy sector

The study is set against the background that, while most of the developed countries are seeking ways out of the fossil-fuel trap, China, being the world's second largest energy consumer and CO_2 emitter, tends to be further locked into it to meet its continued upsurge in energy demand. However, at the same time, strong concerns have been expressed both in China and internationally with regard to the challenges posed by the contribution of China's surging energy consumption to environmental degradation and climate change.

As a consequence, a new interest in "clean" energy has emerged in China in recent years. The government has elaborated ambitious plans to reduce energy intensity and to increase the proportion of clean energy in the energy mix while not jeopardizing economic growth. To achieve these goals, the government invites cooperation from the international energy community. However, the Chinese political leadership is also arguing that there is a need to foster indigenous competence and capacity in relation to development of new technology. Clearly, China needs to find ways to make its energy system more sustainable, and China neither has the intention to reinvent the wheel, nor the off-the-shelf solutions that can be used immediately given the scale and complexity of the issues that the country is encountering. This situation presents interesting opportunities for more Nordic involvement.

Contents and focus

The study provides an overview and analysis of the Chinese energy sector, its policy and business environment, the associated innovation system, and, finally, international and Nordic activities in relation to the energy sector in China. These include more or less formalized government-to-government cooperation agreements and activities, university-to-university cooperation, government-private commercial promotion activities, and corporate R&D activities.

14 case studies exemplify how different international, primarily Nordic, and Chinese stakeholders cooperate with energy related policy and R&D issues and activities. The study also makes detailed recommendations for coordinated Nordic efforts in relation to the Chinese energy sector.

In view of the enormity of China's energy sector, the authors have agreed with Nordic Energy Research to primarily focus on a selected range of renewable energies that hold promises for China and where the Nordic countries would clearly have an interest in both R&D cooperation and the market opportunities. This should not be construed to mean that other opportunities in the energy sector are of no interest to the Nordic countries, e.g. China's strong focus on the need to enhance energy efficiency across the economy.

Findings

The study finds that in order to stimulate the development of a cleaner energy sector, the Chinese leadership has formulated a string of policies, strategies, plans, and concrete targets to guide the future energy sector. Increased energy efficiency is now the top political priority and the growing energy demand should in principle be covered by national energy resources. The energy system should be exceedingly diversified with a strong focus on development of renewable energy. Environmental management is to be strengthened during both production and use of energy, and mutually beneficial international collaboration within the energy sector should be enhanced.

For international players, considerable benefit can be gained from these developments. Huge investments are going into energy R&D in China. International actors may tap into these potentials as China is still keen on international collaboration and partnerships. The Chinese market also offers opportunities for a swifter move from R&D to commercialization of technologies on a large scale. The potential commercial returns are promising as the Chinese energy sector is growing rapidly, not least renewable energies. New business opportunities are emerging and Chinese actors are seeking partners to expand into promising new or existing worldwide markets for new energy technologies.

Opportunities for Nordic interests

Based on an analysis of the experience of a range of Nordic and other international stakeholders from the public, the university, and the corporate sectors as well as of multilateral agencies operating in the energy sector in China, the study identifies a range of opportunities for the Nordic countries to work on renewable energy R&D with China. First of all, there is considerable experience to build on. There is recognition in China of strong Nordic competences in renewable energy R&D and Nordic values and modes of collaboration are appreciated and respected. At this critical junction in the development of China's renewable energy sector, there are excellent opportunities to partner up with Chinese counterparts in the national and regional innovation systems to deal with the development of new renewable energy technologies in a huge and rapidly developing market.

Challenges

Nordic players must be aware of the challenges in China. First of all, the Chinese stakeholders are mostly thinking "big", while the Nordic stakeholders are often small in comparison. The Nordic countries do not have the same weight and influence individually as the EU and the World Bank. It is also worth mentioning that some of the Nordic interviewees were of the opinion that the development of the renewable energy sector in China is primarily, at this stage, driven as much by political considerations, i.e. environmental, security and climate concerns, as by the potential for investors to gain immediate profits from their investments.

Transfer of core technology to China is a key policy issue and often becomes a requirement in project negotiations and in relation to the ownership of proprietary rights. It will also be an important issue in the climate negotiations leading up to the COP15 climate summit in Copenhagen in 2009. There is no simple solution to the issue, and some international players choose to comply, whereas others stay away. Others still muddle along, and the lucky few have just the technologies that the Chinese side needs, almost no matter under which conditions.

Nordic R&D collaboration with China in energy?

There are some public Nordic and other international programmes in the Chinese energy sector, but there is room for more collaboration. Based on the analysis in the report, the authors would argue that it would be timely to establish a strategic Nordic framework for collaboration with China within renewable energy R&D. The Nordic countries have competences that are in demand and where they would evidently benefit from access to the Chinese resource pool and a potentially huge market. Such a framework should be designed to coordinate and mainstream Nordic energy R&D in the Chinese energy sector. This would not only exploit Nordic synergies better and enhance the presence of Nordic energy expertise in China, it would also help the Chinese partners get a better picture of Nordic strengths within energy know-how and technologies as well as who would be the interesting partners.

Many Nordic stakeholders from the public and private sectors indicated to the authors that a Norden-China programme could add value to existing bilateral activities. Nordic and Chinese researchers are interested in collaborating with each other and Nordic companies operating in China have started to localize at least some of their research in the country. The R&D communities in the Nordic countries must be part of that process; otherwise they may be excluded from the Chinese R&D sector and a potentially huge market for clean energy technologies.

Strategic approach and a coordinated Norden-China programme

A number of strategic issues must be considered. First of all, a common Nordic platform would be able to harness stronger influence in China as well as more funding, which is essential to achieve success, but it would also allow the partners involved to get access to a considerable, often complementary knowledge pool in the Nordic countries and China respectively, as well as to each other's research resources and infrastructure. Nordic stakeholders would get better access to a market with a strong focus on developing and integrating renewable energy in the energy mix and an ambition to become leader with regard to some key technologies.

A coordinated effort could facilitate the strategic positioning of the Nordic region and China at the frontier of the battle against unsustainable use of conventional energy sources and climate change. It could create a common understanding of and a framework for joint action to address common challenges in China, regionally as well as globally. The strategies of the relevant Nordic agencies would be fully in tune with this line of thinking and it is highly relevant for China. Effectively, Sino-Nordic partnerships in China could become building blocks in new global R&D and/or business strategies.

Furthermore, a Nordic-Chinese platform would heighten Nordic visibility and maximize Nordic knowledge dissemination in relation to our common challenges, i.e. the increase in energy demand, the need to improve energy security, and the common aspirations to mitigate climate change. The conditions for establishing a Norden-China platform in relation to R&D within renewable energy are mature and it would be possible to align a framework program with Nordic and Chinese policies.

The objectives of a joint programme should be practical and achievable while also being ambitious; it must also be clear which technologies or topics are in focus. The focus should be within the areas in which the Nordic know-how and research capacity are widely recognized and appreciated worldwide, thereby attracting Chinese attention and interest. Collaboration must be based on mutual recognition and institutionalization of mutual agreements, leading to mutual benefits through equal partnership in relation to ownership of research results and property rights. It is necessary to build a strong case to attract Chinese attention.

Nordic synergy and added value must be demonstrable, e.g. by building on existing programmes and infrastructures. Different organizations from the Nordic system and at the national level in the Nordic countries should be invited to participate and possibly be responsible for different components of the programme.

Coordination should also be sought with other international programmes, e.g. the programmes of the European Commission. There is a strong drive amongst both Chinese and international players to set up centres and their activities must be coordinated or complement each other. In order to become successful, they must fit into China's existing structures, otherwise they will not function.

Although not always linked directly to energy issues, the unique Nordic innovation tradition is something that the Nordic countries could offer to China, particularly in the wake of China's promotion of an indigenous innovation strategy.

Specific proposals

It is proposed to consider three levels of cooperation/collaboration, ranging from small scale, over medium scale, to large scale collaboration. They could either integrate into a full-scale programme from the outset or develop through a more sequential or cascading approach.

1. Small-scale collaboration: "Norden-China Renewable Energy R&D Expert Committee"

This proposal is based on the assumption that there is a wish to test the ground initially or that only limited resources are available. The aim is to become familiar with each other's renewable energy research agenda and, possibly, develop a strategy and a plan for a joint framework programme. The program would organize an Expert Committee comprising top energy experts and officials from each side to discuss and identify which energy issues are most significant for China and the Nordic countries and which would be suited for R&D collaboration. Through a series of workshops and other activities, the Expert Committee would determine the need and elaborate the framework for further activities and/or a cooperative programme. In addition, seed funding for small-scale academic activities to stimulate more exchange or feasibility studies could be a part of this initial program.

2. Norden-China Renewable Energy R&D Small Projects Facility

The goal is to move from the initial cooperation that would test the ground into activities with at least a five year perspective. The Small Projects Facility would aim at stimulating collaboration as well as exchange of expertise and information at a higher level with the aim to create common platforms with regard to policies, research, and development of specific technologies. The projects to be supported could comprise:

- Creation of networks between Nordic and Chinese partners
- Creation of a common virtual platform with a science and technology watch function, exchange of news and information about development in R&D in renewable energy in China and the Nordic countries, and activity watch Establishing a facility to support scholarly exchange, i.e. guest scholarships, workshops, conferences
- Establishing a PhD facility for exchange, joint courses, and some trial joint sandwich PhD programmes establishing a start-up fund to test possibilities and opportunities for joint research programmes and/or R&D programmes including corporate stakeholders. This could start with financing of small-scale studies involving researchers and corporate stakeholders
- A financing facility for workshops and conferences
- Energy innovation games for students within business and technology
- Training of Chinese Master's and PhD students in relevant subjects abroad
- A facility in support of student exchange
- The possibility of earmarking Chinese government stipends for Nordic students
- Production of a series of TV programmes for Chinese TV on Nordic environment and energy to be shown on Chinese TV during World EXPO 2010
- Nordic interventions at World EXPO 2010, e.g. presenting the results of joint Nordic and Chinese efforts within R&D in relation to renewable energy.

3. Norden-China Renewable Energy R&D Programme

The third step would lead to large scale collaboration which should institutionalize Nordic-Chinese energy collaboration under a "Norden-China Renewable Energy R&D Programme" in order to be able to work towards common strategic goals through joint R&D initiatives. The following two initiatives are proposed under the "Norden-China Renewable Energy Program":

- A "Norden-China Renewable Energy R&D Council" would be an expansion of the proposed Expert Committee. It should aim at bringing together top expertise from the research sector, the corporate sector, and public bodies on both sides to identify common needs and demands, and regularly consult on and provide guidance for joint activities within the renewable energy sector, either defined broadly or limited to R&D in renewable energy. Ideas and guidelines for public-private partnerships could also be of interest.
- Establishment of a "Norden-China Renewable Energy Innovation Centre" would promote Nordic R&D, projects, and investments and create synergy amongst different Nordic initiatives in relation to all types of renewable energy in China. This would also allow the Nordic countries to utilize each other's expertise in both the public and the corporate sectors to promote comprehensive projects and solutions, e.g. in relation to China's eco-cities or allow them to get specialist advice. The centre could also help establish procedures and channels for effective commercialization of joint research results.

These initiatives could be established as an outcome or they could incorporate the series of activities proposed under the first two types of initiatives. The proposed Renewable Energy Innovation Centre could implement the "Norden-China Renewable Energy R&D Programme" under the guidance of the "Norden-China Renewable Energy R&D Council". Such a programme should provide funding for more comprehensive activities and projects of various types, such as:

- Longer-term joint research or technology development programmes
- Extensive academic exchange
- Joint or collaborative research education, PhD stipends (including business PhD stipends), and regular exchange and joint supervision of PhD students
- Establishment of a Norden-China PhD programme on energy management
- Establish a programme for in-service training of Chinese researchers and teachers in energy programmes in the universities, both in energy systems management and in specific technologies.

4. Norden-China Energy and Climate Change Programme

In view of China's increasingly constructive engagement in the international climate mitigation regime and the particular role of the Nordic countries on the global level in this respect, the proposed "Norden-China Renewable Energy R&D Programme" could be expanded into a "Norden-China Energy and Climate Change Programme" which would include the previously proposed activities as well as the organization of additional projects and events that could reinforce the Nordic-Chinese partnership in relation to dealing with the effects of climate change. The following additional activities are proposed:

- A "Norden-China conference on climate and energy – COP 15/Copenhagen and beyond" ⟐ quick/brief projects on modelling to be used as an input for COP15 by both the Chinese and Nordic side. The proposed titles of the projects are: (1) Review on technology transfer in China; (2) application of sector based approach in China ⟐ Nordic-Chinese workshop on technology transfer for climate change mitigation. The workshop would present and discuss the results of the studies proposed and put them in a global and national context.

The role of Nordic collaboration

Bearing in mind that a considerable number of scattered R&D activities in the renewable energy field are already being undertaken between the Nordic countries and China, the main role that Nordic collaboration could play would be to create synergy, to add value to, to explore new areas and venues that would encourage innovative R&D initiatives, and to source funding.

This study has presented a considerable number of proposals and it is up to the Nordic system to mobilize the necessary political and professional support to move ahead. To be able to do so, it is suggested to establish two types of work forums:

- A Nordic "China Renewable Energy R&D Ideas Factory" comprising key Nordic organizations such as Nordic Council of Ministers, Nordic Energy Research, NORDFORSK, Nordic Innovation Centre, NefCO, NIAS-Nordic Institute of Asian Studies, etc. They would discuss the study and how to move forward, i.e. develop an initial strategy and an outline of a roadmap for the implementation of the program. The group should be able to draw on Nordic and Chinese resource persons as appropriate.
- A small secretariat must be established by the appropriate Nordic organizations to coordinate and implement the activities proposed and initially support the activities of the "Ideas Factory". The staff in the secretariat should have experience with internal Nordic collaboration as well as collaboration with China. The secretariat should help the Nordic system mobilize the resources necessary to initiate a substantial collaborative program in renewable energy R&D with China.

Funding of Nordic-Chinese renewable energy R&D collaboration

The study discusses the issue of funding extensively. A program with small funding would not be feasible, considering the current Chinese and international initiatives in relation to renewable energy R&D in China. Therefore, Nordic collaboration will have to mobilize considerable funding resources through its own channels, through the national channels, and through co-financing from the stakeholders in a program, not least the Chinese side. At the same time, a principle of "smart" funding must be pursued, i.e.:

- Establishment of a Nordic "basket fund" with contributions from different stakeholders in the Nordic system ◈ funding must be used to complement what is already happening ◈ funding of overlapping activities should be avoided ◈ the principle of matching funds from the Chinese side should be applied to the extent possible, preferably in both kind and cash.

NIAS-Nordic Institute of Asian Studies, 1.11.2008

Jørgen Delman and Chen Yong

CONTENTS

PREFACE AND ACKNOWLEDGEMENTS I

1 INTRODUCTION 1

2 CHALLENGES AND OPPORTUNITIES FOR CHINESE ENERGY DEVELOPMENT . 5

2.1 China's energy demand: Past, present and future 5
2.2 Environmental constraints 9
2.3 Renewable energy sources and technologies in China 10

3 ENERGY R&D: THE POLICY, LEGAL, AND INSTITUTIONAL FRAMEWORKS .. 13

3.1 Policy review 14
3.1.1 Strategic policy shifts 14
3.1.2 Policies for renewable energy... 16
3.2 Legal review.. 18
3.3 Impact of the policy and legal regimes 19
3.4 R&D development strategies 20
3.4.1 Programmes and funding mechanisms.. 21
3.4.2 Techno-nationalism and technology transfer... 22
3.5 Key players involved in the Chinese energy innovation system 24
3.6 Policies, plans, and R&D programmes: How do they evolve? 29
3.6.1 From idea to policy 29
3.6.2 The role of government and other stakeholders 30
3.7 Discussion.. 31

4 NORDIC INVOLVEMENTS IN CHINESE ENERGY R&D 33

4.1 Government strategies for China... 33
4.2 Export of energy technology.. 34
4.3 Modes of Nordic bilateral collaboration 35
4.3.1 Government-to-government co-operation 35
4.3.2 University/research institute collaboration.. 36
4.3.3 Technological research, S&T promotion, support to R&D 38
4.3.4 Public promotion initiatives... 40
4.3.5 Investment initiatives... 40
4.4 Nordic Council of Ministers 41
4.5 Other countries and donors 42
4.6 Confidentiality and IPR protection 43
4.7 Opportunities and challenges in international collaboration 44

5 NORDIC-CHINESE COOPERATION FRAMEWORK ON ENERGY R&D............. 47

5.1 Strategic recommendations... 48
5.2 Potential barriers.. 49
5.3 Identifying mutual interests 50
5.4 Cooperation or collaboration.. 53
5.5 "Top-down" and "bottom-up" approaches 54
5.6 "Roadmap" to effective collaboration 55
5.7 Potential partners... 57
5.8 Discussion.. 57

6 SPECIFIC RECOMMENDATIONS 59
6.1 Norden-China Renewable Energy R&D Expert Committee 59
6.2 Norden-China Renewable Energy R&D Small Projects Facility 59
6.3 Norden-China Renewable Energy R&D Programme 60
6.4 Norden-China Energy and Climate Change Programme 62
6.5 The role of Nordic collaboration 62

Appendices

No.	*Title*
Appendix 1	List of people interviewed
Appendix 2	Potentials of renewable energy resource and technological development in China
Appendix 3	Key policy and legal documents
Appendix 4	Actors in the Chinese energy sector
Appendix 5	14 case studies

Tables

No.	*Title*	*Location*
Table 1	Comparison of key country variables	Chapter 1
Table 2	Comparison of energy projections	Chapter 2
Table 3	Indicators for energy in 11th 5-year plan (2005-2010)	Chapter 3
Table 4	Goals for development of renewable energy resources (2010 and 2020)	
Table 5	Nordic export of energy technology to China: Index 1996-2006	Chapter 3
Table A.2.1	Capacity and output of non-electric use of geothermal energy in the world	Appendix 2
Table A.3.1	Key political and legal documents	Appendix 3
Table A.3.2	Nordic Asia and China strategies	Appendix 3
Table A.4.1	Key actors in the energy sector at the central government level	Appendix 4
Table A.4.2	Key R&D organizations working with renewable energies	Appendix 4
Table A.4.3	China's major energy companies (following 2002 reform)	Appendix 4
Table A.4.4	Key national intermediary organizations	Appendix 4

Boxes

No.	*Title*	*Location*
Box 1	Vestas' competition from China	Section 2.2
Box 2	Chinese concerns about climate change	Section 3.1.1
Box 3	Goldwind: How it developed	Section 3.5
Box 4	Research financing	Section 4.3.2
Box 5	DragonPower's offer	Section 6.3
Box 6	BI proposal for energy management education	Section 6.3

Figures

No.	*Title*	*Location*
Figure 1	Energy Intensity of the Chinese economy, 1952-2006	Chapter 2
Figure 2	Energy Balance in China, 1980-2005	Chapter 2
Figure 3	Net coal exporting and importing provinces in China, 2001	Chapter 2
Figure 4	Incremental demand in key fossil fuels and energy-related CO_2 emissions in China, India, and the rest of the world (2000-2006)	Chapter 2
Figure 5	Key actors in the renewable energy innovation system (2008)	Chapter 3
Figure 6	Identification process for collaborative research	Chapter 5
Figure A.2.1	Wind resource map, China	Appendix 2
Figure A.2.2	Annual China direct normal solar radiation	Appendix 2
Figure A.2.3	Hydroelectric resource bases in China	Appendix 2
Figure A.2.4	Geothermal systems in China	Appendix 2

Acronyms

ADB	Asian Development Bank
BIPV	Building integrated phtovoltaics
BTU	British thermal unit
CAAS	Chinese Academy of Social Sciences
CAE	Chinese Academy of Engineering
CARCU	China Association of Comprehensive Resource Utilization
CAS	Chinese Academy of Sciences
CASS	Chinese Academy of Social Sciences
CCS	Carbon capture storage
CDM	Clean Development Mechanism
CEPRI	China Electric Power Research Institute
CER	Certified emission reduction
CHECC	China Hydropower Engineering Consulting Group Company
CMA	China Meteorological Administration
COFCO	China Oil and Food Ltd.
CREIA	China Renewable Industries Energy Association
CRESP	World Bank China Renewable Energy Scale Up Programme
EE	Energy efficiency
EEP	EU-China Energy and Environment Programme
EIA	Energy Information Administration (under U.S. Department of Energy)
ERI	Energy Research Institute (under NDRC)
ESCO	Energy service company
FDC	Fluidized bed combustion
FDI	Foreign direct investment
GDP	Gross domestic product
GEF	The Global Environment Facility
GHG	Green house gas
IGCC	Integrated gasification combined cycle
IEA	International Energy Agency
IPCC	International Panel on Climate Change
IPR	Intellectual property rights
IVA	Royal Swedish Academy of Engineering Sciences
JI	Joint implementation
KTH	(Swedish) Royal Institute of Technology
KVA	(Swedish) Royal Academy of Sciences
m/m	Man-month
MoF	Ministry of Finance
MOFCOM	Ministry of Commerce
MOST	Ministry of Science and Technology
MSW	Municipal solid waste
NDRC	National Development and Reform Commission
NEEC	Norwegian Energy and Environment Consortium
NEFCO	Nordic Environment Finance Corporation
NECF	NEFCO Carbon Fund
NER	Nordic Energy Research (Oslo, Norway)
NORDEN	The five Nordic countries: Denmark, Finland, Iceland, Norway, and Sweden
OECD	Organisation For Cooperation and Development
ONCCCC	National Coordination Committee on Climate Change (China)
PMU	Project Management Unit
PPP	Purchasing power parity
PRC	People’s Republic of China
PV	Photovoltaics
RE	Renewable energy
RED	Danish-Chinese Renewable Energy Development Programme
R&D	Research and development
RET	Renewable energy technology

SERC	State Electricity Reform Commission
S&T	Science and technology
SMW	Solid matter waste
STEM	Swedish Energy Agency
STIP	(National) Science and technology industrial park
TCE	Tonne of coal equivalent
TOE	Tonne of oil equivalent
TOR	Terms of reference
TOT	Transfer of technology
WB	World Bank
WED	Danish-Chinese Wind Energy Development Programme
WTO	World Trade Organisation

PREFACE AND ACKNOWLEDGEMENTS

An unprecedented energy crisis has accompanied China's rapid economic growth. However, in Chinese, the two characters that constitute the word "crisis" refers to "challenges" and untapped "opportunities" respectively. It is never an easy task to seize emerging opportunities in a crisis and it is simply not an option for the Chinese government to address the intertwined energy and environmental issues at the cost of economic slowdown, no matter how reasonable it may sound from a sustainability perspective.

The key message in China's ambitious energy strategies and plans is therefore to improve the energy supply and demand structure, to enhance energy security, and to safeguard continued economic growth. However, contrary to conventional wisdom, opportunities to develop a sustainable energy system for China without economic compromise seem to exist. As energy commodity prices soar globally, economic incentives to go "green" rise significantly and green investments would possibly be able to generate more "green" dollars. The question is how China would invest in development and deployment of new technologies in the alternative energy business.

In the increasingly integrated energy markets and with an emerging new global climate regime, it would be naïve to look at China's challenges as a purely Chinese concern. Active involvement into the on-going transformation of the Chinese energy sector is of strategic importance for international players as well, including the Nordic countries. The authors of this report are convinced that, with the strong R&D capacity in relation to the climate challenge and in low-carbon energy technology, the Nordic region has an important and unique role to play in China. The authors would also argue that working with China to develop a package of solutions for a sustainable energy future would be as important as helping China import renewable energy technologies. Collaboration on energy R&D with energy stakeholders in China could be an effective approach to the unprecedented energy challenges that China is facing. As there is no off-the-shelf solution, innovative thinking powered by collaborative efforts becomes essential.

Nordic Energy Research has commissioned NIAS-Nordic Institute of Asian Studies to conduct this study with the aim to identify the opportunities for Nordic stakeholders, such as public authorities, companies, and R&D institutions, to address the key R&D issues associated with China's future energy production and consumption and discuss how collaboration with Chinese stakeholders and actors in energy R&D, particularly in relation to renewable energy, can be set up and institutionalized.

The study is financed by Nordic Energy Research, but the authors alone are responsible for the contents of the report. Therefore, none of the opinions and recommendations in the report should be construed to represent those of Nordic Energy Research.

The authors would like to express their gratitude to Professor Zhou Yuan for his extensive inputs to Chapter 3 and appendices 3 and 4 and for his review of the draft report, as well as to those who granted their insights, viewpoints, and time through lengthy interviews. Similarly, the authors are thankful to the following reviewers of the report, Professor Thomas B. Johansson (main reviewer), Professor Jiang Kejun, Dr. Gao Hu, Dr. Frank Haugwitz (Chapter 5), and Dr. Ole Odgaard (Chapters 1-3), as well as for our interesting discussions with the staff at Nordic Energy Research and other Nordic researchers working simultaneously on other policy studies on behalf of Nordic Energy Research. Finally, thanks are due to Lau Blaxekjær for his research assistance, to Samatha Pedersen for her language revision, and Leena Höskuldsson for her editorial support.

The study has been carried out by Jørgen Delman and Chen Yong jointly. Chen Yong is mainly responsible for Chapter 2 and Appendix 2, and Jørgen Delman is mainly responsible for Chapters 3 and 4 and Appendices 3, 4, and 5. Chapters 1, 5, and 6 were written jointly.

A note on terminology: in the recommendations in Chapters 5 and 6, "Norden" is used in the names of the proposed programme initiatives. Norden is the same as the Nordic countries, i.e. Denmark, Finland, Iceland, Norway, and Sweden. In Chinese, the translation would be "North Europe" (Bei Ou, 北欧) in both cases.

1 INTRODUCTION

While most of the industrialized countries are seeking ways out of the fossil-fuel trap, China, being the world's second largest energy consumer[1], would be further locked into it until and unless its energy supply structure is significantly improved. As predicted by International Energy Agency (IEA) and the United States Energy Information Administration (EIA) [2], China would double its consumption of energy resources by 2030 from the 2004/2005 level and much of the increase will be met by coal and petroleum if no major changes occur. If measured by per capita, however, China would not be even close to the average level of energy use in industrialized countries, even if total consumption of energy resources were to be doubled, as indicated in Table 1. The same formula can be used for the calculation of Greenhouse Gasses (GHGs) emissions.

Table 1: Comparison of key country variables (2007 data)[3]

Key variables	China	USA	Japan	Nordic[4]
Population (million)	1,320	302	128	24
Per capita GDP (US$) (PPP)	5,345	45,790	33,525	39,041
Energy use per unit of GDP (toe/ thousand US$)	0.26	0.17	0.12	0.15
Per capita CO_{2eq} emissions (2003 data, tonnes)	3.2	19.5	9.8	9.3
Total CO_{2eq} emissions (2003 data) (million tonnes)	4,224	5,889	1,254	223

Then, what could be the key driver to solve China's dilemmas? Over the past decades, China benefited considerably from transferred technologies in all sectors. The technologies that lead to higher productivity also, directly or indirectly, increased the efficiency of utilization of energy resources, thus saving millions of tones of primarily coal for China since the 1980s.

Without doubt, technology transfer is an important and effective shortcut for China to catch up with the developed countries. However, if the capacity to absorb transferred technologies remains under-developed, this sort of catch-up will only be temporary and expensive. China has experienced major frustration from tapping into the circle of conventional technology progress. This happened in the 1980s in its cooperation with the United States in relation to integrated gasification combined cycle (IGCC) plants, mainly due to excessive costs[5], and more recently with the reluctance of foreign companies to give away their core wind technologies.

The recognized barriers in technology transfer have encouraged China to revisit its inward transfer-of-technology strategy, once deemed so successful, and the promotion of indigenous innovations has become part of the core actions in China's long-term science and technology policies. At the same time, China has clearly understood that this would not happen without active cooperation and collaboration with international scientific society. The recent expansion in the number of trained researchers in China and the rapidly growing scientific production (regardless of its varied quality) not only demonstrate China's commitment in this direction but also provide an improved foundation for international technology developers to collaborate with China's R&D communities.

---

1 It accounts for 17% of the world total primary energy consumption, only 4.5 percentage points below the U.S. (IEA 2007; BP 2008).
2 In IEA's World Energy Outlook 2007 and EIA's International Energy Outlook 2006, respectively.
3 The 2008 World Development Indicators, available on line at:
http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20399244~menuPK:1504474~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html#ranking;
EarthTrends Environmental Information, WRI, available on line at: http://earthtrends.wri.org/text/climate-atmosphere/variable-666.html.
4 Data for the Nordic countries were calculated based on data from each country.
5 According to Prof. Yao Qiang of Tsinghua University, China (presentation made in May 2008 on "Science and Technology Innovation for Climate Change" in Beijing).

Unlike in the past, China is now basing international collaborations on a win-win philosophy. The country's robust economic growth provides a huge market potential for most of the successful new technologies. Moreover, given the current low wage standards in China, its R&D expenditure will be considerably lower than in most Western countries. On the other hand, China increasingly wants to share the fruits of common endeavours with the international purveyors of new technology and its various R&D partners, particularly in terms of knowledge sharing and proprietary rights.

Speaking of renewable energy development, just as an example, US$7 billion – one fifth of the world total – was invested in 2005 alone by the Chinese government and private investors (Martinot 2006). In the following year, China imported energy related technologies worth over US$1 billion from the Nordic countries to upgrade its energy infrastructure. This trend is likely to continue if no major issues occur (Maj Dang Trong Analyse 2007).

Against this backdrop, the following benefits can be expected from energy related R&D collaboration with China:

1. The world's future climate and energy security will rest on safer ground and the regional and local environmental quality will be improved by co-developing new generations of low-carbon energy technologies suitable for the Chinese contexts
2. Given the relatively low salaries of high-quality researchers in China, the overall R&D budget could be reduced compared to the costs in the West. This has been a key driver in much cross-university collaboration as well as in outsourcing of R&D centres to China in recent years
3. This will also result in reduced R&D costs as a result of the availability of relatively low-wage but high quality researchers in China which, effectively, has been a key driver in cross-university collaboration and outsourcing of R&D centres to China in recent years
4. There may be a swifter move from R&D to commercialization in China's huge and promising market. The potential commercial returns are high as the Chinese energy sector is already large and growing rapidly; the huge markets with rapidly increasing demand and energy systems have to be upgraded and modernized and this will facilitate the commercialization of more advanced energy technologies and be helpful in reaching the desirable scale of economy while reducing production costs
5. New business opportunities are emerging for international actors to partner up with Chinese counterparts to expand into promising new or existing worldwide markets for new energy technologies.

In view of the enormity of China's energy sector, the authors have agreed with Nordic Energy Research to primarily focus on a selected range of renewable energies that hold promises for China and where the Nordic countries would clearly have an interest in both R&D cooperation and the market opportunities. This should of course not be construed to mean that other opportunities in the energy sector are of no interest to the Nordic countries, e.g. China's strong focus on enhancing energy efficiency across the economy. Other special competences and interests of the Nordic countries such as, for example, carbon capture and storage (CCS), which is of interest to many Nordic stakeholders in the energy sector, has been briefly dealt with, since the authors recognize the debates on the eligibility of it as a clean energy technology.

The study firstly takes a look at China's energy challenges and China's position on a range of renewable energy technologies in Chapter 2. After that, the political and legal environment for the development of the energy sector is analyzed in Chapter 3. The same chapter also looks at how the institutional set-up that commands China's energy policies, strategies, and programmes, especially those relating to energy R&D, is configured and contextualized both at home and internationally. Then, the programmes and partnerships of a representative range of Nordic stakeholders are analyzed in Chapter 4, which also covers the implications for possible Nordic collaboration with China, as a complement to existing bilateral collaboration. Strategic recommendations are outlined in Chapter 5 and Chapter 6 discusses specific recommendations for how the Nordic system could collaborate with the Nordic governments and their agencies, with Nordic firms, and with counterparts in China to promote an energy-related R&D agenda.

The study combines desk research and field visits with a focus on interviews with relevant stakeholders, including government officials, researchers, the business community, and industrial associations. Some interviews were conducted by telephone.

Based mainly on the fieldwork, Appendix 5 outlines a number of case studies as examples of how collaboration or promotion of R&D and competences in renewable energy is being done by Nordic and other stakeholders in China. The lessons learnt and perspectives for the future that can be extracted from these cases are discussed in the main report.

2 CHALLENGES AND OPPORTUNITIES FOR CHINESE ENERGY DEVELOPMENT

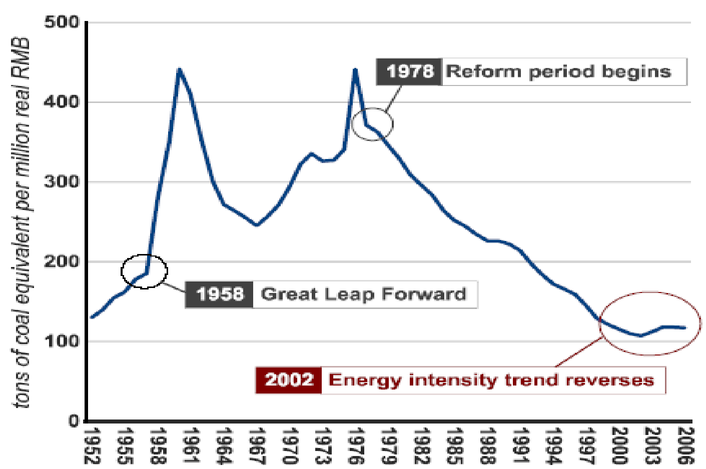
A fundamental transformation of China's energy system is underway and will be the key to its future success. Such a transformation must be addressed innovatively. Undoubtedly, there will be continuing resistance towards deep-going change from some of the vested interest groups in the Chinese energy sector (Sinto et al. 2005). However, China has decided to embark on this transformative cause and there is recognition in the country that China can learn a lot from other successfully operating energy systems in the world, while it is also necessary to explore its own way due to the country's size and the complexity of the issues the energy system is facing.

This chapter focuses primarily on the challenges that the Chinese energy sector is facing and the development potential of cleaner energy technologies in China.

2.1 China's energy demand: Past, present and future

The first two decades after the start of China's market economy reforms in 1978 saw only a modest annual increase in energy demand of 4.6% on average [6], much lower than the remarkable achievements in development in general with average near two-digit annual GDP growth rates which combined with significant achievements in poverty alleviation and better living standards. This has improved the energy intensity, as shown in Figure 1 (Rosen and Houser 2007), and it has been seen as a successful case of decoupling of economic growth from substantial energy use in a phase of rapid industrialization.

Figure 1: Energy Intensity of the Chinese economy, 1952-2006



Source: CEIC from China Statistical Yearbook

However, in contradiction to the predictions [7] that China would be able to carry on with this development trajectory in the new century came a dramatic increase in demand particularly for oil and electricity, as indicated in Figure 2. Indeed, the unexpected rebound, featured by energy elasticity rising up to 1.6 in 2004, shocked the Chinese leadership (Downs 2006). Immediate actions were taken and astonishing results have been made. China's electricity generation capacity has doubled in five years reaching more than 700 GW in 2007.[8] For obvious reasons, the Chinese government turned to coal-fired power plants first, lifting coal's share in the fuel mix to 76% in 2006 from 72% in 2000, according to the National Bureau of Statistics of China.

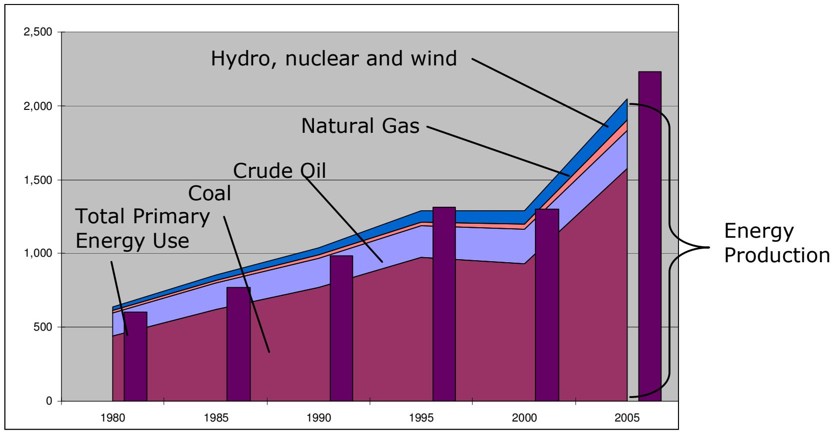
---

[6] Over the same period, the energy intensity fell by 64%, which narrowed the gap with advanced industrialized countries (Xiao et al. 2007).

[7] Such as D.D Zhou, 2002.

[8] It was 350 GW in 2002. These are official figures. Some researchers claim that at local level some additional 100 GW from so-called illegal power plants are operating without approval from the central governmental authority, the NDRC. However, this claim is impossible to verify.

Figure 2: Energy Balance in China, 1980-2005, Mtce[9]



A number of studies have shown that the drastic increase in energy demand was driven largely by energy-intensive heavy industries, primarily due to the WTO entry and domestic infrastructure development, including a booming housing industry, as well as by radical growth of transportation demand (IEA 2007; Rosen and Houser 2007). The question may be asked that, should the momentum remain, how would China meet its future energy needs? In the near term future, China would most probably continue to expand its energy supply by employing mature and least-cost technological options, while in the longer term, particularly if the environmental costs are taken into account, the shift toward a sustainable energy system would be a wiser choice. This may not happen, at least not in as fast as it could, if sufficient R&D efforts are not geared towards dealing with these challenges.

A number of analysts have attempted to depict China's energy future using scenario approaches. Table 2 presents predictions from three of the widely referenced sources.

The following points can be made as a result of the comparison among them, while considering the actual data for production and consumption up to 2007:

- "Chinese sustainable Energy Scenarios (CSES) 2020", published in 2002, is off the track compared with the recent upsurge in energy demand. In 2007, the total primary energy consumption was already close to the 2015 prediction under scenario S1; however, it does suggest how Chinese energy experts envisaged China's energy future before the energy crisis occurred in 2002.[10]
- In terms of assumed population, Chinese researchers estimated that the Chinese population would reach 1.45-1.49 billion by 2020 and not in 2030 as predicted by the United Nations Population Division (2006). The Chinese estimate was based on the Government's "White Paper on Population and Development" issued in 2000 and other relevant research. If the Chinese estimate is taken as a reference assumption and the rest is kept unchanged, both IEA and EIA would have underestimated the total energy demand by 2030. In the case that the Chinese overstated the future population growth, the gap between the prediction and the reality (even if only up to 2007) would be larger than it is now, indicating an even stronger momentum driving the energy demand.
- With respect to urbanization, all three predictions seem to agree that 60% of the Chinese population will be living in urban areas by 2030. According to other sources, this figure might be underestimated as the definition of an urban inhabitant has not yet been made clear. For example, it is unclear for how long an urban migrant has to live in a city in order to count as an urban dweller. On the other hand, to address the migration related issues, China has decided to invest in rural infrastructure to keep the rural population in the rural areas, which may have the same effect as urbanization by rural people moving into the cities since the per capita energy consumption in the urban area is higher than that in the rural.

[9] Million tons of coal equivalent (1kgce=29.27 MJ =7,000 kcal). Source: Based on data from the National Statistics Bureau of China, 2006.

[10] In collaboration with the Chinese Engineering Academy (CEA), the Energy Research Institute (ERI) under NDRC is constructing China's energy scenarios for 2050 as an updated version of CSEC 2020.

- All the three sources predicted that China's GDP would grow at annual average rate of 6-7%. It is likely to be an underestimation based on the escalating economic development at a two-digit GDP growth rate since 2002, and it is hard to see that growth would slow down significantly by 2010. As a consequence, the real energy data up to 2007 were much higher than any of the projections. In 2007 alone, China's energy demand grew by 7.7% which was already lower as compared to the immediately preceding years, yet it was still three times higher than the world average of 2.4% and it almost doubled as compared to the projected high growth future. This indicates the energy elasticity could be double as high as compared with any of the scenarios, implying that by 2020 the total primary energy would be anywhere close to double the 2007 level. Nevertheless, it seems that the pace of economic growth may slow down but it is unlikely to be significantly lower than before 2010. If the modest economic slowdown happens together with the achievement of the national target of 20% energy efficiency improvement across the country, the effect on energy demand would be significant.
- The fast expansion of coal-fired power generation capacity in recent years in response to the sharp rise in energy demand suggests that coal energy is likely to dominate the Chinese energy mix even longer than predicted and that coal will continue to be the main source of energy for a long time to come.
- It must be noted that in all the three high growth scenarios, the environmental and climatic implications are huge, which prompts speculations about what would happen if reality turns out to be even worse than the scenarios presented by the projections.

Based on these points, it is reasonable to conclude that China must take urgent measures to tackle these challenges before the window of opportunity is closed. China must avoid – at almost any cost - that its future will be locked into an unsustainable development path over the next decades. This requires China not only to focus on increasing energy supply capacity, hopefully with a higher portion of renewable energy sources, but, even more importantly, to employ advanced technologies with higher energy efficiency in all sectors including the power sector.

Table 2: Comparison of energy projections

Key Parameters		IEA WEO 2007 (China)			EIA IEO[11] 2007 (China)			ERI CSES 2020 (China)[12]			IEA WEO 2006 (Global)
		Ref.	Alter-native	High Growth	Ref.	Low Growth	High Growth	S2	S3	S1	
Projection Period		2005-2030			2004-2030			1998-2020			2004-2030
Key Assumptions	**Population** *(billion)*	1.31-1.46[13]			1.31-1.45[14]			1.25-1.47	1.25-1.45	1.25-1.49	N/A
	Urbanisation	40%-60%			N/A			30.9%-55.8%	30.9%-58.3%	30.9%-52.9%	N/A
	Annual Average GDP Growth	6.0%	6.0%	7.5%	6.5%	6.0%	7.0%	7.0%			3.4%
Total Primary Energy Demand (Annual Growth)		3.2%	2.5%	4.0%	3.5%	3.1%	3.9%	3.11%	2.23%	3.64%	1.6%
Coal		*3.2%*	*2.1%*	*4.0%*	*3.3%*	*2.9%*	*3.7%*	*2.2%*	*0.9%*	*3.1%*	*1.8%*
Oil		*3.7%*	*2.8%*	*4.8%*	*3.5%**	*3.1%*	*4.0%*	*4.2%*	*3.3%*	*4,6%*	*1.3%*
Gas		*6.4%*	*6.9%*	*7.8%*	*6.5%*	*6.1%*	*6.9%*	*11.7%*	*12.4%*	*10.0%*	*2.0%*
Nuclear		*6.5%*	*9.0%*	*7.4%*	*7.7%*	*7.7%*	*7.7%*	*N/A*	*N/A*	*N/A*	*0.7%*
Hydro		*3.8%*	*4.8%*	*4.4%*	*2.7%*	*2.4%*	*2.9%*	*N/A*	*N/A*	*N/A*	*2.0%*
Biomass		*0.0%*	*0.5%*	*0.1%***	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*1.3%*
Other Renewables		*9.9%*	*11.9%*	*11.1%*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*6.6%*

* Liquids, mostly oil.
** Including wastes.
S1 (Scenario 1): With the same degree of economic growth and market development/openness as those in S2, the policies for sustainable development in S1 are not effectively implemented. This results in fewer applications of clean energy technologies even though they are available on the mature markets.
S2 (Scenario 2): Both economic growth and the degree of market development/openness go as envisioned. This could be the target scenario for the Chinese policy markets.
S3 (Scenario 3): This is a very optimistic scenario. Greater achievements towards sustainability of use resources of energy and material will be made.

[11] International Energy Outlook
[12] Chinese sustainable Energy Scenarios (CSES) 2020, 2002.
[13] United Nations Population Division (UNPD), 2006.
[14] United Nations Population Division (UNPD), 2005.

2.2 Environmental constraints

The adverse impacts on the environment of the Chinese fossil-dominated energy system are serious. Given China's size and the noticeable disparity of economic growth across the country, energy derived environmental issues vary from region to region, depending primarily upon which and how fuels are used.

As discussed above, coal, used for electricity and heat generation, is dominating and will continue to dominate the Chinese energy supply (Wang and Zhao 2001; Zhou and Zhou 1999). Coal reserves are mostly located in the inland and in the north of China while the driving locations in the Chinese economy are primarily in the southern and coastal areas, as shown in Figure 3. The coal reserve in Shanxi, Shaanxi, Inner Mongolia, and Ningxia (4 out of China's 31 provinces) accounts for more than 80% of the national total, according to China Coal Industry Yearbook 2000.

Coal mining and combustion have been blamed for serious local and regional environmental problems including acid rain precipitation, smoke-type atmospheric pollution and ecological damage. This is primarily due to the less-regulated/supervised mining practices, pervasive illegal mining, high sulfur content in coals and weak enforcement of environmental regulations. Some improvements have been made over the past years after the governments have taken a number of serious measures to address those issues.

Figure 3: Net coal exporting and importing provinces in China, 2001[15]

Surprisingly, despite the rapid deployment of clean coal facilities around the country and a rather stringent industrial reallocation strategy, the long term trend of deteriorating ambient air quality in China's major cities has not seen a turnaround as yet. It is even getting worse in cities like Beijing. Massive construction projects driven by the overwhelming urbanization effort is one factor, but the increasing number of petroleum-fuelled vehicles in the urban areas is another important factor. The vehicles emit dramatically increasing volumes of exhaust gases containing mainly NO_x, fine particulate matter (PM), soot, SO_x CO, CO_2 eq., and water vapour.[16] In 2004, the air quality in 210 out of 342 monitored cities was exceeding Class II of the National Ambient Air Quality Standard, while 69 cities were even above Class III, according to Ding Yan of the Vehicle Emission Control

[15] Source: UBS Warburg (Asia) Limited, 2002.

[16] The main components of automobile exhaust are nitrogen (N_2), carbon dioxide (CO_2), and water vapor (H_2O).

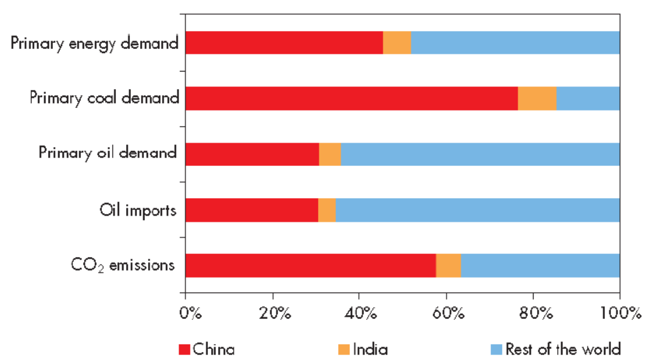
Centre under the Ministry of Environment Protection (former Chinese State Environmental Protection Administration – SEPA). Despite the more stringent vehicle emission standards to be adopted, the projected seven-fold increase of vehicle stock by 2030[17] would challenge the effectiveness of any standards if no substantial technological breakthrough is achieved.

At the global level, the pressure on China to tackle climate change is growing, primarily due to the following reasons:

1. Over the last half century, China has already experienced devastating flooding, abnormal fluctuations of seasonal and regional precipitation, larger and longer drought periods, intensified hurricanes and storms, as well as having observed 20 consecutive warm winters from 1986-2005 (NDRC 2007). Growing scientific evidence suggests that adverse impacts of climate change on China will be severe, thus challenging the continuation of the Chinese economic development model (IPCC 2007)
2. Energy and climate are intertwined at the global level and the challenges from China are glaring. The country needs to acquire a considerable amount of energy resources from the international energy markets if the prospect of doubling its GDP by 2010 and quadrupling it by 2020 from the 2000 level is to be achieved
3. The pressures from the international community on China to become a responsible player in relation to addressing climate change challenges are increasing, particularly in the post-Kyoto period
4. Evidence suggests that pressure is also increasing in China to act on the climate issue.

From 2000 to 2006 alone, China was responsible for nearly 60% of the global incremental energy-related CO_2 emissions due to the upsurge energy demand, as indicated in Figure 4.

Figure 4: Incremental demand in key fossil fuels and energy-related CO_2 emissions in China, India, and the rest of the world (2000-2006)[18]



Given the potential constraints from the environment and scarce resources, a dramatic increase in future energy use would be neither responsible nor physically feasible, albeit it might be considered morally reasonable due to the low per capita energy use in China as compared to the OECD countries and in particular the United States.

2.3 Renewable energy sources and technologies in China

New renewable energy sources such as wind power, solar photovoltaic, and modern use of biomass have only made their real entry on the Chinese energy scene during the last decade, although conventional renewable energy sources, including both small- and large-scale hydropower and traditional use of biomass and solar thermals, have been part of the Chinese energy system for

[17] From 1990 to 2006, the vehicle stock increased seven times according to IEA, WEO 2007. IEA also predicted a 230 million increase in the number of vehicles by 2030 from the 2006 level.
[18] Source: IEA, WEO 2007.

some decades. The Chinese leadership has now recognized the importance of renewable energy as a means of achieving a more sustainable energy future. Thanks to the availability of more mature technologies at lower costs China is eager to see a growing share of renewable energy in its total primary energy supply. The ambition is to reach 10% by 2010 and 15% by 2020, [19] targets set in the Medium and Long-Term Development Plan for Renewable Energy in China (Appendix 3). Of this, at least 3% must come from new renewable energy sources, including solar, wind, and biomass.

With regard to which renewables are viable in the short term in China, most Chinese scholars and officials in the energy field would think of wind first, followed by modern biomass, and then solar energy. This perception is backed by the fact that wind energy seems to have taken off in China. Biomass-based power plants mushroom according to DragonPower, a leading investor in biomass energy in China which has adopted Danish technology[20], and the capacity of solar business is being scaled up through the activities lead by Suntech and Yingli, two fast growing Chinese solar enterprises.

Across the supply chain of renewable energy technologies, there are many opportunities for investors who are not only focusing on a short-term market share in China but also planning their strategic positioning in R&D in the Chinese energy sector as such. While Novozymes China is expanding its share in the Chinese market by working with COFCO, which is China's largest oils and food importer and exporter and a leading food manufacturer, on producing 2nd generation biofuels in North East China, it is also trying out different options to harvest the Chinese brains in a responsible manner. In Beijing, dozens of researchers are working for Novozymes as part of its global R&D capital, indicating that they are assets for researching innovative solutions for Novozymes worldwide rather than merely doing the technical adaptation for the Chinese market (Appendix 5, Case 11).

DragonPower is another example of a company that will most likely head for R&D cooperation in their future strategy. [21] Although the Norwegian Energy and Environment Consortium (NECC) is mandated to promote technology export business in China and although no Norwegian company has set up R&D department in China, it has quickly recognized that R&D is an integral element when it comes to adapting any kind of technology into the Chinese context. There is simply no off-the-shelf Norwegian technology available for China (Appendix 5, Case 10).

In short, it is vitally important to keep developing novel solutions to utilize resources more efficiently. More and more players have realized that China would need capability and capacity in renewable energy technology development rather than just technology deployment in the decades to come. Without global cooperation and collaboration, it would take a much longer time and efforts to build a strong base in China in renewable energies than it would otherwise.

Box 1

Vestas' competition from China

In an interview with Thomas L. Friedman in International Herald Tribune on 11 August, 2008, Ditlev Engell, President of Vestas, comments on the poor US record in renewable energies:

"….[Engel] told me that he simply can't understand how the U.S. Congress could have just failed to extend the production tax credits for wind development in America.

Why should you care? [asks Friedman]

"We've had 35 new competitors coming out of China in the last 18 months," said Engell, "and not one out of the U.S."

…Vestas is the world leader in wind technology and a driving force in the development of the wind power industry. Vestas' core business comprises the development, manufacture, sale, marketing, and maintenance of wind power systems that use wind energy to generate electricity. In 2006 the company had a turnover of € 3.9 billion. In 2006 half of Vestas' sale was in Europe. The second largest markets are in the US and Canada (25 percent), India (9.2 percent) and China (8.9 percent).

(Source: Maj Dang Trong Analyse, 2007)

[19] These are relative targets. Whether or not they can be achieved would depend on the total primary energy consumption in 2010 and 2020 respectively. Bboth targets are specifically for renewable energy development, with a clear intention to create a demand-driven market. They cover all the sources of renewable energies, including hydro.

[20] Interview with DragonPower, Beijing, 22.05.2008.

[21] Ibid.

In Appendix I, the resource potential and technological development for a wider range of renewable energies are presented for the purpose of giving an idea of where China's renewable energies are and where they would go.

3 ENERGY R&D: THE POLICY, LEGAL, AND INSTITUTIONAL FRAMEWORKS

The development of the energy sector and, in this context, the renewable energy sub-sector is driven by a combination of interventions by the government, a multitude of agencies and corporations under its control, and by more or less independent actors in the market who are responding to government policies and incentives while pursuing their own strategies and goals. At the level of consumption, it is primarily large institutional and corporate users that exert influence within the sector.

The relevant international regimes of rules and regulations and the organizations that engage China to participate in or collaborate on these add to the complexity of the sector. In addition, many public and private foreign actors are operating in the Chinese energy market, all of whom have to work with the relevant Chinese institutions that set the framework for the development of the policy and regulatory regime, innovation systems, and the business environment.

This chapter will review China's key energy-related policies, strategies, plans, targets, laws, and regulations with a primary focus on renewable energy. The aim is to describe how China has been responding and will respond politically and practically to the challenges and stresses discussed above. Furthermore, the energy R&D field will be discussed, as well as the role of the actors involved in the energy policy and innovation systems.

Firstly, it is important to understand the framework for the policy and regulatory regime for energy which is formulated within a system that combines different levels of policy making which in turn have a different status in the party-state hierarchy as well as different mandates when it comes to policy interventions, mechanisms, and enforcement.

There are different types of policies, where the highest level of policies provides general direction and guidance. They include speeches by state leaders about development of the energy sector and declarations regarding the Chinese government's standpoint on the global environment, including climate change, as well as sector issues in general. The next type of policies specifies goals/objectives and development plans, and they focus on issues such diverse issues as the renewable energy sector, rural electrification, renewable energy-based generation technologies, and fuel wood. These policies attempt to standardize the directions, focal points, and objectives of renewable energy development from different viewpoints and to formulate industrial regulations. Both central and local government departments may propose concrete policies and regulations. These types of policies play an important role in promoting renewable technologies in China. Finally, the last type of policies consists of practical and specific incentives and managerial guidelines. They outline specific supporting measures for developing and using renewable energy. They aim to support the development of renewable energy in its early growth stages and to mainstream its production and use. Since the mid-1990s, both the central government and many provinces and autonomous regions of China have adopted policies for developing renewable energy, including, for example, subsidies and tax reduction. The central government has also issued several effective regulations.[22]

Secondly, legislation provides legal status to the policies and supports their implementation at the operational level. However, many of China's laws and regulations have a different status as compared with the legal traditions in the West. They are as much a part of the policy framework as being purely legal codes, and often they provide little or no basis for any type of concrete legal recourse.

[22] US National Renewable Energy Laboratory (http://www.nrel.gov/docs/fy04osti/35786.pdf, accessed 23.4.2 2008).

3.1 Policy review[23]

There has been a general thrust in China in the recent 10-15 years to create a more solid legal framework with proper institutions and mechanisms to regulate the market and make public administration more transparent, accountable, and effective (Yang 2004). The energy sector has been no exception and China's leadership is clearly interested in making it more responsive to both market developments and policy initiatives and incentives. As a result of the grave political concerns about future energy security and the impact of climate change, the policy and legislative outputs in relation to the energy sector has been extremely high, especially in recent years (Appendix 3).

3.1.1 *Strategic policy shifts*

Over the past years, the supply of adequate energy to fuel the modernization process has become a major concern. The focus has been on safeguarding energy security through adequate, reliable, and affordable supplies, including increased imports and the build up of a strategic oil stockpile. There has been an interest in renewable energy for many years, but it did not become a policy priority *per se* until recently, when both energy efficiency and renewable energies moved to the top of the political agenda.

At least four strategic policy shifts have paved the way for these developments. First, as discussed earlier, the inability of China to meet its future energy needs will lead to growing dependence on imported energy. In order to fill the gap between demand and available national resources, the Chinese leadership has actively supported China's energy companies, in particular the oil companies, to "go out" and acquire foreign energy assets and import energy resources. However, at the same time, the Chinese leadership has been concerned that excessive dependence on imported energy would be a costly liability, both economically and politically, and this has in part pushed the leadership to consider the exploitation of alternative national energy sources (Lieberthal and Herberg, 2006).

Secondly, there are institutional barriers to the development of a dynamic and responsive energy market in China and to the exploitation and incorporation of alternative energy sources into the energy mix. The re-organization of a politically powerful energy industry has been seen as a key to turn away from state planning and create and test a new combination of market driven development, more transparent regulatory frameworks, and clearer policy incentives, while maintaining continuing state oversight and control of key assets, in particular the oil and grid companies. To achieve these goals, China's State Council approved a plan in April 2002 for structural reform of the power industry. This step paved the way for the potential development of independent power producers, the category that renewable energies providers fall in. The main focus of the 2002 reform policy were: Separation of power plants and the grid; restructuring of regulatory bodies in the power industry through establishment of the State Electricity Reform Commission (SERC); establishment of a competitive electricity market; implementation of a power tariff reform; formulation of environmental cost standards and

Box 2

Chinese concerns about climate change

The Chinese results from the 1st Annual World Environment Review, published on June 5, 2007 revealed that, in a sample of 1,024 people (50% male):

- 88% are concerned about climate change
- 97% think their Government should do more to tackle global warming
- 63% think that China is too dependent on fossil fuels
- 56% think that China is too reliant on foreign oil
- 91% think that a minimum of 25% of electricity should be generated from renewable energy sources
- 61% are concerned about nuclear power
- 79% are concerned about carbon dioxide emissions from developing countries
- 62% think it appropriate for developed countries to demand restrictions on carbon dioxide emissions from developing countries.

Another survey published in August 2007 by *China Youth Daily* and *British Council* sampled 2,500 Chinese with an average age of 30.1 years. It showed that 80% young Chinese are concerned about global warming. However, in spite of this, 85% of them would also buy a car if they could afford one.

(Source: Wikipedia, http://en.wikipedia.org/wiki/Energy_policy_of_China#cite_note-39, accessed 3 Sept., 2008)

[23] The relevant policy and legal documents are listed in Appendix 3.

surcharges for emissions; and the formulation of a pilot programme where electricity generators supply power directly to large customers (Baker and McKenzie et al., 2007).[24]

Thirdly, growing scientific evidence has suggested – as discussed earlier - that adverse impacts of climate change will be severe for China, thus challenging the sustainability of the Chinese economic development model and the impact of traditional energy production and use on the environment. This has lead to a changed attitude amongst China's policy makers who are now showing willingness to improve the energy mix by increasing the share of China's renewable energy resources.

Finally, China has decided to focus on developing and upgrading its R&D competences and capacity in the energy sector. According to the national medium and long-term programme for science and technology development (2006-2020, Appendix 3), China aims to become an "innovation oriented" nation before 2020 and a world power in the S&T field by 2050. The plan has a strong focus on "indigenous innovation" as a key strategic driver to attain the goals. The number of patents granted to Chinese nationals and the publication of scientific papers are expected to rank among the first five in the world.

It has been argued that the focus on indigenous innovation is a response to China's poor record of domestic technological innovation and its overwhelming reliance on foreign technologies. Indeed, the national long term plan for the development of S&T stipulates that China's reliance on foreign technologies will decrease to below 30% in 2020 (Jakobson 2007; Simon et al. 2007; Serger and Breidne 2007).[25] In a globalizing world, such a policy may be considered a legacy of the past, but it has strong implications for the way foreign players will be treated and must respond. At the same time, the policy will undoubtedly give a boost to national efforts to promote R&D in renewable energies.

With reference to these strategic shifts, a string of policies have been formulated to guide the development of the energy sector (listed in Appendix 3) with the following priorities:

- Increased energy efficiency is the top priority
- Increased energy demand should in principle be covered by national energy resources
- The energy system should be exceedingly multi-pronged and diversified with a strong focus on development of renewable energies
- Environmental management should be strengthened both during production and use of energy
- Mutually beneficial international collaboration within the energy sector should be sought.

These policies have been outlined in speeches and reports by top leaders to national assemblies of the Communist Party and the People's Congress. They are incorporated into important national plans, such as the 11th 5-year plan and the above mentioned national S&T plan, as well as in various laws, regulations and other guidance documents (Appendix 3).

The overall quantitative goals set for energy development in the 11th 5-year plan are summarized in the table below.

[24] See also see Appendix 4.
[25] The plan is not specific about the benchmark and how progress should be measured.

Table 3 – Indicators for energy in 11th 5-year plan (2005-2010)[26]

		Year	Target	In % of total energy consumption	In % of total energy prod.
Total energy demand		2010	2.7 bill. Mtce	-	-
Total energy production		2010	2.446 bill.Mtce	-	-
Coal	Consumption	2010	↓3.0%	66.1%	74.7%
	Production	2010	↓1.8%		
Oil	Consumption	2010	↓0.5%	20.5%	11.3%
	Production	2010	↓1.3%		
Natural gas	Consumption	2010	↑2.5%	5.3%	5.0%
	Production	2010	↑1.8%		
Nuclear	Consumption	2010	↑0.1%	0.9%	1.0%
	Production	2010	↑0.1%		
Hydropower	Consumption	2010	↑0.6%	6.8%	7.5%
	Production	2010	↑0.8%		
Other RE sources	Consumption	2010	↑0.3%	0.4%	0.5%
	Production	2010	↑0.4%		

3.1.2 *Policies for renewable energy*

China's policies on renewable energy development fall into three categories. China's central government establishes the first two levels of policy as discussed in the introduction to this chapter, and the local governments, i.e. provincial, municipal, and county governments, primarily establish the third level of policy within overall direction from the central government.

China has issued medium and long term plans for development of the energy sector in general as well as for renewable energy development, including the S&T development plan (Appendix 3). The plans identify hydropower, biomass, wind, and solar energy as the renewable energy sub-sectors with the greatest potentials. They also set forth the guiding principles, objectives, targets, priority sectors, and policies and measures for the development of renewable energy in China up to 2020 and in some cases beyond.

Overall, China aims to raise the share of renewable energy in total primary energy consumption to 10 percent by 2010[27]. By 2020, the aim is to raise this share to 15 percent. This will be achieved by fully utilizing technologically mature and economically feasible renewable energy sources, such as hydropower, biogas, solar thermal, and geothermal, as well as by promoting the development of wind power, biomass, and solar PV industries.

The goals set for the development of renewable energy in the various policies and plans are summarized in Table 4 below. The government intends to achieve the targets by stimulating R&D and market development through a series of directives and support measures that aim at creating a more enabling legal framework (next section; Appendix 3).

[26] Source: Computed from 11th 5-year plan (see Appendix 3). It is worth noting that: 1) this document is a plan with a clear intention to curb (at least signaling to cut) the continued energy growth, both production and consumption; 2) the total energy consumption in 2010 was set at about 2.5 billion toc, which was obviously underestimated according to trends observed in 2007; 3) in relation to renewable energy, it covers only commercial energy sources and does not account for the total amount of consumed renewable energy. Therefore, the targets in the 11th Energy Plan and the development plans for renewable energy sources below can be different as they are intended to generate different signals with distinct energy policy implications.

[27] This figure is higher than what was stipulated for 2010 in the 11th 5-year plan (cf. Table 3). No official explanation has been found for the change. At any rate, the target is indicative, and there are speculations that China will easily move beyond at least some of them, e.g. in wind (Interview with Vestas, Shanghai, June 4, 2008).

Table 4 – Goals for development of renewable energy resources (2010 and 2020)[28]

Item		Goal 2010	Goal 2020
Wind power	Installed grid connected capacity	10 GW	30 GW
	- off shore capacity		1 GW
Hydropower	Installed capacity	190 GW	300GW
Solar power	Total capacity	300 MW	1.8 GW
	- Household PV application	150 MW	300 MW
	- Grid connected PV in Gobi areas	20 MW	200 MW
	- Solar thermal power stations	50 MW	200 MW
	- Grid connected BIPV in cities	50 MW	1 GW
	- Commercial PV based applications	30 MW	100 MW
Solar thermal	Heating	150 mill. m^2	300 mill. m^2
Bio-energy	Biomass power: Total installed capacity	5.5 GW	30 GW
	Biogas production	19 bill. m^3	44 bill. m^3
	Biomass from agricultural and forestry waste (incl. bagasse): Installed capacity	4 GW	24 GW
	Number of large-scale biogas projects on livestock farms	4,700	10,000
	Number of biogas projects processing industrial organic effluents	1,600	6,000
	Large and medium sized biogas plants:	4 bill. m^3	14 bill. m^3
	MSW: Installed capacity	500 MW	3 GW
	Solid waste fuel resources	1 mill. T.	50 mill. T
	Consumption of non-grain based bio-ethanol	2 mill. T. (additional)	10 mill. T.
	Consumption of bio-diesel	200.000 T.	2 mill. T.
Use of renewable energy in rural areas	Proportion of clean energy households	30%	>70%
	Number of pilot green energy counties	50	500
	Number of households using biogas	40 mill.	80 mill.
	Use of solar energy for water heating	50 mill. m^2	100 mill. m^2
Other renewable energy	Consumption of geothermal energy	4 Mtce	12 Mtce
	Tidal energy production	-	100 MW

Whereas the mainstream Western media often depict China as an irresponsible actor when it comes to the negative impact of China's growth on the climate due to its uncritical use of cheap and "dirty" energy sources, in particular coal, it has indeed displayed an increasingly responsible attitude in its dealings with these challenges. It has not only happened through the development of this enabling framework for the use of clean energy. China is also actively involved in international climate change mitigation through several bi- and multi-lateral initiatives (Buan and Heggelund 2008). Evidently, China is increasingly attentive to the needs to deal with the problems caused by climate change, and the State Council adopted "China's National Climate Change Programme" in June 2007 in which key energy targets, including those for renewable energies, were re-confirmed (Appendix 3). These have been translated into a multi-ministerial plan for development of S&T to address climate change (Ibid).

Finally, MOST and NDRC have recently issued a programme document for international S&T cooperation in relation to new and renewable energy. The purpose is to demonstrate to the world that China is determined to explore new and renewable energy, reduce emissions of greenhouse gases, and build a resource-conserving and environment friendly society by S&T driven innovation. The aim is to broaden the channels for introduction of new technologies and facilitate the transfer

[28] Sources : Medium and Long-Term Development Plan for Renewable Energy in China (Appendix 3).

of these technologies from the developed countries. A platform for international exchange will also be established to promote export of Chinese technologies to the world market. Furthermore, international cooperation should provide impetus to the industry through international expertise and through upgrading the level of basic research to solve key technological issues. Mechanisms will also be put in place to connect China even further with foreign authorities, enterprises and research bodies.

The principles of cooperation are envisaged to be: mutual benefit through win-win cooperation, protection of IPR, integration of strengths, sharing of advanced technologies, and joint technological innovation. The priority areas in the programme are: integration of solar powered generation and solar powered building structures, biofuels and biomass power generation, wind power generation, hydrogen energy and fuel cells, and, finally, development of gas hydrates.

The programme will operate through: collaboration in basic research; industrial demonstration, scale application; pursuing a "go-out" strategy which stimulates Chinese enterprises, research institutes and universities to go global; promotion of international exchange and dialogue; and nurturing of high-calibre professionals. The programme will be jointly organized by NDRC and MOST and a Steering Committee will be established together with an Expert Consultation Committee. Funding will come through special government programmes and efforts will be made to attract foreign funding as well and international organizations will be invited to co-implement the programme. The programme will solicit private capital and investment from the business sector, especially the international energy giants, to stimulate their involvement in S&T in China (MOST/NDRC).

Financing is a key issue to be addressed by the government through various policy measures such as preferential tax policies for companies involved in the renewable energy industry, including reduction or even exemption of the standard rate of value-added tax. As another example, the Renewable Energy Law (Appendix 3), stipulates that the government should set up a Special Fund for Renewable Energy. The Fund was inaugurated in 2006 and is meant to support renewable energy exploration and development projects for substitution of fossil fuels substitution in the following areas: (1) scientific and technological research, formulation of standards and demonstration engineering; (2) projects for the daily use of renewable energy in rural areas; (3) construction of independent systems of power generated with renewable energy in outlying areas on islands; (4) surveys, assessments of renewable energy resources, and construction of relevant information systems; (5) promotion of localized production of equipment for exploitation of renewable energy. A recent regulation on the Special Fund jointly issued by Ministry of Finance (MoF), which is the fund manager, and the NDRC focused on enhancing the indigenous wind manufacturing capacity.[29]

3.2 Legal review[30]

The legal basis for implementing the policies and plans outlined in the previous sections is to be found in a comprehensive body of laws and regulations. Again, in recent years the government has been exceedingly eager to create a more transparent and coherent legal environment for the energy sector in general and for its sub-sectors. The relevant legal documents are listed in Appendix 3.

Initially, it must be noted that China's legal system is different from those known in the Nordic countries. China's rule of law is based on two major sources, the Constitution of the PRC and the Law on Legislation in China. The Chinese system of government is based on unitary principles. Laws are approved by the National People's Congress. All powers to enact that are not delegated elsewhere are in principle exercised by the central government, called the State Council, which is lead by the Premier. Any administrative or local rules that break the laws passed by the National People's Congress are – again in principle – annulled.

[29] Renewable Energy Law of the People's Republic of China, art. 24; Provisional Method for Management of Special Fund for Development of Renewable Energy (Appendix 3).
[30] Sections 3.2 and 3.3 are mainly based on the following sources: Review of a variety of Chinese sources by the authors; Baker & Mckenzie et al. 2007; Weber et al. 2007; Li 2007.

This system favours centralization of power and authority, but when it comes to actual implementation, the situation is not that local governments in the provinces or at levels below are powerless. China is far from being a federal system, but considerable powers are delegated to the local levels and power relations between the central and the local party-states are such that the outcome of a policy process or a policy intervention is far from certain if it jeopardizes local interest. In many cases, local party-states are more than willing to go beyond their authority to pursue their own good.

Moreover, one-party rule without public or democratic participation or control makes China's legal system far from transparent and it does not – as yet – condone a lot of public trust, although the situation has improved over the years since legal reforms were initiated in the early 1980es.

This particular system of governance explains why China, in drafting its new laws after 1978, has insisted on its own traditions and ways rather than copying international models. The general pattern has been to issue laws for a specific topic, sector, or location. Often laws are drafted on a trial basis, with the law being redrafted after several years. The legal environment is thus being constructed in a rather gradualist, retroactive manner and it has led to situations where laws are absent, confusing, overlapping, or contradictory. Indeed, Chinese legislative drafting strives at generality and flexibility. Frequently, excessive generality and omissions, coupled with the wide discretionary powers granted on central and local authorities to implement laws, tend to undermine the predictability and certainty of the legal system. Therefore, the laws and regulations are closer to being policy guidelines than providing a basis for subsequent legal action.

The political principles and policies discussed earlier have largely been reflected in the laws and guidelines governing the energy sector (Appendix 3). They send rather clear signals to the stakeholders in the industry. In relation to renewable energy, the main objectives are to remove the barriers to industry development, to establish a financing system to stimulate development of the sector, to send clear signals to the market, to establish a (self-)sufficient industry system, and to build knowledge and awareness around renewable energy.

A Renewable Energy Law was issued in 2005 and it has been followed by a comprehensive set of guidelines (Appendix 3) that elaborate specifics regarding implementation, e.g. quotas, feed-in tariffs, cost sharing arrangements etc. Many local governments have followed up with local regulations. A rural energy development plan is on the way as is a regulation for grid connection and power regulation.

A combination of "carrot-and-stick" measures is applied to stimulate sustainable growth of the renewable energy market. This will happen through improved price incentives, mandated market share, and new tariff and cost sharing arrangements. The power grid and the petrol wholesaling companies are being obliged to buy renewable energy based power and liquid bio fuels respectively. The power companies will be made responsible to provide the necessary infrastructure and logistical support. Standards for construction of "green"/energy saving buildings are being elaborated and/or harmonized.

3.3 Impact of the policy and legal regimes

The efforts described in the previous sections demonstrate that the Chinese government is now focusing on the need to develop a more complete and stronger legal and regulatory framework as well as a better business and market environment for the use of renewable energy.

The government has recognized that the current GDP focused growth patterns and its resulting surge in energy demand cannot be sustained if major measures are not taken to protect the environment and address the issues related to climate change. These issues are now being dealt with in a more coherent, comprehensive, and balanced manner which combines national efforts with international cooperation. Furthermore, the government aims to combine policy and administrative support with government guidance while letting the market play an increasing role in order to achieve the goals for meeting the growing energy demand.

There is also clear evidence that China wishes to be largely self-sufficient in energy and that demand moderation with more focus on energy efficiency and energy saving have become national top priorities to achieve this goal. The government has also realized that the considerable potential for development of renewable energies has to be tapped into to reach the goal of being basically self-sufficient in energy and to reduce the impact of "dirty" energy sources on the environment and the climate. Therefore, "clean" energy, with a strong focus on renewable energies, has moved up the national political agenda to become a top priority.

The government has also made it a priority to tackle issues relating to the protection of the environment in connection with production and use of energy, and measures have been instituted to regulate this area.

Like in other sectors, China wants to develop its indigenous innovation capacity in the renewable energy sector. It is expected that, by 2020, a relatively complete renewable energy technology and industry system will be developed with a domestic manufacturing capacity based mainly on China's own IPRs. The government will support R&D, new technological applications, and commercialization of technologies in both the public and the private sector. Whereas there is a recognized need for import of foreign technology at this stage, there is also a strong focus on speeding up indigenous R&D, and the government will support more effective dissemination of new technologies.

At the same time, specific rules and regulations are aimed to entice or even force foreign technology purveyors to transfer their core technologies to China. In the wind sector, the government has imposed a 70% domestic manufacturing requirement for the wind turbines with the twofold aim of developing the domestic manufacturers and reducing the prices. According to Chinese experts, the localization of wind turbines can reduce the cost by 30% and the electricity purchase price by about 20% (Weber et al., 2007).

The need to protect IPRs has been recognized. Measures have been taken to support the building of a stronger consciousness amongst holders of IPRs about the value and protection of their IPRs. The cost of protection has been lowered and the penalties for infringements have been increased.

Furthermore, the dynamism of the sector will be stimulated through government investments, favourable tax policies, concessions supporting the deployment of renewable energy infrastructure, guaranteed procurement of "green" kilowatts through quotas and better feed-in tariffs.

The government will also institute stronger measures to build knowledge and awareness in society at large around renewable energy.

Finally, the government will strengthen its ability to monitor and control developments and to enforce laws and regulations. The various laws specify the role of the government with regard to leadership, deployment of resources, monitoring, inspection and promotion. Some of the documents stipulate the responsibilities of public servants and that violations, fraud, and corruption must be punished according to the relevant laws.

The policies, the strategies, the plans, the body of laws, and regulations governing the renewable energy sector combine with strong public support which has resulted in the establishment of a more enabling business environment with a more stringent and coherent system of implementation measures.

3.4 R&D development strategies

While China's R&D expenditures as a percentage of its GDP – 1.41% in 2006 – has not yet reached that of a world leader in research and innovation, the underlying trend is that Chinese R&D spending has been growing by an impressive average of more than 20% over the past decade and faster than that of GDP and China is intent on continuing this trend (Simon et al., 2007).

The focus of China's overall technology development objectives is to follow international research in selected technology areas in order to catch up with the world's most advanced nations. However, in some high-tech fields, China has the intention to become a world leader in the foreseeable future. In relation to energy, China focuses on developing both high-efficiency and new energy technologies.

The strategies for energy related R&D are laid out in the S&T plans and in the energy strategies mentioned earlier. The "Medium and Long-term S&T Development Plan" (Appendix 3) sets the targets for energy technology development and breakthroughs are expected in several areas.

Examples include: energy conservation in industry; clean coal energy development and utilization, liquefaction, and polygeneration. The plan also targets oil and natural gas exploration and utilization under difficult geographical conditions, low-cost renewable energy development and utilization, ultra large-scale transmission and distribution of electrical power, and grid security. The level of per-unit energy use for manufacturing of major products is supposed to reach that of the developed countries. Advanced energy technologies such as fuel cells, distributed energy supply technology, fast breeder reactor, and nuclear fusion were added to the plan after several rounds of discussion (Jiang 2007).

These priorities have been incorporated in the 11th 5-year plan and, as far as renewable energy is concerned, spelled out in more detail in a 2005-2020 development plan for new energy and the renewable energy industry (Appendix 3). The plans are quite specific about the core R&D concerns in relation to renewable energy. The technological level in other areas than hydropower, solar energy for heating, and biogas is considered to be low. There is a recognized lack of indigenous R&D competence and a big gap in the level of technological development as compared to the most advanced countries. The manufacturing competence is weak and there is excessive reliance on import of technology and equipment. The systems that undertake resource assessments, formulate technical standards, inspect and certify products and equipment are all weak and understaffed, and there is a lack of educated and skilled staff. Finally, there is not as yet a comprehensive technical service support system in place. Therefore, the development of R&D competence and institutional capacity has a high priority in the coming years.

For all of these reasons, China is not only interested in developing its own competences but also in engaging in international collaboration to move up the value chain and develop competences to become the world leader in some core technologies. Despite the insistence on "indigenous innovation", our interviews with a number of Chinese stakeholders clearly indicated that international collaboration is essential to achieve the ambitious goals. There is also a strong interest in sharing results as also implied in the MOST/NDRC strategy for international collaboration.

3.4.1 *Programmes and funding mechanisms*

A set of government sponsored R&D programmes aim at addressing mid-to-long term scientific and technological issues, including both basic and applied research. However, the distinction between basic and applied research is somewhat vague in practical terms as the frameworks guiding research designs are often not followed due to inadequate evaluation systems.

There are both national and international programmes that support the development of the energy sector in China. But except for the new Special Fund for Renewable Energy discussed earlier, which still needs to become fully operational, there are no R&D funding programmes dedicated specifically to energy. However, a number of key public programmes can fund energy related R&D. They are:

- The "863" programme is China's National High-tech Programme. It covers eight key technical fields, including biotechnology, space, information, laser, automation, energy, new materials and marine technology
- The "973" programme is the major National Basic Research Programme. It has been established on the basis of existing research activities and initiatives by the National Nature Science Foundation. Major dedicated pre-studies have been used to organize and implement basic research to meet the nation's major strategic needs dealing with issues relating to sustainable development such as agriculture, energy, information, resources and environment, population and health and new materials
- Other major programmes comprise: National Natural Science Fund; S&T infrastructure programme; state key lab construction programme; National Engineering Research Centres; Innovation Fund for Small Technology Based Firms; Torch Programme; National Key New Products Programme; Spark Programme; International S&T Cooperation Programme; Special Technology Development Project for Research Institutions
- Special research programmes under ministries, other public bodies, and local governments. In this context, it should be noted that NDRC has established a High and New-Tech Industry

Department which is responsible for the new-tech industries, including those working within the field of renewable energies. Although the division of labour between MOST and NDRC is basically clear, with MOST being responsible for fundamental R&D and NDRC for industrialization, there are unavoidable overlaps between MOST and NDRC in relation to some R&D initiatives.

The enumerated programmes provide the framework and financing for most R&D programmes with public involvement as well as they may finance R&D in the corporate sector. As noted above, the government has established a Special Fund for Renewable Energy. The Fund is not fully functional as yet, but the Ministry of Finance has initially set up a special funding programme, managed by a new division called the Energy Division, to support renewable energy development. This may be the first step to set up the full-scale Special Fund in the future. This kind of fund is necessary, according to a MOST official, because it can be helpful in scaling up near-commercialized technologies. Only a small portion of the fund can be used for R&D and its mission is to support those technologies that have great potential to be commercialized. Effectively, MOST supports the research for prototype development, while NDRC supports deployment of proven technologies. In industrialized countries, venture capital kick in at this stage while in China today there are very few real venture capital funds.[31]

The "863" and "973" programmes are open to EU partners as part of the EU-China S&T agreement. The programmes issue frequent calls for proposals and they are widely used by the Chinese research communities. The National Natural Science Foundation also has financial incentives for projects to establish international relations.

As a result of these efforts, China has significantly increased the spending on R&D, at an annual growth rate of more than 18% in 2000-2005, positioning China as the third biggest R&D spender world wide (in PPP terms) after the United States and Japan (OECD 2007).

There are also international programmes in operation (dealt with below) to stimulate collaboration between international and Chinese partners. They can be classified as follows: Government supported bilateral or multilateral programmes, collaboration between research institutes, and industry collaboration.

International framework programmes (see Section 6.3) are seen by the Chinese government as an effective tool to plan in which areas R&D should be promoted. As a top priority for international cooperation in S&T, energy - in particular renewable energy – supports the government's commitment to pursue "energy saving and emission reduction" which is now becoming a nation-wide goal, if not already a national movement, as China's climate change programme is being rolled out.[32]

However, as the number of Chinese researchers is growing dramatically, reaching 35 million by September 2007 according to MOST and becoming the world's largest in number, competition among the Chinese research institutions for collaboration with well-known international research groups is tough.

3.4.2 *Techno-nationalism and technology transfer*

As discussed earlier, since the reforms started in 1978, China has focused on inward transfer of key technologies from the technologically advanced developed countries as a way to catch up with them. Whereas the strategy has been quite successful, it has also made China dependant on foreign technology. As a response, there is a new focus on "indigenous innovation" and, as a consequence of this, China's approach to technology transfer has become more complex with different requirements applying to different sectors and situations[33], and this has lead to various, mostly selective measures to promote national technology interests[34]:

---

[31] Interview with a group of MOST officials, 23.5.2008.

[32] Interview with Xing Qijun, Director for Europe, Department of International Cooperation, MOST, 9.4.2008.

[33] In fact, in the experience of a Danish commercial officer from the Danish Embassy in Beijing some provinces/cities are so focused on the growth of their own indigenous industry that they are reluctant to import foreign technologies (Interview 22.5.2008).

[34] The bullets refer in part to Dinter 2006.

- **Indigenous innovation** has been discussed earlier. It is a political priority that encourages, if not forces, local governments to pursue R&D policies that favour local institutions and companies. Some of the interviews indicated that if companies registered in China have foreign shareholders, the majority of shares should be held by a Chinese organization or business owner for the company to qualify as "indigenous", and the business licence issued by the Ministry of Commerce will be specific about this. This policy may also promote enforced technology transfer.
- **Enforced Joint Ventures** - The regulations imposed on foreign companies that wish to invest in China often results in far reaching influence of both the central and the local government. In economic sectors with special strategic relevance, for example in the car industry, the Chinese partner companies are chosen by the NDRC. The decisions are often motivated by strategic rather than economic considerations. The collaboration with foreign partners is meant to enable the Chinese companies to use the best benchmark, i.e. the global market leaders, for their own business development and activities.
- **Design or R&D Centres** - In certain industrial sectors, e.g. in the capital goods industry, foreign investors are obliged to cooperate with local design or R&D centres when they want to set up a new business in China. The Chinese partners are often state owned R&D centres. The transfer of technology mainly happens via the extensive documentation which has to be submitted to the Chinese partner, through in-house research, and through the subsequent strategic move of technologically experienced employees from the R&D Centres to other Chinese R&D institutions or companies in the same line of business.[35]
- **Local content** - In some sectors, there may be a requirement for localization of part of the production through regulations that require a percentage of local content in the production process. Such regulations are meant to enforce foreign enterprises to transfer some of their know-how to local partners. The foreign company will have to enable the Chinese firms participating in their supply chain, i.e. the "local content partners", to deliver the requested quality through documentation, training programmes, quality assurance programmes etc. This is the case with the wind sector, where, in 2002, the government stipulated that at least 70% of components in installed wind power generators should be manufactured in China (Jiang 2007). To comply with this, the world market leader - Vestas from Denmark – has used its sourcing division in Shanghai to set up a network of Chinese sub-suppliers. Vestas sources components that are not core technologies. To comply with the regulation and out of cost considerations, Vestas is increasingly focusing on developing and integrating its supply chain in China and the company conforms to the requirement for 70% local content. The Chinese authorities verify the local content by checking whether items on the Bills of Ladings have been paid in RMB or foreign currency. If paid in RMB, they are considered local. Ownership of the purveyor of specific parts is not an issue.[36] Needless to say, this requirement will also help Vestas become more competitive in the global market as long as production costs in China are still lower than elsewhere.
- **Government procurement** - International companies that wish to respond to an invitation to tender in China have to fulfil certain requirements. The fact that the companies have to submit extensive documentation at the beginning of the bidding procedure can be seen as a means to ensure enforced technology transfer.
- **Illegal copying, industrial espionage, piracy, and violation of IPR** – These are forms of enforced technology transfer that are of concern to many foreign companies and research institutions.[37] A number of our interviewees discussed the issue at length. However, the authors were left with the distinct impression that the Chinese system for legal protection of proprietary knowledge etc. has improved over recent years and that the

---

[35] However, other reasons motivate the outsourcing of R&D as well: proximity to market and production; supply of knowledge resources; "copy-cat" effect, i.e. "the others do it, we must do it also!" (Lundin & Serger 2007).
[36] Interview with Vestas, Shanghai, 4 June 2008.
[37] It must be noted that Chinese companies and research institutions are getting increasingly concerned about theft of their proprietary knowledge as well, and they may suffer as much financially as their foreign competitors.

foreign stakeholders are getting increasingly experienced and are often able to prevent such theft through a combination of in-house market measures.

- **Government discretion** – Our interviews indicated that some foreign companies are concerned that the tendering and contracting of local projects is often decided at the discretion of the local government, e.g. by informally waiving standard bidding procedures. Given the requirement for "indigenous innovation", foreign companies may loose contracts that they would otherwise have won because local governments want to or feel obliged to select national companies as their suppliers.

- **Climate change** - The global aspirations to address the challenges of climate change more forcefully than now under a new post-Kyoto regime may be used as a vehicle by China to insist on technology transfer, especially of core technologies, as a condition for joining such a regime. This will be negotiated at the planned COP-15 meeting in Copenhagen in December 2009. Whereas current CDM projects under the Kyoto Protocol, of which China is host to 23% of the total number of registered projects and takes 52% of global CERs[38], do not entail requirements for technology transfer, many of the authors' interviewees on both the Chinese and the Nordic side expected China to insist on technology transfer, especially transfer of core technologies, in the next round of climate negotiations. Whereas China's new Climate Change Programme (Appendix 3) is not overtly specific with regard to this issue, many of the statements in it regarding technology cooperation may effectively be interpreted to indicate a stronger Chinese stance on this issue.

These policies are implemented differently in different sub-sectors and in different parts of China. They have emerged in response to claims that foreign direct investment (FDI) has been detrimental to the innovative capacity of Chinese firms and R&D organizations. Obviously, they have raised concerns among foreign firms in China of a backlash against them. Prompted by these concerns, Chinese subsidiaries of European firms recently instituted a campaign titled "We are a Chinese company, too" (Serger and Breidne 2007). Indeed, there is reason for concern amongst China's international partners that opportunities in the country for operating in sectors such as renewable energy may be restricted by the policies and practices described above.

3.5 Key players involved in the Chinese energy innovation system

Over the recent more than a decade, a number of organizations have emerged as champions of what could be termed "China's renewable energy innovation system".[39] An innovation system is often seen as a set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation processes in the country or the region. Through its structures and mechanisms, the system interconnects institutions and companies to innovate, i.e. to create, store, and transfer the tangibles as well as the intangibles, such as knowledge, skills, proprietary information and rights, which define new technologies. Companies are obviously key actors in the system, both at the political, the technological and the operational level (Metcalfe 1995). Therefore, this study looks at both non-corporate and corporate organizations.

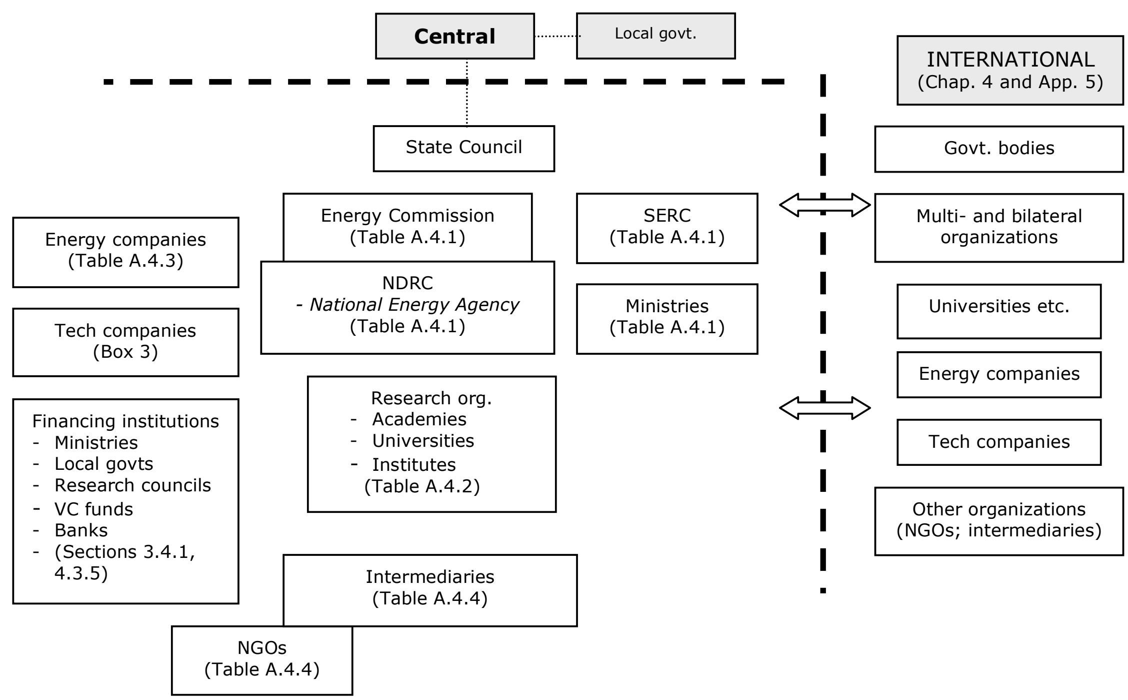
Given the high degree of state involvement in the energy sector in China, the directions for R&D formulated by public bodies are important for the technological development across the sector. Indeed, for many years the push in the market place for new technologies was mainly attended to by foreign players, often through Chinese partners or intermediaries. However, this has been changing over the last decade or more. Many Chinese commercial players are developing their technologies and their business very fast and there is a strong public focus on fostering much stronger Chinese competences in the corporate sector to enable it to take up competition with international technology leaders in the local market and later in the global market (see Box 3). This

[38] http://cdm.unfccc.int/Statistics/Registration/NumOfRegisteredProjByHostPartiesPieChart.html (accessed 24.9.2008).

[39] Most of these organizations work across the energy sector or in specific sub-sectors and there are more than those mentioned here. The focus on renewable energy in this study is the background for the selection of those presented here (see Tables in Appendix 4).

is happening, while the government is also boosting its technical and organizational capacity to deal with the energy and climate challenges. The simplified diagram in Figure 5 shows the key actors in the renewable energy R&D arena.

Figure 5 – Key actors in the renewable energy innovation system (2008)



The actors listed in Figure 5 constitute what may be termed "China's renewable energy innovation system". However, as a backdrop, it must be noted that China's energy bureaucracy and the associated state owned enterprises are far from behaving in a structured and well-defined way. There is no agency that has the necessary power to render effective coordination and each of the public bodies have their own authority and may easily decide to pursue their vested interests rather than a nobler common good (Xu 2007). Therefore, it would be difficult to argue that the system depicted would be in a position to work in unison to implement the policies and strategies elaborated above. The system is highly fragmented and it does not work according to the principles of a flow diagram. Therefore, it has not been attempted to show how the system works by inserting arrows or other symbols that indicate relations, subordination, or flow. However, in spite of its fragmentation and complications, it would be wrong to postulate that such a system cannot work towards the goals elaborated in the various policy and legal documents. Effectively, as discussed in other parts of this study, the system is highly dynamic and able to deliver impressive results.

Under each type of organization or level in Figure 5, there are references to where more detailed descriptions of the key stakeholders can be found in the study. In the remainder of this Section, the linkages and interactions of the system will be discussed. Firstly, the following relationships are of consequence for the future development of China's renewable energy sector:

- **Within the central government**

  The main government institutions engaged in R&D within renewable energies are listed in Table A.4.1. The organizations enumerated are not the only ones, but clearly the strongest. They have a strong track record in the field, and they are those most sought after by international cooperation partners.

An Energy Leading Group (Table A.4.1) was established in 2005 under Premier Wen Jiabao following an energy supply crisis in 2003-2004. It was a sign that the central leadership was dissatisfied with China's energy apparatus which comprises a multitude of different agencies, corporations, and companies across the party, the state, the military, and the corporate sector that all pursue their own interests. The Energy Leading Group was supposed to provide the guiding principles and framework for the policies to be made for a highly fragmented energy sector as well as a strong measure of coordination.[40] Although the proceedings of the Energy Leading Group are largely unknown, the recent spate in new strategies, policy documents, plans, and legislation bears witness to a process that has given strategic direction and momentum.

In March 2008, the State Council announced yet another restructuring programme for the central energy bureaucracy. The programme emphasized the need to strengthen the public agencies involved in the energy sector and it was decided to establish a National Energy Commission that would be able to provide guidance to the development of the sector and be responsible for coordinating the many "agendas" of its stakeholders. Furthermore, under the continued leadership of the NDRC, the National Energy Agency[41] (Table A.4.1) will be reorganized and elevated in the administrative hierarchy through incorporating other agencies dealing with energy issues under the NDRC as well as those of the Office of the National Energy Leading Group and those relating to nuclear energy under the Military Science and Technology Industry Commission. The "new" National Energy Agency will be responsible for planning within the energy sector, industrial policies and standards, development of new energy, energy efficiency etc. The Office of the Energy Commission will be charged by the National Energy Agency and the Energy Leading Group will be dismantled.

Prior to the reorganization of the energy bureaucracy in 2008, the expectation in China and the West was that China would establish a new Energy Ministry on par with other ministries in the State Council (e.g. Sinton et al., 2005), since the original Ministry of Energy was abolished in 1992. Why did it not happen and is this a better solution? Given the intricacies of China's bureaucracy and traditional difficulties with coordination across the many administrative and corporate agencies, this is at least a step forward and may also be a wise one. Effectively, a ministry may not be able to coordinate across party, state and military interests. It would rather add another layer to the already fragmented bureaucracy. The solution with a new Energy Commission above the ministries with high level representation and presumably still under the leadership of the Premier combined with an executive National Energy Agency with a sufficiently high status in the administrative hierarchy may in fact be a smarter way of defeating the 'system logics'.

As a sign of government determination to make the renewable energy sector more influential, the administrative body for renewable energy sources was elevated from division level to department level through establishment of a "New and Renewable Energy Department" under the National Energy Agency. The position of the new Department equals that of the traditionally dominant energy sectors such as coal and nuclear. Under the department, three divisions have been established to be in charge of hydropower, renewable energy (other than hydro), and rural energy respectively. This new institution would be fully engaged in the renewable energy sector. [42]

This may be seen as another step forward to encourage the development of renewable energies. However, it is too early to draw conclusions about how effective and to what extent new stakeholder organizations within the renewable energy sub-sector will be allowed into the policy making process. What is not clear as yet is who will be doing what at the central level in relation to R&D in the future. ERI seems to compete with other

[40] Downs, 2006

[41] The former "Bureau of Energy". The term "Agency" is used here to reflect that the Bureau was elevated to vice-ministerial level in 2008. A new official English name has not been posted on the website of the Bureau of Energy as yet.

[42] Interview with Wang Zhongyi, Director of Renewable Energy Centre, ERI, 8.4.2008.

national bodies for the leadership position in renewable energy development in China, although many R&D bodies are outside its control and supervision.

Nonetheless, given the added focus on renewable energy in recent years, this type of organizational set-up may actually accelerate the development of the sector. However, if the new "meta-body", the National Energy Commission, lacks sufficient foresight and power it may encourage counterproductive responses to agendas like "indigenous innovation" which may again create new barriers to foreign participation in this promising sector.

- **Between central and local government**

  Whereas China is a Unitarian state, the central government does not exercise monopolistic power nor can it control the local governments beyond their perceived interest. This means that the localities have a high degree of discretionary powers which allow them to adapt the policy frameworks and even the legal framework to local conditions and interests, as long as their actions do not threaten the power of the central party-state.

- **Between government and enterprises**

  Reforms in the power sector in 2002 broke up the past ministerial functions and corporations into the companies and organizations shown in Table A.4.3. Despite the reforms, the corporations remain politically and financially strong. The major players are the oil companies, the electricity companies, and the grid companies which in principle operate in separation from each other. Many of these were ministries or part of ministries in the past which explains their solid bureaucratic anchorage and authority. Adding their strategic importance to the economy, they can exert significant political influence. In 2005, the net profits of the three major oil companies listed on foreign stock exchanges accounted for 22% of the total profits earned by all state owned enterprises. Therefore, the energy companies are also vital to the survival of the Chinese political system, since they provide cash in hand for the national budget. But the influence of the energy companies on policy making is not unlimited. First of all, they must respond to the need for maximizing profits for the benefits of their shareholders, and this may not always correspond with the interests of the party-state. Secondly, the party-state has a major hold on the companies through appointment and dismissal of their boards and their top managers who effectively combine a bureaucratic or political career with a business career through shifts between political or administrative positions and corporate management positions respectively (Downs 2006).

Box 3

Goldwind: How it developed

Goldwind Science and Technology Company is one of China's largest domestic manufacturers. Company headquarters are located in Urumqi in Xinjiang Autonomous Region. The company has been one of the driving forces in wind power technology development in China since the 1980'es. By 2006, it had a 33% share of the Chinese market.

The Company started as an international research cooperation project in 1986. It was supported by the Dutch government and started with a program to test imported small 150 kW wind turbines. By 1995, it received loans from the German government to develop 600 kW turbines. In 1996, MOST decided to support Goldwind to become a world leader in wind power.

Goldwind focuses on low-cost, large-scale wind power. The company has in-house expertise covering the whole business chain, from R&D to designing, installing, operating, and maintaining wind farms.

In 2007, Goldwind's sales reached RMB 3.24 billion, with profits of RMB 600 million.

At the moment Goldwind produces 600 kW, 750 kW, 1.2 MW and 1.5 MW wind turbine sets. The company is investing billions of RMB in both R&D and capacity expansion. The focus is on larger wind turbines with a capacity up till 5 MW.

At the moment, the company does not export wind turbines, but in anticipation of this move, international investors have helped push up the market value of the company to US$ 6 billion.

The main Chinese competitors of Goldwind are: Huarui (Sinovel), Zhejiang Windey and Dong Fang.

(Source: China's Clean, 2008)

In the context of this study, it is important that the companies are being obliged by policies, laws, and regulations to play a central role in the development of renewable energies or – in the case of the electricity companies - in procuring and supplying electricity produced on the basis of renewable energies. Whereas it is difficult to assess the effectiveness of the new policies at this early stage, our interviews indicated that there was a positive assessment amongst both Chinese and Nordic stakeholders of the willingness and responsiveness of the Chinese energy companies to accommodate the new quotas and policy incentives.

- **Between government and intermediaries**

  China has its own unique "system" of intermediaries (Table A.4.4.) that are supposed to help the government in carrying out its past service functions as well as new ones, while also representing the interests of their members, e.g. companies in the sector, vis-à-vis the government. There is no patent solution for the organization of intermediaries as it is, but none of them are true non-governmental organizations (NGOs) in terms of having full independence from the party-state. However, there has been a strong drive to create new or to strengthen existing intermediary organizations during recent years to bridge the space between government and society, including the business community. The main players are professional associations primarily comprising experts from the government and academic institutions and business associations or chambers of commerce that represent the industry. However, the national business associations may have both expert and academic members as well as membership from government organizations and public and private business. The organizations work on different agendas and try to exert as much influence as possible on government policies. Standards and codes is one issue that organizations are eager to influence and where the government is interested to involve the business sector through its organizations (Kennedy 2005).

- **Between national and international stakeholders**

  Finally, international organizations are involved in both policy making and capacity building within the public R&D system. A host of international commercial players, many of them Nordic, are involved in the renewable energy sector, through shareholding, through own companies, or through other types of business arrangements, e.g. "hybrid" companies or through subcontracting. The role of these, in particular Nordic stakeholders, will be discussed in a subsequent chapter. International business chambers, like the EU Chamber of Commerce, and International NGOs like Greenpeace and WWF are also involved in the sector. As an example, WWF is implementing a low carbon development project with "Baoding National High and New technology Industrial Development Zone" (see below and Appendix 5, Case 9).

Secondly, to foster a well functioning innovation system, there has to be a demand pull and a creative and dynamic relationship amongst all the stakeholders in the system, including the business sector which must obviously play a central role. Indeed, reforms within the R&D organizational system in China in the last twenty years or more have shifted R&D activities from the public to the corporate sector (Sigurdson 2005). More and more enterprises set up their own R&D teams or departments. However, while the technology manufacturers are getting stronger, they are still weak in comparison with their international competitors in most sectors, except - maybe - for solar thermal, hydropower, and biogas (Jiang 2007).

There are an increasing number of cases that show how local innovation systems are being organized in new and innovative ways around the renewable energy sector and often in conjunction with a need to address environmental issues. The "eco-city concept" and high-tech development zones are examples of how a local innovation system may stimulate development of R&D in relation to renewable energy:

- **Eco-cities** - The move to establish eco-cities around China is one example of how the key players from central and local governments collaborate to engage stakeholders from business and research in the drive to achieve the political goals, plans, and targets for renewable energy. The aim of the eco-cities is to create a clean environment. One of the means is through using clean energy. The most prominent eco-city at this stage appears to be the "Sino-Singapore Tianjin Eco-city" (Appendix 5, Case 8). The eco-cities would be interesting partners or customers for Nordic authorities, R&D organizations, and companies.
- **High-tech development zones** - Baoding City in Hebei Province south of Beijing demonstrates how a city can use a science park as well as international partners to pursue

a low carbon agenda. The "Baoding National High and New technology Industrial Development Zone" was established by Baoding City in the early 1990s as a key National Science and Technology Industrial Park (STIP). It was set up under the auspices of MOST with support from its "Torch" programme. The zone has a strong focus on renewable energy and is a national leader today (Appendix 5, Case 9). There are many high-tech development zones in China and some have a special focus on renewable energy.

These examples illustrate how the Chinese government at the central and local level is putting itself in the driver's seat to develop new sectors, new technologies, and new clusters within the sectors or around the technologies based on a strong demand for new solutions to the energy and environmental challenges. The initiatives have a strong focus on stimulating "indigenous innovation", while the participation of foreign partners is far from excluded.

The diagram at the beginning of this section does not render full justice to the complexities of the Chinese political and administrative system nor to the renewable energy innovation system. Both the political and the innovation systems are fragmented, often fragile, and the lines of command, influence, and cooperation are not always clear. However, at their best, they are highly entrepreneurial with well defined roles for the various stakeholders. At the same time, the systems possess strong cohesive power, due to prevailing historical traditions and institutions still at play. There is a powerful sense of commitment to the mission, and, finally, the Chinese Communist Party exerts an all-pervasive authority and influence, if not control. We have avoided dealing with the relationship within the so-called party-state here. Suffice it so say that the Communist Party maintains a high degree of control over the policy process, over key state officials at all levels, as well as over executives in the major energy companies. This being said, the individuals concerned certainly have considerable room for independent manoeuvring in the interest of their organization or locality, or even in their own interest.

Finally, we must note that the renewable energy sector is a new sector and it is far from clear at this stage whether strong, historically embedded hierarchies are able to accommodate the interests of the many new stakeholders in such a dynamic new sector or whether they will create their own organizations to challenge traditional authority structures and innovation system dynamics.

3.6 Policies, plans, and R&D programmes: How do they evolve?

3.6.1 *From idea to policy*

How do ideas and proposals make their way into policies, plans, and programmes? Taking government R&D programmes as an example, they primarily (but not exclusively as discussed earlier) focus on emerging and applied technologies before they move to the commercialization stage. Technologies listed in the plans and programmes are decided by steering committees with experts from different fields as members. In relation to the "863 programme", a steering group of specialists is organized by MOST. The experts are from research institutes, universities, and enterprises and they are nominated through a process of expert and government consultation. The steering committee selects the technologies to be included in the programme after a series of studies, meetings (some of them including more experts) and consultations. The technology selection process in the "973 programme" is similar. A new approach is being tested under the "863 programme through a so-called "discovery research programme". It is intended to explore new theory and technological ideas for the whole programme. This programme is organized by the National Natural Science Foundation (Jiang 2007).

Experts from a large variety of organizations, mainly those described in Figure 5, are thus important to promote and develop the renewable energy agenda and they entertain close contacts with the relevant government departments and officials.[43]

[43] NDRC and the Ministry of Foreign Affairs are responsible for formulating China's position with regard to international climate change negotiations (Lewis, 2007-2008).

3.6.2 *The role of government and other stakeholders*

In order for the government to achieve its goals in transforming the energy sector it must simultaneously support economic growth, strengthen environmental protection, address climate change issues, enhance energy security, and ensure social stability while allowing a multitude of businesses in the sector, be they small or large, to operate in markets that are properly regulated. Finally, there must be a strong focus on stimulating R&D and innovativeness in the sector to address current and future challenges in the most effective and sustainable manner. The government must also employ a well-funded, highly qualified corps of energy specialists that can support the implementation of government policies in all its dimensions and at all levels of governance (Sinton et al. 2005).

Whereas our interviews indicated a growing recognition of the need for China's enterprises to invest more in R&D, the government will continue to play a central role in the years to come as planner, coordinator, organizer, regulator, controller, funding body, etc. of all kinds of energy initiatives. At the same time, the central government is a key shareholder in the large energy companies and local governments are equally involved in the regulation, control, monitoring, and ownership of local companies. Add to this that key local officials who are not civil servants may be entrepreneurs or shareholders in companies in the energy sector themselves. This trend would likely be intensified rather than weakened as energy commodities are traditionally regarded as national strategic resources. The new interventionism has made it even more difficult to define the role of the Chinese government on its energy arena.

The intermediaries such as technology service providers, science parks, high-tech development zones, consultants, and business associations must provide meaningful services to the enterprises and represent them vis-à-vis the government, but they are still rather weak and many of them are in a nascent stage. Therefore, they will continue to rely on the government for support and service provision for a long time. Foreign intermediaries such as services providers (e.g. the Nordic Innovation Centres, see Appendix 5, Cases 10 and 12), consultants, and business associations are generally an exception to this rule.

Despite its strong position in the sector, it is evident at this stage that, in the interest of continuing its reforms, the Chinese government must balance the roles played by the state and the market respectively. Whereas the current leadership is not particularly in favour of leaving more to the market, it does recognize that too much state involvement can also be detrimental to the development of the energy sector. The debate whether to establish a Ministry of Energy or not is an example of the sensitiveness of this issue. It could be argued that the reluctance of the central leadership to establish a new "super-ministry" for energy is grounded on the need to be able to add new actors from new sectors, such as the renewable energy sub-sectors, to the institutional landscape rather than to struggle to shift power amongst existing ones (Downs 2006).

The proliferation of the renewable energy sub-sector (with its sub-sectors) and all its associated interests and organizations supports the argument for the need for flexibility and openness, at government as well as private sector level. In the past, the development of the sector was hampered by existing, rather inflexible organizations and China cannot allow that situation to continue. Therefore, while traditional actors are being encouraged to establish themselves in the sub-sector, new actors, such as CREIA (Table A.4.4), and their international partners as well as other independent international actors in the renewable energy sector are seen as welcome and necessary additions to the institutional landscape.

The role of local governments is another key issue to be considered. If they are not playing along with the new policies and the emerging legal framework but rather pursuing their own interests, the regulatory regime established around renewable energies may stall or even collapse. On the other hand, however, the strong focus of the central government on development of new energy resources may prompt local governments to contribute to the creation of a "bubble" phenomenon in the energy sector with development of excess capacity on the production side in terms of new coal-fired power plants and power from renewable energy sources while the grid capacity remains under-developed.

However, evidence suggests that many local governments are acutely aware of their environmental problems, the need to save energy, and the need to shift to more sustainable development through use of new energy sources and development of more flexible and effective energy systems. The eco-city initiatives and the development zones discussed above are examples of how local governments may play a constructive and central role in the development of the renewable energy sector.[44]

3.7 Discussion

In sum, the specific strategies for development of renewable energy focus on the following elements:

- The use of available renewable resources should be broadened and deepened
- The proportion of renewable energy within the energy mix should be increased
- The technological and commercial development within renewable energy should be promoted and supported by the government in collaboration with the public and the corporate R&D sectors
- The capacity to undertake R&D in renewable energy shall be strengthened with the government playing a leading and coordinating role.

China has become such a powerful economic and political player that the rest of the world must accept that it is in a position to pursue a certain measure of techno-nationalism that will force international players operating in China to reassess their strategies for R&D and protection of proprietary rights.

Whereas, the governance and legal regimes and the business environment created around key energy priorities indicate a strong political will to exert concerted efforts to achieve the goals and targets set, there are still concerns in China about the ability of the administrative and legal systems to deal effectively with lack of compliance:

- There is a need to enhance coordination among the government departments in terms of supporting the development of the renewable energy sector. This is particularly true when it comes to R&D activities. As a new and high tech sector, renewable energies need to be based on long-term R&D plans and activities, which is exactly what China's R&D work lacks. It would be difficult to improve the situation without an effective inter-governmental coordination mechanism
- The planning departments are preoccupied with planning, scrutiny, and approval of feasibility studies for new projects. Other departments have similarly narrow responsibilities. No government agency has the necessary authority to undertake independent and efficient inspection of compliance of projects or investments within renewable energy with rules and standards. For example, there is hardly any monitoring of project performance, e.g. with regard to wind parks, once the projects become operational
- The approval process for renewable energy projects and investments is tedious and complex and there is a lack of transparency in relation to public planning and approval of renewable energy investments and projects
- The legal procedures for monitoring of compliance by public agencies with legal requirements are unclear, and there is no framework for effective monitoring
- It is often unclear which agencies are responsible to report to whom and at which time.

Effectively, there is a need to develop a more coordinated, coherent, and efficient regime for policy making, strategy development, legislation, planning, legal enforcement, and innovation. The role of

[44] A recent study on the environmental sector in Shanghai explains Shanghai's plans to increase its energy supply and improve its energy mix. However, Shanghai is not in a position to increase the proportion of renewable energy considerably within the current 5-year plan period. The goal is to increase the proportion from zero in 2005 to 0.5% in 2010 (Gu 2007).

key stakeholders in relation to formulation of policies and their implementation is far from clear. Given the strong historically rooted institutions and vested interests in the sector, it is uncertain how and to what extent new stakeholder organizations, e.g. within the renewable energy sub-sector, will be allowed into the policy making process. It will therefore be a particular challenge for new actors working with renewable energies to make themselves heard, to exert influence, and to become competitive in a market and with an institutional and administrative set-up that will tend to favour old rather than new interests.

4 NORDIC INVOLVEMENTS IN CHINESE ENERGY R&D

Each nation in the Nordic region has its own perspective and/or strategy on how their country should contribute to and benefit from the development of the Chinese energy sector. However, as discussed above, the energy system is complex and it is difficult to say what the future holds in store. Without effective coordination at a level higher than the national, the Nordic countries may – each being small in relation to the huge Chinese administration and market - easily waste resources and the mysteries of the system would remain.

This chapter reviews important relevant bilateral and multilateral activities related to energy R&D. In Chapters 5 and 6, the study then discusses whether and how a Nordic-Chinese cooperation framework on energy R&D could benefit a critical mass of Nordic stakeholders since this would – initially – be the criterion for assessing the relevance of any joint effort.

4.1 Government strategies for China

Until China's reforms and opening-up started in 1978, Nordic bilateral activities with China were limited to trade in selected sectors and some collaboration in the cultural and educational fields. With the opening of China, its economic rise, and its increased importance in the global economy and political affairs, the Nordic countries have realized the need for more national efforts to engage with China and benefit from its development. Until now, some national strategies have been elaborated to address this need and more are on the way. Some of the strategies relate to Asia in general, whereas others deal with China specifically (Appendix 3, Table A.3.2).

The strategies have a strong focus on the environment, energy - not least clean and sustainable energy - and climate change. These focus areas are, of course, on the top of all national political agendas and therefore quite politicized at the operational level. Governments will invariably play a key role, not only with regard to energy policy-making and regulation, but also in relation to other aspects of energy production, transmission, and use. In China, this is even more the case as discussed above. Therefore, there are similarities, but also asymmetries between the roles played by the Nordic and the Chinese governments in relation to the energy sector. However, due to the international focus on the need to enter into agreements regarding the mitigation of climate change, both the environment and energy sectors may well render themselves easier to handle for the Nordic governments in relation to China in terms of coordination and funding of activities than most other sectors.

But what is the purpose of these strategies? Are they worth more than the paper they are written on? The argument here is that they do play a role. First of all, they create a dialogue between politicians and public administrators internally in the Nordic countries about the need to engage constructively with Asia and – in the context of this study - with China in particular. The strategies also challenge the "interested" public in the Nordic countries to recognize that Asia and China are strategically relevant and important for our future.

Furthermore, they send a signal – *in casu* to China – that, although the Nordic countries are small, both sides have something to offer that the other side needs. The strategies are used as the basis for the public sector in the Nordic countries to expand its presence in China. Finally, they inform us that if we do not rise to the challenge from China, we may do ourselves damage.

It is also evident however that the strategies may not necessarily help us addressing the challenges identified in a more efficient manner than has been the case until now. The reasons are many:

1. They are packed with intentions, the strategic orientation can be difficult to determine, and there is little guidance for more tangible action. They mostly present catalogues of ideas, many of which are already being implemented
2. Although the corporate sector is seen as a key driver, the focus is – for obvious reasons - mostly on the role of the public sector. A host of different government agencies are involved in collaboration with China already, but it is hard to imagine that any meaningful national coordination is practical, unless new organizations are established with

coordination as their task. Furthermore, the market in China, as well as the globalizing economy challenge enterprises to operate in ways that are increasingly evasive when it comes to well-intended national support programmes

3. The willingness to commit fresh funds on a large scale to specific China programmes is largely absent[45], and, effectively, public funding is mainly available through existing funding channels.

For these reasons, it is as yet uncertain to what extent the strategies can be useful tools when it comes to harnessing bargaining power towards China and engaging national Nordic or other players in more coordinated efforts.

In addition, further development of the bilateral ties between the Nordic countries and China in any sector, including the energy sector, will pose new challenges. Many actors are increasingly vying to cooperate with or be present in China, and due to the size of the Nordic countries and their economies, their limited capacity and resources, and the distance to China, the high-flying intentions expressed in the strategies may be difficult to realize unless a more concerted effort is pursued.

4.2 Export of energy technology

In an analysis undertaken for Nordic Energy Research of the exports by the energy technology industries in the Nordic countries, Maj Dan Trong Analyse (2007) found that exports of clean energy technology (i.e. renewable/energy efficiency technology and equipment) in all Nordic countries show a very positive development trend, with increasing growth:

- In Sweden, clean energy technology had an export growth of 15% in 2004, largely in wind power, bio-energy, and solar energy. The export of clean energy technology amounted to €2.7 billion, of which companies active in renewable energy/energy efficiency technology accounted for 33%. If this trend continues, it is estimated that Swedish clean energy technology exports could reach €4.3 billion in 2008
- Danish energy technology exports have experienced a remarkable increase, in particular as a result of significant growth in exports of wind turbines and wind-turbine technologies. No total statistics exist that include the whole range of clean energy technologies, but in 2006, the wind power industry accounted for approximately 50 % of the export of Danish energy technology. In 2004 the total revenues from Danish export of energy technologies amounted to €7,733 million
- Like Denmark, Finland is, relative to its size, among the leading manufacturers of sustainable energy technologies. During the 1990s annual export of environmental technologies quadrupled to over €3 billion with renewable energy technology now accounting for a major part of Finnish energy technology exports. Around 10-20% of the main components for the world's wind power plants are manufactured in Finland. Finnish wind power technology has an annual export value of €200 million
- For Iceland and Norway, no national statistics show the energy technology export figures with respect to export of renewable energy technologies/energy efficiency technology. In Iceland, geothermal energy is in focus. In Norway solar energy is a rapidly growing industry due to success of one company, REC (Renewable Energy Corporation).

Total Nordic energy technology export to the rapidly growing economies in Brazil, Russia, India, and China (BRIC) and Eastern Europe (EU-10) was approximately €2.8 billion in 2006, corresponding to 15 percent of the total Nordic energy technology export. By comparison energy technology export to the US was 9 percent of the total.

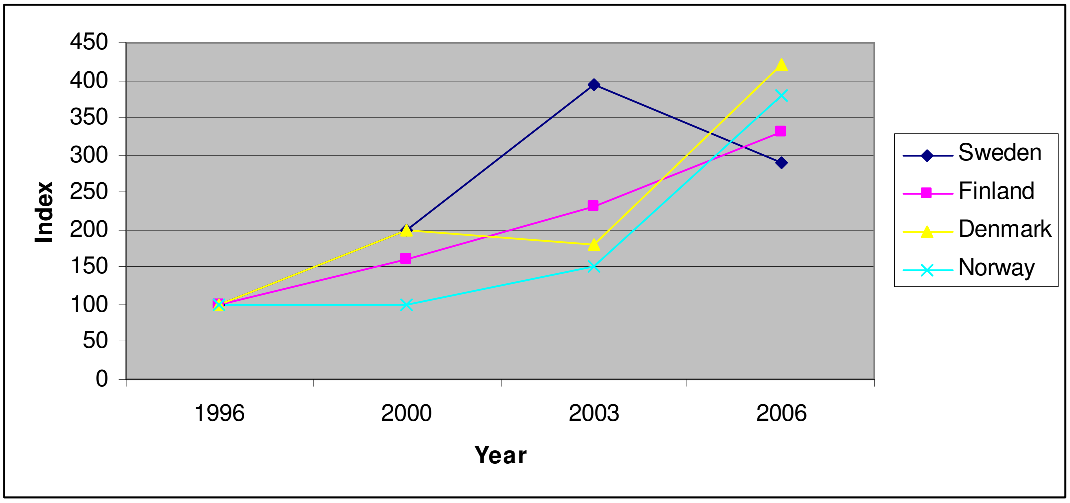
China accounts for 4 percent of the total Nordic technology exports, Russia for 3 percent and Brazil for 1 percent. Exports to China appear to increase more rapidly than exports to other countries. Furthermore, Nordic export of energy technology to Eastern Europe has increased during the past

[45] With some exceptions, e.g. the Danish WED and RED programmes (Appendix 5, Case 6 and Case 7) and a proposed Sino-Danish University Centre (Appendix 5, Case 5).

10 years but with significant variations between the years in consideration. Denmark, Norway and Finland seem even to have lost export shares in India.

Table 5 shows an index for export of Nordic energy technology to China.

Table 5: Nordic export of energy technology to China: Index 1996-2006 [46]



4.3 Modes of Nordic bilateral collaboration

As discussed in the previous section, the Nordic countries are increasingly active in relation to the energy sector in China and renewable energy features prominently on the agenda. This section looks at different types of collaboration involving a variety of stakeholders. Given the scope of the study, it has only been possible to look at players in the renewable energy field. However, it must be emphasized that energy efficiency is a focal area for many bilateral and commercial activities, and the focus on renewable energy here should in no way be construed to indicate that this area is more important than others.

The subsequent sections provide an overview of Nordic programmes and activities. The study has identified three types of cooperation/collaboration: top-down governmental cooperation, intermediate institutional cooperation, and bottom-up cooperation.

Due to the number and variety of activities with Nordic involvement in China, it must be emphasized that the overview is not all-inclusive. Therefore, a synthesis of the different modes of collaboration is presented with due reference to a number of interesting and representative cases in Appendix 5.

4.3.1 *Government-to-government co-operation*

Each of the Nordic governments has signed a number of agreements with the Chinese government in relation to scientific and technical collaboration, and there are also regional S&T agreements or specific framework agreements for collaboration in relation to energy.[47]

[46] Maj Dan Trong Analyse 2007. Index figures are approximates as they are extracted from graphs in the original publication. Figures are not available for Iceland.

[47] Two examples: (1) Since 1986, Finland has had regional framework agreements with Jiangsu, Shenzhen, Shanghai, and Beijing (interview with Finnish S&T Counselor in Shanghai, 2.6.2008); (2) NCRD and the Norwegian Energy Department signed a MOU on energy and environment in 2006 which focuses on: 1. Energy efficiency and energy management; 2. water management; 3. green technologies for use in smart green modular buildings; 4. financing mechanisms (Interview with Innovation Norway, Beijing, 21.5.2008; (Interview with Norwegian Ministry of Petroleum and Energy, Depart. for Climate, Industry and Technology, 26.8.2008).

The agreements vary in level of detail and in terms of the funding allocated to implement them. Mostly, they provide for intellectual exchange, possibly in support of specific research fields, including energy, or even ongoing projects.

Norway and Denmark have specific government funded programmes within environment and energy. As for Sweden, energy has not yet been put on the top of the Swedish agenda when it comes to China. However, clean coal is an important area of work and commercial promotion in the sector has been scaled up recently. Finland and Iceland[48] both pursue a similar approach.

Norwegian bilateral cooperation in China is mainly focused on environment, but there are openings for cooperation in the energy field as well.[49]

Danish bilateral cooperation with China has focused on environment for many years, including both energy efficiency and renewable energy, of which the latter has had a high priority in recent years. Currently, Denmark is operating a wind energy development programme (WED) with NDRC (Appendix 5, Case 6). The project has two components that include research collaboration between Chinese and Danish partners: (1) Meso and micro-scale modelling and (2) grid absorption and grid connection studies. The main counterpart of the project is ERI under the National Energy Agency, but other partners are involved as well. The project took some time to become operational, but is now working well. The main lessons have been that there is a need to create a mutual understanding about all aspects of the project at all levels, including operational and management matters, before the project can move ahead.

The Danish side has been able to create a strong partnership which now leads to a new programme: "Danish-Chinese Renewable Energy Programme (RED)" (Appendix 5, Case 7). This programme will also be located at NDRC. A MOU will be signed in October 2008 and a project agreement will be signed later on. The project moves beyond wind and incorporates more renewable energy sub-sectors but it excludes hydropower. The project will focus on helping the NDRC establish a Renewable Energy Centre under the National Energy Agency. It will also promote development and transfer of innovative renewable energy technologies through cooperation between R&D environments at institutes, universities, and in private sector enterprises in Denmark and China. The Danish contribution to the WED project was 45 million DKK and to the RED it will be 100 million DKK.

Not surprisingly, the development of an effective Danish-Chinese platform for cooperation has been challenging due to the lack of experience in the field on both sides. But the authors are of the opinion that Denmark's experience with working with the NDRC and the National Energy Agency could be an important resource for the development of a Nordic Framework Programme for R&D in relation to renewable energy. At the same time, the Danish platform inside the National Energy Agency and the NDRC, especially the planned Renewable Energy Centre, could be seen as a key resource for other Nordic stakeholders.

4.3.2 *University/research institute collaboration*

University cooperation is representative of intermediate institutional cooperation and there is a variety of university agreements and cooperative frameworks in place between Nordic and Chinese universities. The focus here is on energy related research and education.

Energy related research

Norway and Denmark have attempted to map research collaboration activities with China in the energy field systematically. The Norwegian mapping exercise was done specifically for energy and environment (Buan 2008) and in Denmark it was part of a comprehensive research mapping exercise[50]. The mapping shows that energy is an important field as also indicated by the bilateral strategies discussed above. However, a scanning of home pages of universities and research institutes in the Nordic countries revealed a picture of activities where intellectual exchange, i.e.

[48] When contacting the Icelandic Embassy in Beijing, the authors were referred to Glitnir Bank's representative in Shanghai (Appendix 5, Case 14).

[49] Interview with Per Schive, Environmental Counsellor, Norwegian Embassy, Beijing, 7.4.2008.

[50] "Strategi for Vidensamarbejde mellem Danmark og Kina" 2008 (Appendix 5, Case 5).

exchange of scholars and joint conferences and workshops, is still the dominant form of cooperation, rather than more consolidated research collaboration. A simple search of the international scientific publications databases only revealed a small number of joint Nordic-Chinese publications and conference papers.[51]

However, it does appear that an increasing number of activities are being undertaken. Most researchers seem to be in a phase of exploring possibilities and building mutual trust which is essential to ensure successful research collaboration. There are some notable exceptions with longer term and deeper collaboration, some of which are presented in the cases in Appendix 5 (Cases 2, 3, 4, 6).[52]

"Intermediate institutional cooperation" may take a variety of forms:

- *Memorandum of Understanding/Letter of Intent:* Many Nordic universities, faculties, and/or departments as well as many research institutes have signed such documents with partners in China. The documents are usually of a general nature, but in a few cases there has been a strong focus on building structures for implementation. The research institutes are often more successful in pursuing this approach because of a more focused mission (Appendix 5, Cases 3 and 4) whereas university researchers seem to follow a bottom-up approach (see below). Some collaborative activities have been going on for years and strong ties and networks have been established at the institutional level. Such networks are important in China and should be utilized (wisely) by Nordic collaboration in case a programme of activities should materialize.

  In some cases, seed funding is provided to realize the intentions, but in many instances this not the case. Therefore, and maybe especially for the universities (due to their size), such documents mainly have symbolic value for the partners. It would probably not be incorrect to venture the proposition that most of the documents do not lead to activities beyond official exchange visits, and the occasional exchange of the odd researcher and some students.

  Some agreements have been established to provide the basis for more consolidated infrastructure or organizational presence in China. KTH has been trying to establish a network of energy related centres (Appendix 5, Case 4) and the Danish Ministry of Science, Technology and Development (VTU) and the Danish universities have just decided to establish a Danish University Centre in China (Appendix 5, Case 5).

  The Nordic Centre Fudan (NCF) is a Nordic platform for cooperation within research and higher education between Nordic and Chinese universities and institutions. The Centre is located at Fudan University, ranked as the third best university in China. Today, the Nordic Centre consists of 26 top universities, representing all the five Nordic countries and China. When the Centre was established in 1995, it was the first Nordic university collaboration in Asia and it is still the only joint Nordic academic institution in China today. The centre hosts an increasing number of international academic activities, and is a unique platform which has become a model for other academic platforms. At this moment, NCF has had no activities within the energy field, but there is an interest to pursue activities if a Nordic lead partner can be found.[53]

---

[51] The authors have not looked into patent databases. Such a search may produce other insights on the outcomes of collaborative activities.

[52] Other cases include: (1) At the institutional level, RISØ/DTU has established a framework for long term collaboration on wind energy with Danish government funding (Appendix 5, Case 6); (2) at the individual level, Professor in Energy Systems Analysis, Thomas B. Johansson, who is Director of the International Institute for Industrial Environmental Economics (IIIEE) at the University of Lund, Sweden, and former Senior Advisor on Energy and Climate Change to the UNDP, and former Co-Chair of the Working Group on Energy Strategies and Technologies of the China Council for International Cooperation on Environment and Development has produced a series of publications with various co-authors on energy and climate issues in China. Prof. Johansson is also the main reviewer of this report.

[53] Interview with NCF Programme Director, 30.5.2008. The Department of Environmental Science & Engineering at Fudan University is keen on such collaboration also. They are now promoting a programme with the University of East Anglia (UK) on a comprehensive district CO_2 reduction system (CRED – Carbon Reductions System). It is a system designed to involve multiple stakeholders at the city district level. Effectively, the

- *Education:* In this context, it should be noted that agreements between universities often provide the basis for student exchange, but there is clearly a stronger interest from Chinese students in the hard science fields to go to the Nordic countries than *vice versa*. There is little tradition for organizing joint courses for Nordic and Chinese students. However, BI Norwegian School of Management has been running MBA programmes at Fudan University for Chinese students from the corporate sector for several years and is now planning to establish an MBA in energy management. BI already offers such a programme in Norway in collaboration with a French partner. The course will mix general MBA modules with specific energy related modules and it is expected to be up and running within two years. It may be linked to a possible Nordic energy related PhD programme and BI is interested in soliciting the interest of other Nordic universities to collaborate on this.[54]

Bottom-up collaboration is the most common and probably the preferred model for most researchers. The mapping of Nordic research activities in China done by this study has indeed revealed a number of such activities. Many of these may have been facilitated by university agreements, but this is not necessarily the case, since researchers mostly pursue their own contacts and networks.

One particular form of bottom-up collaboration has a Chinese researcher based in a Nordic university as the principal architect. It appeared from our interviews with Chinese universities that such an "out-posted" staff member (either on a Chinese or a bilateral government programme or hired in by a Nordic university, typically after successful completion of a PhD degree) are often instrumental in creating linkages between senior researchers. In fact, the Chinese professors interviewed indicated that such an arrangement had comparative advantages, since access to the Nordic environment was easier and since the Chinese intermediary could also play a role as a "bridge" between the two cultures, not least the academic cultures.

In sum, there are fine traditions for Nordic-Chinese academic collaboration. At the institutional level, most of the interested Nordic research organizations have agreements with Chinese partners. At the individual level, joint research projects are underway, but the majority of activities focus on intellectual exchange. However, in spite of the indisputable Nordic reputation in China, this study also finds that there is little substantial experience in large tracts of the Nordic R&D system with renewable energy in China. Not many Nordic and Chinese research institutions collaborate on joint research programmes, and there is even less evidence of joint R&D activities with a commercial perspective. At times, there may also be a mismatch of scientific ambitions and competences between Nordic and Chinese partners. Therefore, there are only few "good practice" cases to refer to. With reservations with regard to the limitations of the methodology applied here, major breakthroughs in terms of scientific output or institutional collaboration promoting long term, substantial research have been difficult to identify.

4.3.3 *Technological research, S&T promotion, support to R&D*

TEKES and VTT Technical Research Centre of Finland (Appendix 5, Case 12) are examples of public organizations that facilitate, fund, or get involved in R&D at the applied end of the scale. Both organizations are involved in the energy sector, but they are relatively new to this field in their collaboration with China. Between them, TEKES has more substantial experience on the ground with implementation of programmes and projects in China. In the energy sector until now, TEKES has mainly been undertaking studies and VTT has mainly been involved with the sector through an Eco-city project in Mentougou outside Beijing (see also Appendix 5, Case 8).

Both organizations demonstrate that it takes considerable time to develop a network and adequate experience in China, but that persistence will also pay off in the end. However in relation to the energy sector, there is little experience as yet with both public and private Finnish and Chinese

Fudan campus will be used as a pilot case to demonstrate the capacity and viability of the system, especially in new buildings. The system is based on proven UK technologies, but they must be adapted to the local conditions (interview with Prof. Wen Bodong, 30.5.2008).

[54] Interview with BI Director of Studies, China Programmes, 30.5.2008.

R&D partners involved with activities that follow an R&D process all the way through from conceptualization to the commercialization stage.

Another example is the Norwegian Research Council which has made China, USA, Canada, and Japan the priority countries for funding of research collaboration. In the autumn of 2008, the Research Council issued a call for cooperation with China in the field of Climate Change. However, there was no particular emphasis on energy issues in this call. The outcome of the call will only be known later. Furthermore, the Research Council has issued a call for bilateral cooperation with the priority countries mentioned above for projects with industrial components. Again, the outcome is yet unknown.

Energy is mentioned as a possible topic for cooperation with China in different forums, both on a joint Nordic and joint European scale. However, the Norwegian side is not prepared to go into detailed negotiations on participation in joint initiatives towards China in energy topics yet. The research programme RENERGI would therefore be a natural node for such cooperation.

The Research Council of Norway has experienced a considerable interest in cooperation with China from the research community. At the same time, the actual amount of operational projects with Chinese institutions as partners is generally low. During 2006 and 2007, in particular, a special effort has been made to stimulate establishment of new collaborative Sino-Norwegian projects, and the Council expects that this effort will lead to more project collaboration in the years to come. In general, the Research Council wishes to see Chinese partners involved in many more of the regular programmes.[55]

There are similar initiatives with different priorities in the other Nordic countries. A more comprehensive overview of Norwegian academic collaboration with China in environment and energy can be found in Appendix 5, Case 3.

The KTH energy centre and its sub-centres in China (Appendix 5, Case 4) are examples of long term collaboration that has lead to the creation of a comprehensive institutional base around China. It started with nuclear energy but has moved into other energy technologies as well. The centres organize a whole range of activities from joint research, over intellectual exchange, to PhD education. Thus far, the centre is receiving positive feedback from both the Swedish and the Chinese governments and it is recognized by the EU that has funded a number of projects organized and implemented by the Centre. Looking at the Centre's portfolio of projects, a large part of the financing appears to come from externally funded projects and it may be difficult to sustain such a massive operation if an adequate flow of external projects cannot be maintained.

The Swedish-Chinese exchange programme on renewable energy between the Royal Swedish Academy of Engineering Sciences (IVA) and the Chinese Academy of Engineering (CAE) has been established under the auspices of the Swedish Energy Agency (STEM) (Appendix 5, Case 2). It is an example of a bilateral intellectual exchange programme that was set up to facilitate mutual understanding and trust and which is now ready, funding permitting, to move to the next stage of collaboration, particularly narrowing down to specific technologies that the two partners can work on. It is also an example of a cooperation model where two institutions have been obliged to act in alliance to bring in or service other potential partner institutions from the two sides and also to perform some services, e.g. to incoming missions.

The announcement in September 2008 of a new Danish University Centre in China (Appendix 5, Case 5) was a sign that bilateral collaboration can move to an even higher stage. The Danish University Centre will be located at the Graduate University of CAS (GUCAS) in Beijing. It will foster research and offer educational programmes at Master and PhD level. When the Centre has been fully developed in 2013, it will host 100 researchers and 300 students, half of them from Denmark. The Centre will have renewable energy as one of its focus areas.

Some Swedish universities have been interested in establishing a Swedish Campus at Fudan University in Shanghai, but the idea has not materialized as yet.

[55] E-mail correspondence with Thomas Hansteen, Norwegian Research Council, September 2008.

In sum, research collaboration in relation to renewable energy between the Nordic countries and China is still largely in an exploratory phase, where intellectual exchange coupled with some research collaboration has been the dominant form of cooperation. Funding for these activities has mainly come through the normal research funding channels and some dedicated programmes (see Box 4). With the exception of the KTH Centre, there has been no clear strategic focus, nor have any of the support instruments proven their strength or worth as yet. Of course, there may be exceptions that the authors are unaware of, but they have not been obvious. It should also be noted that apparently none of the programmes have been evaluated until now.

> ***Box 4***
> **Research financing** is mainly provided by public research financing programmes on both sides and also through international funding, e.g. the EU. Some research funding organizations in the Nordic countries have special programmes with funds dedicated to collaborative research with Chinese partners. There are also a few examples of programmes with energy as a focus area.

The new Danish University Centre is a collaborative framework in a new league. If successful, the Centre could become a key Nordic R&D player in relation to renewable energy.

4.3.4 *Public promotion initiatives*

The public commercial promotion teams at the Nordic embassies and consulates and the Finnish and Danish Innovation Centres in Shanghai (Appendix 5, Case 10) have different missions and tasks and clearly serve the national interest. They are all increasingly focusing on energy, environment and climate change related business, but the commercial teams are not necessarily focusing very clearly on R&D promotion. In contrast, that is exactly the mission of the innovation centres that have been set up to establish triple helix linkages between the corporate sector, the public sector, and universities, research institutes, and other R&D communities.

As China is moving from being a manufacturing base to a more innovation based economy all of the Nordic agencies provide more and more support to their national clients and stakeholders to enter the Chinese R&D scene. Therefore, these organizations are important platforms for promotion of Nordic energy technologies and they help create awareness in China about Nordic capabilities in the energy sector at the public and the corporate levels as well as within the R&D communities. They are also active in creating national networks with the interested stakeholders. Finally, they have a strong focus on the provincial and the sub-provincial levels.

The Chinese "eco-city programme" (Appendix 5, Case 8) has attracted the attention of many Nordic stakeholders and could be an interesting target for joint Nordic interventions by these agencies. The Nordic countries could complement each other, brand the Nordic region as a region with a "green" or "clean" mission, offer a full package of services and technologies, and be able to cover all of China. If they would be willing to share contacts, experts, and resources to create more visibility and public awareness about the Nordic countries in China, the Nordic Region would be able to harness much more bargaining power vis-à-vis the eco-city administrations. This was actually suggested by a number of interviewees from these organizations as well as by some of the companies interviewed. They recognized that it is important to be able to make it to the top level in each of the cities. Once the top leaders, especially the mayors, have made a decision to sign agreements with potential or actual partners, then it will be much easier to handle the contacts further down in the local system.[56]

4.3.5 *Investment initiatives*

In excess of US$ 50 billion were invested in renewable energy worldwide in 2006, and it is estimated that China invested US$ 10 billion (Thomas, 2008). In 2007, the estimate was that the figure had reached US$ 12 billion, making China number two in the world, trailing after Germany, the world's number one investor, with a total of US$ 14 billion. *New Energy Finance* predicts that another US$ 398 billion of investment will be needed to reach China's 2020 renewable energy goals,

[56] One of the interviewees formulated it as follows: "一把手工程,一路绿灯", i.e. "if No. 1 is in charge of the project, then there will be green lights all the way",

i.e. an average of US$ 33 billion per year mainly for wind, biomass, hydro and solar installations (see Sections 3.1.1 and 3.1.2).[57]

China's low carbon industry has experienced rapid growth over the last decade. For example China's six largest solar PV manufacturers had a total market value of over US$ 15 billion in July 2008. Some other rapidly growing areas are the solar water heater market which employs over 600.000 people in China and which is worth over US$ 2 billion per year and growing at an annual rate of 20%. The energy efficient compact car market was worth over US$ 50 billion in 2007 and the electric bicycle market was worth over US$ 6 billion. China's leading wind turbine manufacturer, Goldwind Science and Technology Company (see Box 3), has a rapidly rising market value of US$ 6 billion.[58] Many of the new manufacturers are companies that previously operated in other sectors. As an example, many of the sub-suppliers of Vestas in China are former military companies that have received generous government investments and/or loans from government banks to transform themselves into civilian enterprises.[59]

This development is driven by a combination of government regulations and incentives, developments in the market, and increasing investments in R&D across the public and corporate sectors, often in collaboration with each other. Therefore, there is scope for Nordic investments as well, in addition to exports to China from the Nordic countries (discussed in Section 4.2).

Effectively, a number of Nordic investors are already operating in China. Field projects involving renewable energy applications, e.g. wind parks, biomass projects, or geothermal projects, need financing and there is Nordic interest in such projects. Most of these projects do not incorporate R&D[60] and therefore it has not been the ambition here to map the Nordic institutions that finance such projects and only two specific organizations will be listed here as examples.

Through a joint-venture company registered in China, Glitnir Bank from Iceland is involved as an investor in a geothermal project in Xianyang City in Shaanxi Province. Glitnir is an investor in the project together with two other Icelandic investors and a local geothermal company backed by SINOPEC. The project has developed very fast and is slated to become one of the biggest in China. The core technology is provided by the Icelandic partners. The project does not finance R&D and the Icelandic partners (one of which is a technology partner) are responsible for adaptation and the combination of the technologies used (Appendix 5, Case 14). The project is an example of how a proven world-class technology can still turn into a business opportunity once the financing is in place, even if China has a strong focus on the need for transfer of core technologies.

In the recent decade or so, the Nordic Environment Finance Corporation (NEFCO) has supported investments in environment, including renewable energy, mainly in the Nordic countries and the region around the Baltic Sea. However, the Fund is also interested the climate business and has already approved one demonstration project in China in 2007. In 2008, the NEFCO Carbon Fund (NeCF) was launched. It is a global fund working with a Public Private Partnership model. Based on a trust fund administered by NEFCO, it is an instrument for purchasing greenhouse gas emission reductions under the joint implementation (JI) and clean development mechanism (CDM). The NeCF invests in a wide range of projects by providing carbon finance to renewable energy, energy efficiency, fuel switching, and other investments. China is one of the principal target markets. Given that China will most likely focus on technology transfer in relation to climate change projects in the future, NEFCO may be considered as a potential platform in the future that could support Nordic R&D related investments within the Fund's target fields and involving both business and research partners.

4.4 Nordic Council of Ministers

At the Nordic level, the Nordic Prime Ministers have initiated a process to explore how Nordic collaboration can help the Nordic countries maintain and enhance their competitiveness in a

[57] China's Clean 2008.
[58] Ibid.
[59] Interview with Vestas, Shanghai, 4 June 2008.
[60] The authors did not identify Nordic financial institutions involved in projects with R&D components.

globalizing economy.[61] In this context, initiatives in relation to Asia are being considered, and this study is a contribution to the process.

At this stage, there is little research or R&D cooperation with China funded by Nordic collaboration. The primary Nordic activity is NIAS-Nordic Institute of Asian Stud*ies* which has been working with Asia for 40 years and which has had research on China as a focal activity on its research agenda throughout.

In the recent couple of years, NORDFORSK has been an active participant in a "Chinese Academy of Sciences (CAS)-Nordic Forum" which has conducted two meetings in 2006 and 2007. The focus of the Forum is on life sciences, nano-science, information science, environmental science, synchrotron light and accelerator physics. These events have been a platform for researchers to meet and discuss joint activities. They also offer an opportunity for discussion regarding joint activities between China, the national research funding bodies, and NORDFORSK as well as for high-level meetings between CAS and the Nordic Council of Ministers.

NORDFORSK is also involved in a project, "NORIA-net", with the aim of stimulating Nordic-Asian research funding cooperation, in particular in relation to China and India. The aim at this stage is to identify the needs and prepare a model for joint research funding activities to be implemented together with the Nordic countries and their Asian counterparts. The ultimate goal is to establish long-lasting funding instruments and funding mechanisms jointly coordinated and funded by NORDFORSK and the national research councils.

4.5 Other countries and donors

The Australian Embassy in Beijing has gathered information about the activities of the bilateral and the multilateral donors in China. Apart from the activities of the Nordic countries already discussed in this study, the following countries are listed as having financed or planning to finance activities in the energy field, including renewable energy: France, UK, Germany, Japan, the Netherlands, Spain, UK, and the United States. From the available information, there is no evidence that any country operates in ways that are different from those described elsewhere in this study. As is seen with the Nordic countries, there may be an increasing focus on R&D, but no substantial evidence is available to support such a supposition.

As the largest and the second largest energy consumers in the world, the United States and China have realized that they need to engage in dialogue to tackle common challenges and prevent potential conflicts over energy resources. A Sino-American Energy Policy Dialogue was established between NDRC and the U.S. Department of Energy in May 2004, to facilitate bilateral exchanges at the policy-level of views on energy security, economic issues, and energy technology options. Before the policy dialogue started, the two governments also launched an Oil and Gas Industry Forum in 1998 to facilitate opportunities for government and industry leaders from both countries to have discussions about their respective needs in the oil and gas sector. On an international level, both countries have also been involved in multilateral forums, such as the Asia-Pacific Economic Cooperation, the Asia-Pacific Partnership on Clean Development and Climate, and the International Energy Forum's Joint Oil Data Initiative. In December 2006, the policy dialogue became part of a newly launched China-U.S. Strategic Economic Dialogue. Before that, the policy dialogue topics had included energy policy making, energy supply security, power sector reform, regulatory issues, energy efficiency, and the development of energy technology. Through the dialogue, the Chinese side has become familiarized with various U.S. policy initiatives and what the government of the United States does to encourage the commercialization of advanced technology in the energy sector. The Americans also had opportunity to learn from China about China's energy policies (discussed elsewhere in this report). Another outcome – which might of course have happened anyway - has been China's establishment of a strategic oil reserve as a hedge against supply disruptions. Nevertheless, it is concluded by one expert, that although both countries feel very strongly about sustaining the world's economic growth and ensuring access to reliable and affordable energy, the policy dialogue has so far achieved little beyond understanding each other's policy making and positions on various energy issues (Hu 2008).

[61] http://www.norden.org/globalisering/sk/index.asp?lang=6, accessed 24.9.2008.

The ADB, the World Bank, the European Commission, and the UN system are the major multilateral agencies working with China in the energy field. The initiatives of the World Bank and the EU are described in Appendix 5 (Cases 1 and 13).

In terms of grant aid, the World Bank and the EU are the major donors and somewhat comparable in terms of their focus and approach. They both work with key players in the Chinese energy system, primarily NDRC. They differ in the sense that, although both are big in terms of funding and have profiles that similarly target China's key political and technological concerns in relation to both renewable energy and energy efficiency, the World Bank has handed over implementation of its programme to the Chinese government whereas the EU is seeking joint implementation based on EU rules. The different formulas produce different challenges, and none of them have found their final form as yet. The programmes have provided various policy outputs, but in relation to renewable energy R&D, they have not rendered anything of substance as yet.

The WB case may not be as valuable as a reference as other cases, considering the nature of the WB organization, its long and strong presence in China, the scale of its investments and grants, and its focus that is mostly on energy policy studies rather than on energy R&D. Nevertheless, if and when Nordic collaboration gets into energy policy collaboration, the WB may be a partner to team up with and learn from. The same may be said for the EU which will clearly have a lot of experiences to share, if need be.

The donors working with energy hold an informal coordination meeting in Beijing twice a year. Apart from what has been noted in this section, there is no systematic collection of information on the donors' initiatives. At the same time, it should be noted that development assistance to China is being phased out by most donors. Climate change, environment, and energy will be the areas where funding will be available in the near future, but development assistance within these areas will also be phased out eventually as China's economy continues to develop fast.

Therefore, new structures, mechanisms, and possibly institutions will have to be put in place to finance international cooperation in energy in the future. This report has discussed some of the initiatives from the Nordic countries. In this context, it must be expected that China will be increasingly willing to co-finance activities that relate to policy development and R&D related collaboration.

4.6 Confidentiality and IPR protection

It has long been recognized in China that sound IPR policies can facilitate the transfer of research results from public research organizations to business enterprises in China and from foreign research bodies and firms to the Chinese economy. Since China joined the WTO and signed the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), the Chinese patent system has been aligned with international standards and conventions and applications to the Chinese Patent Office have picked up considerably since then.

Nevertheless, the situation still falls short of the needs of both domestic and foreign enterprises operating in China. Infringement of intellectual property rights, particularly of copyright and trademarks, remains a worry for many. This is mainly due to weaknesses in the enforcement regime since both judicial and administrative decisions are difficult to implement owing to the lack of appropriate infrastructure and mechanisms as well as of manpower.

The lack of effective IPR protection affects innovation in China in various ways:

- Some foreign firms hesitate transfer technology to China and the threat of IPR infringement may limit their willingness to produce in or even to export goods to China.
- Concerns about IPR protection have reportedly reduced the interest of some Chinese inventors to commercialize the results of their R&D. According to the Department of Commerce of the United States, in 2006 alone there were only 353 foreign related civil IPR

cases in China of a total of 12,219, while the rest were cases between Chinese firms involved in infringement on trademarks, patents, and copyright.[62]

- IPR infringements, combined with low standards of quality, may also affect the national and international reputation of Chinese firms.

However, China's move towards a more innovation based economy can be expected to lead to improvements. It should also be noted that, as Chinese enterprises become more innovative, and they, too, are adversely affected by a lack of effective IPR protection. Therefore, it is likely that awareness of this problem will become more widespread and lead to more effective counter-measures. As an example, Tsinghua University, one of China's largest IPR applicants, vigorously pursues every instance of infringement.[63]

The authors' interviews in China revealed that both Nordic and Chinese stakeholders are concerned about IPR infringements and also at times uncertain about how to handle the IPR issue properly. In a wider perspective, different cultural, academic, and business traditions and perspectives may also have an impact on the attitudes towards contractual relationships and IPR protection.

However, the stakeholders also indicated that there is less talk about IPR now, since there is more awareness of the need to comply, and also better legislation and legal protection. Furthermore, foreign firms have learnt from past experiences and now have better procedures in place to protect their knowledge and IPR. They may not be immediately understood or accepted by Chinese researchers, but they quickly learn how the system works and accept that they must comply if they want to collaborate (Appendix 5, Case 11).

At the R&D Unit of the Danish company Grundfos, IPR is not considered a major issue, but extra precautions have been taken to protect the proprietary knowledge of the company. Employment contracts are very specific on the issue and technical precautions are implemented so that proprietary knowledge cannot leave the organization unnoticed. Grundfos has also employed a patent-engineer to follow the state-of-the-art in China, to assist in implementing internal measures, and to supervise what is happening in China in general. Grundfos would be ready to take cases to court, if necessary. There have been a few legal cases as a result of serious infringement as several Chinese companies copy Grundfos' products, the logo, etc. Effectively, more than 50 companies are under supervision. In the opinion of Grundfos, however, the best way to handle copycats is always to be a step ahead through innovation. Copies of the products will always exist. The most important thing is to be careful to protect products and product concepts that are under development.[64]

TEKES has been involved in one case about Chinese infringement. It was solved through a Chinese court. In research projects, TEKES uses the same contract formats as it does elsewhere. It starts with an agreement on confidentiality. Researchers are often shy to address these issues in advance but they gradually accept the need for the procedures and the process. If need be, TEKES advises its partners to go the EU Representation in Beijing which has a very effective IPR helpdesk that can be contacted by newcomers (Appendix 5, Case 12).[65]

4.7 Opportunities and challenges in international collaboration

The following opportunities have been identified by the study:

- At this critical junction in the development of the renewable energy sector in China, there are excellent opportunities to partner up with Chinese counterparts in the Chinese national and regional innovation systems that deal with renewable energy as exemplified by Novozymes (Appendix 5, Case 11) and Swedish KTH (Appendix 5, Case 4)
- There is recognition in China of the strong Nordic competences in renewable energy R&D
- Nordic values are appreciated and respected

[62] Available on line: http://www.stopfakes.gov/presentations/Mark_Cohen_for_Public.ppt, accessed 17.10.2008.
[63] The above is based on OECD Reviews, 2007, p. 19.
[64] Interview with Grundfos R&D Manager, 3.6.2008; Appendix 5, Case 12.
[65] http://www.china-iprhelpdesk.eu/links.php (accessed 16.6.2008).

- There is a possibility to become partners in the Chinese national and regional innovation systems dealing with renewable energy at a critical junction in the development of the renewable energy sector in China
- There is a recognition that mutual familiarization is an important precondition for moving into deeper collaboration; there are established formats for moving from cooperation to collaboration
- There is considerable experience among Nordic and other international players to learn from.

The main issues identified in relation to collaboration in R&D in energy are the following:

- The Chinese stakeholders are mostly thinking "big". The Nordic stakeholders are small in comparison and mostly only bring small amounts of money while often thinking that they can have a lot of influence. The Nordic countries individually do not have the same weight and influence as the EU and the World Bank
- It is worth mentioning that some of the interviewees on the Nordic side were of the opinion that the renewable energy sector in China is primarily, at this stage, driven by political considerations, i.e. environmental and climate politics and the associated financial benefits, and not necessarily by a desire to achieve profitability
- Technology transfer is a key policy issue and often becomes a requirement in negotiation about projects and the ownership of proprietary rights. There is no simple solution to the issue. Some international players choose to comply, some choose to stay away, others try to muddle along, and some simply have technologies that the Chinese side needs and therefore must buy, almost no matter under which conditions
- There may be differences in perceptions of what is good practice when it comes to scientific approaches, research management, and science administration in China and the Nordic countries respectively. Modern science came to China at a late stage and many disciplines suffered from political control and repression for decades after the establishment of the People's Republic in 1949. The major issues involved have already been dealt with in other parts of this study, for example: the institutional framework; the procedures involved in project formulation, assessment, and implementation; use and ownership of data[66], knowledge, and proprietary rights; different approaches to tender procedures, i.e. bidding procedures and evaluation of bids. There may also be different approaches to cooperation and collaboration, e.g. in relation to decision-making as well as with respect to dissemination of research results. While differences will persist for some time to come, the rapid internationalization of China's science will lead to increasing convergence with Western practices
- There is a strong drive amongst both Chinese and international players to set up centres. They often have overlapping mandates, one example being the planned EU "Clean Energy Centre" (Appendix 5, Case 1). In order to become successful, such centres must fit into China's existing structures, otherwise they will not function. The Danish Renewable Energy Programme is linked into the planned Renewable Energy Centre under NDRC (Appendix 5, Case 7). Nordic collaboration should make sure that it does not compete with other partners. Activities must be complementary and be coordinated with the other international players, not least with those of the Nordic countries
- In relation to some types of programmes and projects, it may be difficult to generate matching funds in cash in China. In many cases, the Chinese side contributes in kind and the valuation may cause friction. However, a project with foreign funding only, will not condone as much respect as a project with joint Sino-foreign funding

[66] In China, certain data may be considered state secrets, e.g. natural resource data.

- On the Nordic side, it is a disadvantage that the Nordic countries have little experience in joint collaboration with China and at times they also seem to have more complex decision-making procedures than the Chinese side
- It must be recognized that "not one size fits all" in China. Therefore, a programme must be targeted and flexible.

5 NORDIC-CHINESE COOPERATION FRAMEWORK ON ENERGY R&D

As China's national energy policies and initiatives are increasingly influenced by the country's global integration in relation to acquisition of energy resources, technological development, and climate change, China has taken a fresh strategic perspective on both cooperation and collaboration with international energy R&D communities. As discussed in Chapter 3, there is now much more insistence than in the past on the need for enjoying the benefits of collaboration, primarily in relation to sharing of knowledge and proprietary rights.

All players obviously acknowledge that the issues associated with energy R&D are complicated and inevitably have long-term strategic implications for governments, research organizations, and the business sector on both the Nordic and the Chinese side. In addition, uncertainties with regard to the reallocation of authority and resources in relation to China's energy R&D capacity arising from the ongoing sector reforms and the push to develop new and clean energy technologies discussed above will persist until the ongoing restructuring of the sector is accomplished and while the market is finding its feet to stand on.

However, the combination of development of advanced low-carbon energy technologies with an open and multi-pronged approach to international cooperation within the environment, energy, and climate fields has won the Nordic region as a whole a favourable position on energy and environment in China. Public and private Nordic stakeholders have not only helped China upgrade its energy technology portfolio, but, more importantly, trust has been built to collaborate further in exploring the next generations of energy technologies that not only China, but the world would need.

Normally, the Nordic countries enjoy a good image in China and many Chinese civil servants, academics, professionals, and business people believe that working with Nordic people saves them a lot of unnecessary headaches. Firstly, most Chinese with knowledge of the Nordic region describe Nordic people as honest, trustworthy, and reliable. They appreciate that the Nordic management approach is based on the principles of low power distance, delegation, involvement, team work, personal development, and responsibility, and that the Nordic approach to cooperation is based on partnership with joint responsibilities. Finally, there is generally a high degree of transparency in Nordic decision-making and administrative practice.

Nordics in China express similar views. Once you know China and have generated trust with Chinese colleagues, employees, or partners, the Chinese are easy to work with. However, it must also be recognized that the level of trust among public institutions and within the corporate sector in China is substantially lower than in the Nordic countries. This can make it difficult to work across administrative, organizational, or sector divisions.

Difficulties can be overcome, and, based on the findings of this study, the authors would argue that it is timely to establish a Nordic framework for strategic collaboration with China within energy R&D, in particular in relation to renewable energy. Nordic involvement would undoubtedly benefit from access to the Chinese resource pool and a potentially huge market.

It must be noted that the proposal is not made to exclude other options. There is certainly a strong common interest to work on energy efficiency, in which field the Nordic countries have strong competences, which are in demand in China. With energy efficiency being a top political priority in China, such cooperation should be considered as well.

The proposed framework should be designed to coordinate and mainstream Nordic energy R&D into the Chinese energy sector. This would not only create a critical mass of activities that could exploit Nordic synergies better, and enhance the presence of Nordic energy expertise in China, it would also help the Chinese partners get a much better picture of Nordic strengths on energy and environment know-how and technologies, as well as who could be the interesting partners.

Although the details of a framework need to be worked out by a joint effort from the relevant Nordic and Chinese partners, a number of strategic ideas and proposals are discussed below. Chapter 6 will then discuss more specific proposals.

5.1 Strategic recommendations[67]

One of the interviewees for this study argued that if the Nordic Region as a whole wants to protect its competitiveness, which is a key argument for the "globalization initiative" initiated by the Nordic Prime Ministers, then Nordic countries should just go on with business as usual. The technological level in the Nordic countries in almost any renewable energy sector is clearly more advanced than in China, it was argued. The technologies are known, and the main point is that China needs them and has to buy them. Therefore, there is not much need for joint technological research.

This is a "realist" argument, but the interviewee also provided a counter-argument. With the climate change agenda becoming more and more pressing, there is a need for fast change. China's main gains are in energy efficiency, but renewable energy is equally important for the future, so the focus should be on collaboration in these areas, and as an example important collaboration could be undertaken in relation to the integration of new energy technologies in the energy systems and in the construction sector.

There is already considerable Nordic presence, projects, and investments in renewable energies in some fields in China where Nordic technologies and solutions[68] are well recognized by a variety of Chinese stakeholders and partners. However, most Nordic actors are small and dispersed and the question is whether their efforts are rewarded adequately. Nordic initiatives are spread, they may have overlapping mandates, and at this stage, there is no common platform to coordinate interventions to create synergies.

Moreover, potential conflicts of interest amongst the Nordic countries could be reduced by a common platform designed to help Nordic players operate in a more coordinated way. Support is needed from across the Nordic system as well as from the relevant Nordic agencies and stakeholders to attain scale and critical mass. The proposal here is that a joint Nordic effort in energy related R&D would harness stronger collective promotion, lobbying, and bargaining power than any single Nordic country or player or even individual Nordic governments can muster. This argument was supported by a number of the Nordic interviewees from both the public and the private sector, some of whom actually volunteered the proposition, even before the authors had brought it up. Furthermore, the Chinese side would certainly appreciate to work with bigger partners with more muscle and finance.

Based on the findings of the study and the arguments above, the subsequent justifications and strategic ideas regarding a possible Nordic-Chinese programme must be taken into account:

- The conditions for establishing a major Norden-China programme in energy R&D are sufficiently mature and it would be possible to align it with Nordic and Chinese policies and public programmes in relation to the energy sector and climate change
- A collaborative Norden-China programme in energy R&D with a focus on renewable energy would be able to address issues relating to the challenges posed by rising energy prices, dwindling traditional energy resources, and the common concerns about the impact of climate change
- Such a Nordic platform would not only be able to harness stronger influence in China, as well as more funding, which is essential to achieve success, but it would also allow the partners involved to get access to a considerable knowledge pool in the Nordic region and China respectively as well as to each other's research resources and infrastructure
- Nordic public and corporate actors would get better access to the huge potential market in China. There should be a strong focus on developing and integrating renewable energy in the energy mix in China and R&D results from public sector research institutions will have to be commercialised through involvement of the corporate sector at the appropriate

[67] Some of the recommendations in this section derive their inspiration from: "Summary Document. International Energy Agency and IEA Expert Group on R&D Priority Setting and Evaluation Workshop on *Energy Technology Roadmaps*, 15-16 May, 2008" (Paris: IEA Secretariat; provided to the authors by Nordic Energy Research).

[68] A recent report by Klitkou et al. (2008) provides a comprehensive overview of internal Nordic collaboration in R&D in renewable energies and of Nordic technologies.

moment in order to test the product and scale it up for commercial production.[69] Through extensive collaboration with China, which is effectively a large scale laboratory for experiments with new technologies, the ambition of the Nordic countries to become or stay leaders with regard to some key technologies might materialize earlier than would otherwise be the case. Biomass energy, biofuels, or wind technology may serve as examples in this context

- Furthermore, such a platform would heighten Nordic visibility and maximize Nordic dissemination of knowledge and technologies
- Many Nordic stakeholders from the public and private sectors have indicated that a Norden-China energy programme can add value to existing bilateral activities
- Nordic and Chinese researchers are interested in collaborating with each other
- Larger Nordic companies operating in China have started to localize some of their research in the country, but at this stage few energy companies undertake core R&D there. However, the public R&D communities as well as the sub-suppliers in the business sector in the Nordic countries must be aware of these developments and take part in the process, otherwise they may eventually be excluded from the global R&D activities of the larger corporations and thus from the huge potential market in China
- By implication, there is an interest among Nordic companies to pursue their R&D with other Nordic and Chinese R&D partners in China
- Although not always linked directly to energy issues, the unique Nordic innovation tradition is something that the Nordic countries could offer to China, particularly in the wake of China's promotion of an indigenous innovation strategy[70]
- The strategies of the relevant Nordic organizations are relevant for China
- Sino-Nordic partnerships in China could be building blocks in global R&D and/or business strategies.

In sum, a coordinated programme could facilitate the process to strategically position the Nordic region and China at the frontier of the battle against unsustainable use of conventional energy sources and climate change. It could create a common understanding of and a framework for joint action to address our common challenges in China, regionally, and globally. Finally, it would help integrate China globally, even more than now, through efforts to address these common challenges. It would contribute to setting the rules of the game so that specific "Chinese characteristics" would be considered on the basis of their merits and integrated through common efforts to elaborate global rules and standards. In order to achieve such ambitious goals, a collaborative effort must have a long term perspective beyond the coming decade.

5.2 Potential barriers

A number of potential barriers can be identified in relation to such proposed collaboration:

- The relative absence of experience in the Nordic system in working with China on energy related R&D
- The Nordic countries may see a potential conflict of interest since they want to pursue their own national competitive advantages in the Chinese energy market. Therefore, there could be a lack of interest or willingness to pursue Nordic synergy
- The Nordic countries only have small resources in comparison with the "gigantic" energy sector in China; other agencies with considerable funding available are already operating in the energy sector and may have "skimmed" off the interesting partners and projects

[69] Cf. the approach of Novozymes (Appendix 5, Case 11).
[70] The Nordic innovation agencies, including Nordic Innovation Centre, should be interested in this also (see also Delman & Madsen, 2007).

- A number of programmes deal with similar issues. Many centres with overlapping mandates are being established. Thus, there will be considerable competition from other programmes
- The threat of IPR infringements is considerable
- There could easily be a mismatch of scientific ambitions between Nordic and Chinese researchers
- A programme would fail if it is only based on one-directional activities, from the Nordic countries to China
- The Chinese tradition for making contributions in kind may impose extraordinary costs on the foreign partner when it comes to aid projects, while for a joint research programme or project this kind of risk will not be as prevalent. Furthermore, once a partnership has been established, it may be difficult to work with other partners for both institutional and financial reasons.

The authors are of the conviction that the approach and the recommendations elaborated in the subsequent sections will be able to address these barriers in a satisfactory manner so that they will not jeopardize the proposed Nordic initiative.

5.3 Identifying mutual interests

Following the old Chinese adage - "a good beginning is half the success" - it is important to identify genuine common interests as a first step in any collaborative effort in the academic field. Past experience has shown that it is easier said than done. There have been many failures due to lack of real common interests. Therefore, in the future, both Nordic and Chinese research teams will spend longer and longer time trying to figure out what they want to do with their partners and what they can get from them rather than primarily aiming for partners with only a superficial interest or partners that just have money.

These experiences combine with the new Chinese policy directions and the availability of increased research funding in China which creates a new framework for R&D activities and may new stakeholders have emerged. There is also a wish to stimulate a more demand-driven R&D approach which promotes more market oriented research and this is particularly true when it comes to the vast potential for new R&D applications in the lucrative energy market.

In terms of energy R&D, the biggest confusion to foreign researchers is perhaps the question of who is really doing what and how to identify true research priorities and capabilities, as the research agendas, portfolios, and outputs of many Chinese research organizations appear to be overlapping and at times redundant. In addition, the distinction between basic and applied research is often somewhat vague in practical terms in China as research designs may not be particularly clear due to a poor evaluation system.

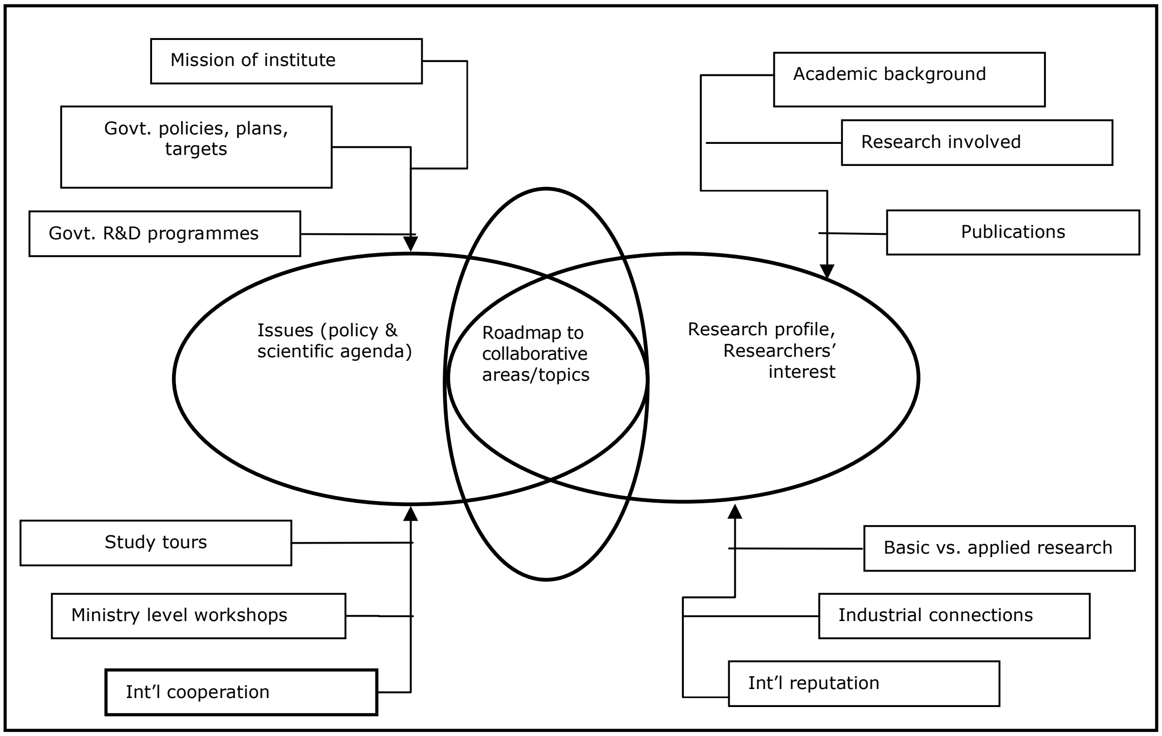
Without reliable insider information combined with publicly available evidence in the form of patents and/or publications testifying to appropriate academic qualifications or even excellence, it will be a daunting task to propose the right research themes with the right partners that may eventually lead to successful collaborative outcomes in the form of scientific publications or new technologies.

As discussed earlier and illustrated in Figure 6, key research agendas in China are still driven by policies that are formulated or supported by the top leaders through their official statements and promises and by the governments at different levels through their plans, targets, and programmes. Effectively, the political agenda is formulated on the basis of a large amount of previous research which discusses the most urgent issues that the Chinese government needs to address. Certainly, this has also been the case for renewable energy as discussed above. Therefore, it is important to understand the political dimensions and interact with the political environment, not only within sector, the sub-field, or the region, but also with the specific partner institutions and even the individual researchers. Little can be done in China without appropriate contacts (*guanxi* in Chinese) and networks.

More specifically, Figure 6 illustrates the following points that need to be taken into consideration during the formulation of a joint initiative:

- Whereas the mission of a particular institute may be seen as the benchmark for assessing its desired orientation, it may not be as clear in real life. The notions of the market economy have also penetrated the academic world and marketing techniques are increasingly applied by the research institutes to "sell" themselves. Therefore, it is important to assess accurately the academic background, i.e. research competence and "excellence", and, not least, the development potential
- In contrast to the past, study tours for familiarization purposes organized by ministries or other organizations at the central or provincial level are now often seen as real exercises in learning. This tendency is even stronger when a ministerial level official heads a delegation. Therefore, carefully planned familiarization visits may help potential partners in developing their focus and prepare the groundwork for subsequent agreements, programmes, and funding arrangements
- Ministerial level workshops are important for two reasons: 1) They may discuss urgent issues that need to be better understood or solved; 2) They may address an already recognized political need. Such workshops can also be used to initiate a collaboration process. In China, regular workshops of this nature may provide Nordic partners in R&D programmes with opportunities to influence the Chinese policy and research agendas. This approach is pursued by the EU energy programme (EEP) and the Danish wind programme (WED) (Appendix 5, Case 1 and Case 6)
- Already existing international cooperation, like the EU EEP programme and the World Bank's CRESP (Appendix 5, Case 1 and Case 13) offer clear indications about the areas in which the Chinese are seeking to cooperate with the international R&D communities
- The researchers' interests, capacity, and reputation as well as their commitment are crucial factors in successful collaboration

Figure 6: Identification process for collaborative research



The following steps are recommended for a Nordic R&D organization (institute, department, or research group) that has had little exposure to collaboration with China[71] and for its Chinese partners:

- Research interests and research topic(s) must "fit" with each other
- The "sponsor" agency or "owner" of the Chinese target partner must be identified
- The academic and political agendas of the Chinese target institute and its supervisory agency must be made clear
- The internal and external networks of the Chinese target partner within politics, administration, academia, and the industry must be identified and assessed
- The existing international collaboration of the Chinese target partner should be identified and assessed
- The following should also be assessed:
  - The scientific track record of the Chinese target institute and its key researchers
  - The potential of its PhD programme as well as its recruitment and career policies, including possibilities for international mobility[72], of the target partner
  - The research infrastructure and the funding situation should be assessed
  - The management capacity and the research culture.

Certain preconditions would be helpful to ensure that a programme could materialize:

[71] Apart from information gathered through the interviews, the experiences gained by KTH in setting up its energy centres in China (Appendix 5. Case 4) have informed these recommendations.

[72] At Tsinghua's School for Nuclear and New Energy Technology, the professors are – quite surprisingly - only allowed one PhD student a year and the professors are not always happy to let them go abroad as it may disrupt their own research programmes (Interview 21.5.2008).

- On the Chinese side, high level leaders often need to get involved to make sure that the process moves forward, that funds are mobilized, and that the process is handled efficiently. The Nordic partners should consider the same. Involvement of top leaders from government, the public sector, or from one's own organization or firm will help give visibility and appropriate contacts to a programme that is hedged onto the strategically important global environment and climate initiatives
- Governmental support would also be helpful to ensure coordination with other relevant R&D communities on both sides to create synergies and avoid redundancy
- Intermediaries who understand both sides are needed to assist in nurturing and bringing about joint R&D initiatives and to stimulate the development of a comfortable environment for collaboration. In particular, intermediaries may be helpful overcoming both language, cultural, business, and administrative barriers as well as in bridging the gaps between different research traditions and cultures.

Finally, it must be noted that evidence suggests that a donor-driven research agenda often leads to frustrating experiences for both sides, especially if the research agenda/topic chosen by the foreign side is not in line with what the Chinese partners are interested in or if it is beyond their research capacity or focus.

The principles elaborated here should be applied by Nordic collaboration as well as by the individual R&D unit to develop a "roadmap" for effective and transparent collaboration. This will be discussed further in Section 5.1.6 below.

5.4 Cooperation or collaboration

"Cooperation" and "collaboration" are often used synonymously, even if the two words have very different connotations. "Cooperation" is undertaken to exchange and share ideas, information, R&D plans, results, and experiences, while "collaboration" signifies a partnership that works together towards a common goal or following a common agenda. Obviously, both are needed in relation to China, given the scale and complexity of the Chinese energy sector but also due to the differences in research and business culture. Effectively, no R&D organizations are ready to embark on collaborative efforts from day one.

At this stage, the authors would argue that collaboration should be the long term goal since:

- Over the last more than fifteen years, China has become exceedingly capable of working with international energy R&D communities in many fields and even of taking leadership in certain technologies
- Furthermore, given such diverse development trends as China's ambition to become an innovation oriented economy, its increasingly techno-nationalist policies, China's successful experiences in R&D in relation to key technologies in some sub-sectors, and the strong international competition for partnerships with key research environments in China, the Chinese R&D communities are becoming increasingly self-confident when selecting their international partners. The interest and political will to seek international collaboration is evident, but there is a demand for a stronger international commitment to collaborate on equal terms between partners with shared interests
- The Chinese IPR record is not as good as in developed countries, but it is improving; collaborative activities in R&D would speed up the process to normalize the situation in this respect
- Chinese policies towards multinationals establishing R&D facilities in China require more efforts in collaboration with local R&D environments.

Collaboration should be based on the principles outlined in Section 5.1 which would eventually lead to a detailed roadmap for collaboration (Section 5.6).

5.5 "Top-down" and "bottom-up" approaches

Each Nordic country has its own bilateral cooperation with China at various levels as described in Chapter 4, and there can be different approaches to collaboration which may be categorized as "top down" or "bottom-up" as discussed earlier.

A government-to-government agreement or a similar type of instrument is a typical top-down instrument. Although there are different views among governmental officials and researchers on how effective such an approach is, it is clear that the Chinese partners are quite familiar with it and are also keen to exploit it, since it often entails access to both international and national funding. This may not necessarily be the case with university-to-university agreements as noted earlier; they often have a more symbolic nature. However, such agreements will continue to be important as a basis for establishing more focused arrangements or agreements between the stakeholders.

The bottom-up approach is a traditional, well-tested, and popular approach in the research communities. Evidence suggests that Nordic and Chinese stakeholders engaged in energy related R&D, especially researchers, are quite active in pursuing it to test ways to achieve more productive collaboration at a higher level. Researchers meet each other in different academic contexts and they test each other's potential as partners, instinctively, before they move to define and develop research topics of mutual interest.

On the Chinese side, the internationalization of research is partly a result of the rapid internationalization of the Chinese research population. Those who return from abroad after years of study often continue with international research collaboration. Those who remain abroad, e.g. as employees in Nordic R&D environments, are often active in pursuing partnerships in China. They encourage their colleagues, not least their professors, to engage in or to supervise their projects. In this context, it should not be forgotten that the "professor" title commands considerable respect in China and that it is associated with high power status. The Chinese professor has much more influence when it comes to the formulation of research agendas, organization of research staff, and allocating funds than is the case with professors in the Nordic countries.

Despite considerable efforts in pursuing internationalization, it must also be recognized that for most of the Chinese scholars who have never been to a foreign country for a longer period, the middleman who has been in a foreign institute for years usually plays an important role in bridging the gap, not only in relation to language but also in relation to research culture, research methodology, compliance with contracts and IPR, and operational performance.[73]

At a certain stage, researchers engaged in bottom-up collaboration will need to avail themselves of the instruments and funding offered through top-down or other types of programmes. A framework programme that combines the top-down and the bottom-up approaches and which has clear strategic priorities could be a useful and productive instrument to promote deeper research collaboration. There is evidence that the Nordic research councils, including NORDFORSK, as well as other R&D funding bodies already are or will be interested in dedicating funds to specific programmes, often of a strategic nature, with China as a partner. Given the Nordic Asia and China strategies discussed above, energy R&D is or should become a key focus area in such cooperation programmes.

Furthermore, Nordic collaboration should be in a position where it could harness Nordic support for a larger programme in relation to clean and/or renewable energy R&D with contributions from all the Nordic research funding bodies. Ideally, matching funds should be sought from the Chinese side, at central level primarily from MOST and its research funding programmes as well as from NDRC.[74] However, the possibility of seeking regional partners should also be considered, since the Nordic countries and many Nordic stakeholders have started pursuing a regional approach in

[73] The energy research group in the Institute of Nuclear and New Energy Technology at Tsinghua University affirmed our observations on this point. Prof. Wang Gehua, the Director the Institute, stated that the opportunities for them to attend international academic events were still limited. Therefore, someone in the middle could facilitate the collaboration process. Prof. Zhu Bin of KTH is playing such a role in the Tsinghua-KTH cooperation programme (Appendix 5, Case 4).

[74] The authors' interviews seemed to indicate that NDRC is primarily interested in contributing to partnership programmes and international projects in kind.

different contexts (examples in Appendix 5, Case 10 and Case 12). In addition, matching funds should be solicited from the implementing partners and partners from the business world who would be interested in participating in the programmes.

Collaboration under a larger framework programme must be attractive for both sides in scientific as well as financial terms. As noted earlier, the Chinese side may be quite selective in relation to international partners due to the strong international competition for partnerships with the best Chinese R&D communities, also in relation to renewable energy. Therefore, the strategic aims of a collaborative programme must be aligned with the relevant policies and strategies on both sides. The Chinese efforts in this respect were discussed in Chapter 3.

A framework programme must also be ready to take risks. It must be able to support bottom up activities from the early beginning by provision of seed funding to test the ground, even at the risk that the activities do not move beyond the initial stage. It is also clear that collaboration between public or semi-public R&D organizations and the commercial sector, with partners from both the Nordic and the Chinese side are quite difficult to establish. Such partnerships may benefit from special nourishing through the proposed framework programme.

The MOST and NDRC programme for international collaboration in renewable energies (Section 3.1.2) provides a guideline that can be used as a basis for developing a Nordic-Chinese framework programme.[75] If so, the benefits would be obvious since MOST is the host of solid and recognized S&T programmes, such as the "863 Programme" and the "973 Programme", among others, and NDRC is the foremost public stakeholder in the energy sector when it comes to industrialization and commercial development of new high tech industries.

5.6 "Roadmap" to effective collaboration

For Nordic collaboration a proper "roadmap" could be an important way to elaborate a framework for a collaborative partnership with China. The "roadmap" is a concept that is far from being set in stone and it could address the need to develop a common collaborative framework on the one hand, and it could address the need to tackle specific technological issues on the other hand.

The roadmap is a flexible process and management tool that guides the development of a programme. It needs to facilitate a common language and reach consensus on common definitions (technologies, boundaries, milestones etc.), common principles for prioritization, as well as tools for implementation. There must also be agreements on measurement of progress and performance. Here, the roadmap is primarily meant to guide the process towards a framework programme of for the programme itself. Roadmaps for selected technologies could then b elaborated later.

There are different roads leading to the formulation of a roadmap and they are discussed in general terms here, while the specific recommendations will be elaborated in the subsequent Chapter.

First of all, based on the strategic considerations above, the roadmap must include the following elements:

- The objectives of a joint programme should be practical and achievable, while also being ambitious
- It must be clear which technologies are in focus. The focus should be within the areas in which the Nordic know-how and research capacity are widely recognized and highly appreciated worldwide, thereby attracting Chinese attention and interest. This could also help the Nordic countries to sustain a cutting-edge position in these areas in China and beyond. Within renewable energies, China does recognize the strong capacity in the Nordic countries in relation to wind, biomass, biofuels, hydropower, geothermal, and solar energy. The authors also believe that CCS will be an area that both China and the Nordic countries would be interested in (see Appendix 2)
- Collaboration must be based on mutual recognition, institutionalization of mutual agreements, leading to mutual benefits through equal partnership in relation to ownership of research results and property rights

[75] Interview with Xing Qijun, Director for Europe, Department of International Cooperation, MOST, 9.4.2008.

- It is necessary to build a strong case not only to attract Chinese attention, but also to convince both the Nordic and the Chinese sides that there would be no risk of undermining the current cooperation with the EU and each individual Nordic country. Therefore, Nordic synergy and added value must be demonstrable, e.g. by building on existing programmes and infrastructures. Furthermore, different organizations from the Nordic system, as well as at the national level should be invited to participate and possibly be responsible for different components of the programme. Coordination should also be sought with other international programmes[76]
- Identification of the most important and appropriate stakeholders, partners, and beneficiaries is a key to the success of a programme. In addition to R&D communities, incorporation of leading companies and public bodies from both sides would be a strong advantage
- The programme should build on good practice experiences in similar programmes
- The programme should only support activities with at least two Nordic countries involved
- On the Chinese side, it should be possible to work with several partners. The programme should be open to any partner meeting the requirements for participation
- The proposed activities must integrate with existing governmental or Nordic promotional schemes. In this way, a joint programme could be used as a platform/mechanism to coordinate - not only between Nordic partners, but also among Chinese partners, e.g. different ministries and R&D institutions - to create more synergy amongst R&D initiatives with regard to new and renewable energy
- Many institutes in China already have an excellent research infrastructure, and principles for joint use of existing infrastructure should be elaborated while new infrastructure should only be established if absolutely necessary
- Both the programme and the project design for individual projects under the programme must be kept flexible in order for projects to adapt easily to a rapidly developing renewable energy scene in China
- The pursuit of a scaling or cascading approach that advances step by step to gradually gain experience through incorporating new types of activities in accordance with experiences gained is being proposed
- Adequate funding is a key to the success. A principle of "smart" funding must be pursued, i.e.:
  - Establishment of a Nordic "basket fund" with contributions from different stakeholders in the Nordic system
  - Funding must be used to complement what is already happening
  - Funding of overlapping activities should be avoided
  - The principle of matching funds from the Chinese side should be applied to the extent possible, preferably in both kind and cash
- The ground rules for the processing of project applications must follow those already established by the Nordic system while considering that China may well pursue different principles.

The roadmap must be elaborated through stages, i.e. from ideas to conceptualization, then to formulation, and, finally, to implementation.

A minor programme would be irrelevant in China, since other international players are already there in the renewable energy field with high levels of funding. However, a cautious cascading approach might be advisable. This would entail testing the ground through a number of small-scale activities of different natures before moving into a full-fledged programme.

The specific recommendations are discussed in Chapter 6.

[76] In Beijing, there is already a framework for coordination amongst international donors and agencies within renewable energy.

5.7 Potential partners

It is evident that the collaboration with international research groups in energy has increased in China over the years, although the Nordic countries are still primarily testing the ground. The central government, the provinces, the energy sub-sectors, the universities, and other research organizations all have distinct collaborative patterns corresponding to their different levels of economic, technological, and scientific development or their status. To determine which model fits Nordic collaboration best depends on the scale and the nature of the collaboration and who would be the counterparts at the programme level on the Chinese side.

Appendix 4 lists a number of key stakeholders in the Chinese energy sector and a few more are introduced in Appendix 5. These organizations and companies are presented here because they are relevant key stakeholders in relation to energy related R&D in China. The main partners for existing international collaboration in energy related R&D are all there, except for provincial governments that are now the focus of attention of many Nordic public agencies and companies (Chapter 4; Appendix 5, various cases).

Therefore, the core partners for a Norden-China programme will have to be found among these organizations. Being an intergovernmental organization, Nordic collaboration would have to and would also benefit from collaborating with the two key government agencies on the Chinese side, i.e. MOST and the NDRC.

Given the experience of MOST with implementation of national S&T programmes as well as in collaborating with international partners, the ministry could act both as a partner and as a coordinator at the national level to mobilize and coordinate the research institutes or universities that would be involved in a Norden-China programme. MOST has a Department for Renewable Energy as well as an Agenda 21 Centre, "ACCA 21", which are both key stakeholders in relation to R&D within renewable energy.

NDRC is the foremost stakeholder in relation to industrial policies and industrialization in the energy sector and it will need to have an important stake in any programme with regard to formulation of the strategy, the roadmaps, the programme's operational mechanisms, the management of the programme etc. The New and Renewable Energy Department under the National Energy Agency and the ERI are the key units under NDRC when it comes to clean and/or renewable energy. A new Renewable Energy Centre appears to be on the way as well, and Denmark has already established contacts with regard to future collaboration with this centre (Appendix 5, Case 7).

In this context, it is noteworthy that MOST and NDRC have already decided to work together in relation to international collaboration in renewable energy and it would be wise to engage both.

Teaming up with excellent research centres is critically important while identifying research topics of mutual interest should be considered the primary task since both are crucial for the success of any collaboration with China. Therefore, Nordic collaboration would have to involve the key research institutions and the key energy companies in both China and the Nordic countries. This could be done through a bilateral Expert Committee or Energy Council (see Chapter 6). It would also be important to engage key corporate partners and the emerging intermediaries and/or NGOs in China as they will play an increasingly important role in the renewable energy sector in the future, also in relation to R&D. The associations listed in Table A.4.4 could be important intermediaries between the public and the private sector in the future.[77]

5.8 Discussion

It is of course difficult to spell out exactly what should be done without having an idea how big a possible collaborative initiative could be. Different scales of collaboration would necessarily have distinct goals to be met. It is also appreciated that, at this stage, it is difficult to determine what resources are available for promoting such cooperation and collaboration with China. The discussion and suggestions in this report are part of the process to reach a conclusion and should be seen as an initial step that could contribute to formulating a possible strategy in collaboration

[77] Norway is already supporting China New Energy Chamber of Commerce through the NEEC.

with the Nordic stakeholders, including the relevant governmental agencies such as the Nordic Energy Boards, the research councils, and the relevant Nordic organizations, i.e. Nordic Council Of Ministers, Nordic Energy Research, NORDFORSK, Nordic Innovation Centre, NeFCO, etc.

However, it is also clear from the discussions above that only a programme with significant funding would make sense in the Chinese context. Therefore, a cascading approach is proposed where a programme of initial activities will test the ground for developing a more substantial programme.

Nordic synergy and benefits will be important and both of these presuppose commitment with a long term perspective to joint action at different levels of the Nordic system. This study has primarily focused on renewable energy, but it has implications far beyond that in relation to the wider energy sector and in relation to other environmental issues and the climate change agenda. Given the scope of the study, it is impossible to deal with all of these issues and therefore the specific recommendations in the following chapter address the key concern of the study, renewable energy. However, the authors are convinced that the general discussion above as well as the discussion about strategic and specific recommendations here are also valid for the wider context.

6 SPECIFIC RECOMMENDATIONS

Following the discussion in the previous Chapter, it is proposed to consider three levels of cooperation/collaboration, ranging from small scale, over medium scale, to large scale collaboration. They could either integrate into a full-scale programme from the outset or develop through a more sequential or cascading approach.

6.1 Norden-China Renewable Energy R&D Expert Committee

Goals

The assumption underlying this proposal for small-scale collaboration is that there is a wish to test the ground initially or that only limited resources are available. Therefore, small-scale collaboration should focus on facilitating exchange of information, sharing of experience, and ienhance the understanding of each other's research capacity, portfolio and interests/priorities. With a view to the longer term perspective, there could be a focus on formulating a larger framework programme.

Approach/activities

To become familiar with each other's energy research agenda and, possibly, develop a strategy and a plan for a joint framework programme, the following steps are proposed:

1. Organize an Expert Committee comprising 6-10 top energy experts and officials from each side to discuss and identify which energy issues are most significant for China and the Nordic countries and which would be suited for R&D collaboration. The Committee should have two meetings during the first year, one in the Nordic countries and one in China, which would combine with interviews with some of the key stakeholders from the two sides, including technology companies. The aim of the first meeting would be to introduce experiences and ideas and to raise and discuss questions for a future programme agenda.

   The Expert Committee could establish working groups that could come up with concrete proposals for the second workshop, which would continue to discuss experiences and proposals and – if agreed - elaborate a strategy and an outline for a programme proposal. The working groups could also make assessments of the R&D environments to deem their appropriateness and interest as potential partners. The Expert Committee could establish a database of relevant expertise within the public and the private sector. The committee should be able to invite additional expertise to any of the workshops.

2. Determine the need and elaborate the framework for further activities and/or a cooperative programme.
3. Seed funding for small-scale academic activities to stimulate more exchange or feasibility studies could also be a part of this initiative.

6.2 Norden-China Renewable Energy R&D Small Projects Facility

Goals

In order to move from the initial cooperation that would test the ground into activities with at least a five year perspective, a medium scale program is proposed that would test many different types of collaboration. The goal would aim at stimulating collaboration as well as exchange of expertise and information at a higher level with the aim to create common platforms with regard to policies, research, and development of specific technologies. This facility should challenge R&D communities in the Nordic countries and China to be more ambitious with regard to their collaboration and to set their sight at longer term collaboration. The facility should strive to involve stakeholders from both the public and the corporate sectors as well as from public R&D communities.

Approach/activities

Based on the proposed first stage activities, the Expert Committee would finalize the framework programme which could be called: "Norden-China Small Energy R&D Projects Facility" which could provide funding for small projects of various types, such as:

- Creation of networks between Nordic and Chinese partners. For example, the Nordic renewable energy networks funded by Nordic Energy Research could be opened to Chinese participation (e.g. the School for Renewable Energy under the North China Electrical Power University)
- Creation of a common virtual platform with a science and technology watch function, exchange of news and information about development in R&D in renewable energy in China and the Nordic countries, activity watch, etc.
- Establishing a facility to support scholarly exchange, i.e. guest scholarships, workshops, conferences
- Establishing a PhD facility for exchange, joint courses, some trial joint sandwich PhD programmes, etc.
- Energy innovation games for students within business and technology
- Establish a start-up fund to test possibilities and opportunities for joint research programmes and/or R&D programmes including corporate stakeholders. This could start with financing of small-scale studies involving researchers and corporate stakeholders
- A financing facility for workshops and conferences
- There is a great need for training of Chinese Master's and PhD students in relevant subjects abroad. The Nordic programme NORDPLUS could cooperate with Nordic Energy Research to open a facility in support of such student exchange. The possibility of earmarking Chinese government stipends for Nordic students could be explored
- Production of a series of TV programmes for Chinese TV on Nordic environment and energy to be shown on Chinese TV during World EXPO 2010
- The Nordic Council of Ministers considers organizing Nordic interventions at World EXPO 2010 in Shanghai, in addition to what is being planned by the Nordic countries in conjunction with their national pavilions. One such intervention could focus on presenting the results of joint Nordic and Chinese efforts within R&D in relation to renewable energy.

The programme must have a clear set of rules guiding applications, assessments, assessment, implementation, and evaluation. Common interest areas will be identified through workshops under the Expert Committee. Sustained funding should be made available from the sponsors of the programme and co-financing by the participants should be considered.

6.3 Norden-China Renewable Energy R&D Programme

Goals

The goals for large scale collaboration will be to institutionalize Nordic-Chinese energy collaboration under a "Norden-China Renewable Energy R&D Program" in order to be able to work towards common strategic goals through joint R&D initiatives that will address the need to safeguard future energy security while dealing with the climate change challenge by increasing the proportion and the competitiveness of clean energy, in particular renewable energy, in the energy mix.

Approach/Activities

With a view to creating a long term sustainable platform for collaboration, the following two initiatives are proposed under the "Norden-China Renewable Energy Program":

- A "Norden-China Renewable Energy R&D Council"[78] would be an expansion of the Expert Committee proposed above (Sections 6.2). It should aim at bringing together top expertise

[78] Several Nordic stakeholders found that it could be interesting for the Nordic countries to establish such a joint Nordic platform in China.

from the research sector, the corporate sector, and public bodies on both sides to identify common needs and demands, and regularly consult on and provide guidance for joint activities within the renewable energy sector, either defined broadly or limited to R&D in renewable energy. Ideas and guidelines for public-private partnerships could also be of interest.

- Establishing a "Norden-China Renewable Energy Innovation Centre" that would promote Nordic R&D, projects and investments and create synergy amongst different Nordic initiatives in relation to all types of renewable energy in China could be considered. This would also allow the Nordic countries to utilize each other's expertise in both the public and the corporate sectors to promote comprehensive projects and solutions, e.g. in relation to China's eco-cities (Appendix 5, Case 8) or allow them to get specialist advice. Such a centre could help establish procedures and channels for effective commercialization of joint research results. In principle, it would be possible for Nordic collaboration to pledge its funds, if only small amounts are available, into a common basket, e.g. to support the establishment of the new Chinese Renewable Energy Centre which is already supported by DANIDA and the Energy Research Institute under the NDRC.

These initiatives could be established as an outcome of the series of activities proposed in Sections 6.1 and 6.2. Effectively, the Renewable Energy Innovation Centre could guide and supervise the implementation of the "Norden-China Renewable Energy R&D Programme". under the guidance of the proposed "Norden-China Renewable Energy Council" with the proposed Renewable Energy R&D Council as its advisory body. Such a programme should provide funding for more comprehensive activities and projects of various types, such as:

> ***Box 5***
> **DragonPower's offer**
> DragonPower has been successful in gaining a share of the market for biomass based power and is experience rapid expansion of its business. The company is ready to work with researchers who have results that are close to the market. They can be tested in a real commercial environment on a commercial scale. It is not difficult to arrange. This would speed up testing and reduce the costs, which can be very high in our countries. Of course, Dragon Power would have a first right to share the property rights (interview 22.5.2008).

- Establish a funding platform for longer-term joint research and technology development programmes based on competitive bidding. Common interest areas (even specific technologies) could be identified through the proposed workshops and studies.[79]

- Stimulate extensive academic exchange, e.g. guest professorships, that last more than 2 months

- Create a fund to support joint or collaborative research education, PhD stipends (including business PhD stipends), and regular exchange and joint supervision of PhD students. PhD stipends funded by Nordic Energy Research could be linked to existing partnership programmes. Alternatively, a PhD facility could be used to stimulate new partnership programmes. Co-funding with the Nordic or Chinese home institutions and – possibly – the corporate sector would be an advantage

> ***Box 6***
> **BI proposal for energy management eductaion** BI-Norwegian Business School at Fudan University, Shanghai, could be interested in a joint Nordic approach to a PhD programme in energy management. BI has institutional capacity and the expertise in development of programmes and partnerships in China (interview 30.5.2008).

- Both public and corporate R&D programmes in the Nordic countries and China are challenged to focus on better energy management and energy systems management to achieve higher energy efficiency. Given the increasing engagement of Nordic companies, universities and public bodies in relation to this issue in China, it is proposed to set up a Norden-China PhD programme or programme of PhD workshops on energy management. Such a programme

[79] It should be noted that often the Chinese side would prefer that research institutions should be recommended by the governments and not selected through competition, since – for smaller programmes and projects - this is quite demanding on resources.

should pertain to corporate strategy, business operations, and production management. The programme should appeal to PhD students from different disciplines within the hard, management and other social sciences. The participants should pursue their PhD studies at their home organizations, ideally as pairs consisting of a Nordic and a Chinese partner, and have a joint programme of courses/workshops.

- In view of China's needs in terms of energy systems management, a programme for in-service training of researchers and teachers in energy programmes in the universities could be established. It should focus on technical systems as well as management aspects, while equipping the participants with pedagogical skills to meet the needs of future managers in the energy sector. North China Electrical Power University could be a key partner for such an endeavour due to its wide connections in the energy sector.

6.4 Norden-China Energy and Climate Change Programme

In view of China's increasingly constructive engagement in the international climate mitigation regime and the particular role of the Nordic countries on the global level in dealing with mitigation of the effects of climate change, it is proposed that the framework programme could be expanded into a "Norden-China Energy and Climate Change Programme" which would include the previously proposed activities as well as the organization of additional projects and events that could reinforce a Nordic-Chinese partnership in relation to dealing with the effects of climate change. The following additional activities are proposed:

- A Norden-China conference on "climate and energy – COP 15/Copenhagen and beyond" (http://www.cop15.dk/en). The conference should have at least two Nordic universities and one or two key Chinese universities as lead organizers. The conference could run in two tracks. It could have a scientific track with presentation of papers addressing the theme, but it could also take stock of current activities, especially joint programmes, and identify ideas for joint programmes/projects/activities in the future. In addition, the conference could come up with proposals for future collaboration. If possible, the conference could discuss and make recommendations for the COP 15 with regard to a joint Nordic-Chinese R&D agenda, e.g. in relation to renewable energy. The conference should be open to Nordic universities and key energy research environments in China. In order to be organized in a timely fashion, the conference should be fully financed by a Nordic organization and it could be a useful precursor to COP15 which is to beheld in Copenhagen in December 2009. It could create a dialogue that would position the Nordic countries centrally in relation to finding ways to facilitate China's participation in the post-Kyoto regime
- Two quick/brief projects on modelling to be used as an input for COP15 by both the Chinese and Nordic side. The proposed titles of the projects are: (1) Review on technology transfer in China; (2) application of sector based approach in China[80]
- Sino-Nordic workshop on technology transfer for climate change mitigation[81]. The workshop would present and discuss the results of the studies proposed and put them in a global and national context.

6.5 The role of Nordic collaboration

Bearing in mind that a considerable number of scattered R&D activities in the renewable energy field are already being undertaken between the Nordic countries and China, the main role that Nordic collaboration could play would be to create synergy, to add value to, as well as to explore new areas and venues that would encourage innovative R&D initiatives.

Given that the resources available to Nordic collaboration would probably be rather limited, it is most important to consider how Nordic collaboration can add value to what is already being done.

This study has made both strategic and specific recommendations. The authors have argued that the time is ripe for joint Nordic initiatives in relation to the energy sector in China, in particular

[80] Proposal from ERI.
[81] Proposal from ERI.

within renewable energy. The Chinese stakeholders would clearly be interested in dealing with larger players with considerable resources at hand. Therefore, Nordic collaboration should consider developing a platform that would be so interesting that it would be difficult to say no to participate in it.

The authors have presented a number of proposals in this study and it is up to the Nordic system to get the necessary political and professional support to move ahead. To be able to do so, it is suggested to establish two types of work forums:

- A Nordic "China Renewable Energy R&D Ideas Factory" comprising key Nordic organizations such as Nordic Council of Ministers, Nordic Energy Research, NORDFORSK, Nordic Innovation Centre, NefCO, NIAS-Nordic Institute of Asian Studies, etc. They would discuss the study and how to move forward, i.e. develop an initial strategy and an outline of a roadmap for the implementation of the program. The group should be able to draw on Nordic and Chinese resource persons as appropriate.
- A small secretariat must be established by the appropriate Nordic organizations to coordinate and implement the activities proposed and initially support the activities of the "ideas factory". The staff in the secretariat should have experience with internal Nordic collaboration as well as collaboration with China. The secretariat should help the Nordic system mobilize the resources necessary to initiate a substantial collaborative program in renewable energy R&D with China.

References

Baker and McKenzie et al., 2007. Renewable Energy Law in China. *RELaw Assist Issues Paper*. http://www.bakernet.com/NR/rdonlyres/B06FB192-EF10-4304-B966-FBDF1A076A8C/0/relaw_issues_paper_jun07.pdf, accessed 15.06.2008)

Bian, Y.S., 2005. The Treatment and Reutilization of Wastes in Ecological Agriculture (in Chinese) (Shengtai Nongye Zhong Feiqiwu de Chuli yu Zaisheng Liyong). Beijing: Chinese Chemistry Industry Press

BP, 2008. BP Statistical Review of World Energy. http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2008/STAGING/local_assets/downloads/pdf/statistical_review_of_world_energy_full_review_2008.pdf

Buan, I.F., 2008. Norwegian Actors in the Fields of Energy and Climate Change in China. *FNI Report 1/2008*. Oslo: Fridtjof Nansen Institute. http://www.fni.no/doc&pdf/FNI-R0108.pdf, accessed 24.9.2008

China's Clean Revolution, 2008. London, Beijing, New York: The Climate Group (www.theclimategroup.org)

Delman, J. and S.T. Madsen, 2007. Nordic 'Triple Helix' Collaboration in Knowledge, Innovation, and Business in China and India. Copenhagen: NIAS-Nordic Institute of Asian Studies

Dinter, M. 2006. Technology Transfer to China - opportunities, risks and measures. Braunschweig: Institute for International Business & Law (http://www.law-and-business.de/www_law-and-business_de/content/e153/e747/e748/datei921/Dinter,ex.sum.ChinaTechnologytransfer_ger.pdf, accessed 20.9.2008)

Downs, E., 2006. China. *The Brookings Foreign Policy Studies – Energy Security Series.* December

EIA/DOE, 2007. International Energy Outlook 2007. Energy Information Administration of Department of Energy of United States

EREC, 2007. Energy [r]evolution – a sustainable world energy outlook. European Renewable Energy Council. http://www.energyblueprint.info/

FAO, 2007. A Review of Current State of Bioenergy Development in G8+5 Countries. Rome: FAO/GBEP (Global Bioenergy Partnership)

Gu, Y.Z., 2007. A Study on Environmental Sector in Greater Shanghai Area 2007-2010. Shanghai: Swedish Consulate General

Hu, R.W.X., 2008. Advancing Sino-U.S. Energy Cooperation Amid Oil Price Hikes. *Brookings Northeast Asia Commentary*, Washington D.C.: The Brookings Institution, 6 October

IEA, 2007. World Energy Outlook 2007. OECD/International Energy Agency.

IPCC, 2007. Climate Change 2007: Impacts, Adaptation, and Vulnerability. Cambridge: Cambridge University Press

Jakobson, L. (ed.), 2007. Innovation With Chinese Characteristics. High-Tech Research in China. N.Y.: Palgrave MacMillan

Jakobson, L., 2007. *China Aims High in Science and Technology. An Overview of Challenges Ahead.* Jakobson (ed.), 2007, pp. 1-36

Jiang, K.J., 2007. *Energy Technology Research in China.* L. Jakobson, 2007, pp. 99-133.

Kameyama, Y. et al. (eds.), 2008. Climate Change in Asia, Perspectives on the Future Climate Regime. Tokyo, N.Y., Paris: United Nations University Press

Kennedy, S., 2005. The Business of Lobbying in China. Cambridge Mass.: Harvard University Press

Klitkou, A. et al., 2008. Competitive policies in the Nordic Energy Research and Innovation Area eNERGIA - Synthesis report. Oslo: Nifu-Step (http://www.nifustep.no/norsk/publikasjoner/competitive_policies_in_the_nordic_energy_research_and_innovation_area_energia_synthesis_report, accessed 19.10.2008)

Lewis, J. I., 2007-2008. China's Strategic Priorities in International Climate Change Negotiations. *The Washington Quarterly*, Winter 2007-2008, pp. 155-174

Li, H.J. (chief ed.), 2007. Annual Report on China's New Energy Industry. Beijing: China New Energy Chamber of Commerce, November

Lieberthal, K. and M. Herberg., 2006. China's Search for Energy Security: Implications for U.S. Policy. *NBR Analysis*, vol. 17, 1 April. Washington, Seattle: National Bureau of Asian Research

Liu, S.S., 2005. Utilization and Preservation of Geothermal Resources. Beijing: Chinese Chemistry Industry Press. Beijing

Lundin, N. and S.S. Serger, 2007. Globalization of R&D and China - Empirical observations and policy implications. *ITPS Working paper*, no. R2007:013. Stockholm: ITPS Swedish Institute for Growth Policy Studies

Luo Y.J. et al., 2008. Technologies for Solar Energy Utilization. The Chinese Chemical Industry Press. Beijing, 2008. ISBN: 7-5025-5680-x/tk

Maj Dang Trong Analyse, 2007. Energy Technology Industry – A Business in Growth. On-line available: http://www.nordicenergy.net/download.cfm?file=902-B6A1085A27AB7BFF7550F8A3BD017DF8, accessed 3.6.2008

Martinot, E., 2006. Renewables Global Status Report 2006 Update. Published by REN21. On-line available: www.ren21.net. See also: Martinot, E., 2007. Renewables Global Status Report 2007 Update. Published by REN21. On-line available: http://www.ren21.net/pdf/RE2007_Global_Status_Report.pdf

Metcalfe, S, 1995. The Economic Foundations of Technology Policy: Equilibrium and Evolutionary Perspectives", P. Stoneman (ed.), Handbook of the Economics of Innovation and Technological Change. Oxford (U.K.), Cambridge (U. S.): Blackwell Publishers

MOST/NDRC (2007?, undated). International Science and Technology Cooperation Programme on New and Renewable Energy. Beijing: Ministry of Science and Technology and National Development and Reform Commission, P.R. China

NREL, 2005. Available on-line:
http://swera.unep.net/index.php?id=map_search&action_method=external_archive_query&datatype=70,79&geoarea=-1&energycategory=16,81&orderby=geoarea

OECD, 2007. Innovation and Performance in the Global Economy. OECD, 2007. ISBN 978-92-64-03788-5
OECD Reviews of Innovation Policy: China, Synthesis Report, 2007. OECD and the Ministry of Science and Technology, China

Pang, J. and J. Zou. *China: Policy-making Process on Climate Change*. Kameyama (eds.), 2008, pp. 66-82

REDP, REDP, NDRC/ GEF/ The World Bank China Renewable Energy Development. Overview of renewable energy development in China: recent progress and future prospects. Beijing, China. http://www.ndrcredp.com/

Rosen, D.H. and Houser, T., 2007. China Energy – A Guide for the Perplexed. A Joint Project by the Centre for Strategic and International Studies and the Peterson Institute for International Economics

Serger, S.S. and M. Breidne, 2007. China's fifteen-year plan for science and technology - An assessment. *ITPS Working paper*, no. R2007:014, Stockholm: ITPS Swedish Institute for Growth Policy Studies

Shi, P.F., 2007. *2007 Report on Wind Power Industry Development*. Li, H.J. (ed.), 2007. Chapter 7, pp. 66-75

Sigurdson, J., 2005. Technological Superpopwer China. Cheltenham, UK: Edward Elgar.

Simon, D.F., C. Cao, and R. P. Suttmeier, 2007. China's New Science and Technology Strategy: Implications for Foreign Firms. *China Currents,* Vol. 6, No. 2, Spring

Sinton, J.E. et al., 2005. Evaluation of China's Energy Strategy Options. The China Sustainable Energy Program http://china.lbl.gov/files/china.files/nesp.pdf, accessed 14.4.2008

Thomas, M., 2008. China: The Green Paper. *Eversheds China Renewable Energy Bulletin*. http://www.mondaq.com/article.asp?article_id=56910&lk=1, accessed 24.4.2008

United Nations Population Division (UNPD), 2005. World Population Prospects: The 2004 Revision and World Urbanization Prospects. http://esa.un.org/unpd

United Nations Population Division (UNPD), 2006. World Population Prospects 2006. New York: United Nations

Wang, D.Z. (Ed.), 2007. China's Energy Technology Outlook in 21st Century. Beijing: Tsinghua University Press. November

Wang, J.C. and Z.P. Zhao, 2001. Chinese Energy Report (2001) (*Zhongguo Nengyuan Baogao 2001) (In Chinese)*. Beijing: Chinese Metrology Press

Wang, Z.Y. and J.F. Li, 2008. Development Report of Chinese Renewable Energy Industry (Chinese). Beijing: Chemistry Industry Press January

Weber, M. et al., 2007. The Chinese Power Sector: Wind and Clean Generation Sectors – Main Challenges and Trends. Torino: Centro di Alti Studi Sulla Cina Contemporenea

Wesley, M. (ed.), 2007. Energy Security in Asia. *Routledge Security in Asia-Pacific Series.* Oxon: Routledge

Xing, Y.M. and Y.H. Tao, 2007. Modern Energy and Power Generation Technologies. Xi'an: Xi'an University Press. July, 2007

Xu, Y.C, 2007. China's Energy Security. Wesley (ed.), 2007, pp. 42-67

Yang, D.L., 2004. Remaking the Chinese Leviathan. Market Transition and the Politics of Governance in China. Stanford: Stanford University Press

Zhang, B.M., 2005. Geothermal Resources in China. Proceedings World Geothermal Congress 2005, Antalya, Turkey, 24-29 April, 2005.

Zhang, C., 2005. Development and Utilization of Hydroelectric Resources. Chinese Chemistry Industry Press. Beijing. January, 2005

Zhao, L.X., and Y.S. Tian, (Eds), 2007. Chapter 3: Utilization Technologies for Biomass Energy Resources. Green Energy Technologies for Rural Areas (in Chinese) (Nongcun Lüse Nengyuan Jishu). Beijing: China Agricultural Science and Technology Press

Zhou, D.D. (ed.), 2003. China's Sustainable Energy Scenarios in 2020. Beijing: China Environment Press

Zhou, F.Q. and D.D.Zhou, 1999. Study on Long-term Energy Development Strategies of China. (Zhongguo Zhongchangqi Nengyuan Zhanlue). Beijing: Chinese Planning Press

APPENDICES

Appendix 1

List of People Interviewed

No.	Name	Organization	Title
1	Prof. Zhou Yuan	The Administrative Centre for China's Agenda 21, MOST	Vice-Director
2	Ms. Ping Höjding	The Swedish Embassy in China	Environmental Attaché
3	Dr. Jiang Kejun	Energy Research Institute of China	Centre Director
4	Dr. Gao Hu	Energy Research Institute of China	Senior Researcher
5	Prof. Ma Chi	National Research Centre for S&T for Development	Senior Researcher
6	Dr. Zhao Gang	National Research Centre for S&T for Development	Department Director
7	Dr. Yang Hong Wei	Energy Research Institute of China	Centre Director
8	Dr. Meng Fanqiao	China Agriculture University	Senior Scientist
9	Mr. Liu Wenqiang	National Development and Reform Commission	Official
10	Prof. Huang Qili	Chinese Academy of Engineering	Academy Member
11	Mr. Per Schive	Norwegian Embassy in China	Environmental Councillor
12	Ms. Vibeke Skaiaa	Norwegian Embassy in China (Innovations Norway)	Project Manager
13	Mr. Wang Zhongying	Energy Research Institute of China	Centre Director
14	Mr. Xing Jijun	Ministry of Science and Technology of China	Division Director
15	Mr. Guo Yuan	Environmental Protection Agency of Heilongjiang	Vice-Director
16	Mr. Ju Xiaowei	Ruifeng Wind Farm Corporate, Heilongjiang Province	Project Manager
17	Dong Xiaoshi	Guohua Investment Corporate	Project Manager
18	Prof. Yan Jiyue	KTH	Professor
19	Mr. Henrik Martens	Danish Embassy in China	Commercial Counsellor
20	Dr. Magnus Breidne	Embassy of Sweden Science Office (ITPS)	Counsellor Science and Technology
21	Dr. Dong Changqing	North China Electric Power University	Associate Professor/ President's Assistant
22	Mr. Ma Xuelu	Baoding National High and New technology Industrial Development Zone	Director
23	Prof. Wang Gehua	Institute of Nuclear and New Energy Technology of Tsinghua University	Vice-Director
24	Prof. Mao Zhongqiang	Institute of Nuclear and New Energy Technology of Tsinghua University	Professor
25	Dr. Zhang Jian'an	Institute of Nuclear and New Energy Technology of Tsinghua University	Associate Professor
26	Dr. Zhang Yong	Institute of Nuclear and New Energy Technology of Tsinghua University	Vice-Director, Office of Research Administration
27	Mr. Tony Clark	Embassy of Sweden	Commercial Counsellor
28	Mr. Joakim Diamant	Embassy of Sweden	Commercial Officer
29	Ms Luo Zhihong	China Renewable Energy Scale-up Programme Management Office	Deputy Director
30	Ms. Fan Lijuan	China Renewable Energy Scale-up Programme Management Office	Project Officer
31	Prof. Li Junfeng	Energy Research Institute of China/Renewable Energy Industry Association	Vice-Director/Secretary General
32	Mr. Li Baoshan	Ministry of Science and Technology of China	Senior Official
33	Mr. Jin Xueqi	Admin Centre for Innovation Fund for Small Technology-Based Firums, MOST	Deputy Director
34	Ms Sissel Hammerstrøm	BI Norwegian School of Management	Director of Studies, China Programmes
35	Mr. Anders Kjær	Innovation Centre Denmark, Shanghai	Counsellor (S&T)
36	Ms Julie Øst Andersson	Innovation Centre Denmark, Shanghai	Commercial Assistant
37	Mr. Erik Kjaer Sørensen	Danish-Chinese Wind Energy Development (WED)	Senior International Advisor

38	Ms Hu Wei	Danish-Chinese Wind Energy Development (WED)	Programme Manager
39	Mr. Morten Søndergaard	Danish-Chinese Wind Energy Development (WED)	Senior International Advisor
40	Mr. Søren Ishøy	Grundfos R&D, China	Head of Department, R&D China
41	Mr. Husayn Anwar	Independent Consultant (RE, solar)	Independent Consultant
42	Mr. Jaani Heinonen	TEKES, Shanghai	S&T Counsellor
43	Ms Tone Helene Aarvik	Nordic Centre Fudan (NCF)	Programme Director
44	Ms Wu Jie	Shanghai Technology Innovation Centre (STIC)	Exchange and Cooperation Department
45	Mr. Torben Andersen	Vestas Wind Technology China Co. Ltd. Shanghai Branch	General Manager, VP
46	Dr. Yang Yunfeng	VTT Technical Research Centre of Finland, VTT China Office	Chief Research Scientist, Managing Director
47	Dr. Frank Haugwitz	EU-China Energy and Environment Programme	EU Renewable Energy Manager
48	Dr. Kurt Wiesegart	EU-China Energy and Environment Programme	EU Co-Director
49	Ms Li Aizhen	EU-China Energy and Environment Programme	Chinese Deputy Co-Director
50	Mr. Carsten Vang Lauridsen	Novozymes, China	Director R&D
51	Mr. Thomas Hansteen	Norwegian Research Council	Desk Officer (China)
52	Mr. Jan Øivind Johansen	Norwegian Ministry of Petroleum and Energy, Dept. for Climate, Industry and Technology (KIT)	Head of Department
53	Dr. Ole Odgaard	Danish Energy Agency, Division for Energy Supply and Renewable Energy	Head of Section
54	Mr. Haflidi Saevarsson	Glitnir Bank Representative Office, Shanghai	Analyst, Business Management
55	Professor Thomas B. Johansson	International Institute for Industrial Environmental Economics (IIIEE) Lund University, Sweden	Director

Appendix 2 - Potentials of renewable energy resource and technological development in China

With reference to Chapter 2 and Sections in the main report, this appendix focuses on the resource potential and development of each of the renewable energy sources in China in a qualitative rather than a quantitative way.

Wind Energy

There is a lack of reliable data on wind potential in China. None of the many studies that have attempted to assess wind resource in China have been able to provide an accurate estimate of the real resources, primarily due to lack of reliable historical data. Based on the 30-year (1971-2000) data collected from 2,384 meteorological stations, the 2006 wind resource assessment from the Chinese Meteorological Administration (CMA) suggests about 1 TW of exploitable potential at 10 m. above the ground level, including 297 GW for on-shore and 750 GW for off-shore. Although this report is seen as the most authoritative source, some provinces produced their own wind resource assessments to demonstrate a higher wind potential than estimated in the CMA report.

Under the auspices of the Global Environment Facility (GEF) and under the management of UNEP, the Solar and Wind Energy Resource Assessment (SWERA) Programme has suggested the exploitable wind potential to be as high as 1,400 GW at 50 m above the surface, equivalent to approximately 700 GW at 10 m above the surface. The Geography Institute of the Chinese Academy of Science, using remote sensing data, estimated that the near-shore (10 km) wind potential was greater than 1,900 GW.

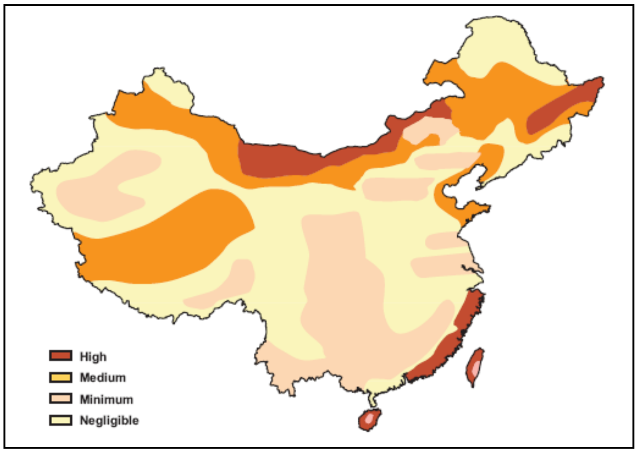
In comparison, the estimate from the CMA seems to be conservative. Even so, it can be said that the wind resource potential in China is huge and there is room for improving the assessment quality. But the present assessments are good enough for strategic planning for wind development at the macro level. It is found that China enjoys an adequate wind resource potential to support wind power development on a large scale (multiple 100 GW) in the future. As shown in Figure A.2.1, the northeast, the north, the north-western, and the south-eastern coastal regions with surrounding islands have the greatest wind resources in China. However, at project levels more precise data are required for a sound feasibility study and technical design of a proposed wind farm. The misuse of data is one of the key factors contributing to the failure of some wind projects. To better address this bottleneck, the National Energy Agency under the NDRC has planned to set up a nation-wide wind resource monitoring network consisting of 400 anemometric facilities.[82]

On the aspect of technological development, China's primary focus until the mid-1990s had been on small-scale stand-alone wind turbines ranging typically from 50W to 1kW to provide electricity in remote areas that were not connected to the national grid. The technologies as well as the manufacturing capacity were accordingly developed on a solid basis. To date, China is the biggest producer and user of small-scale wind turbines in the world and this sub-sector is continuing its expansion at a fast pace. For example, through the production of 30 kW turbines witnessing an annual 34% increase in 2005-2006 (Wang and Li 2008).

For grid-connected wind farms, China is now catching up with regard to the installation scale at an unprecedented pace, although national technology development is still basically chasing after the development of the industrialized Western wind leaders. According to the China Association of Comprehensive Resource Utilization (CARCU, see Table A.4.4), 2007 was the year with the highest installed capacity ever in China, resulting in an accumulated installed capacity of 6 GW which already exceeds the 5 GW target set for 2010. Over the past decade, from 1995 to 2006, the installed capacity of wind energy grew at an annual rate of 46.8% (Li, 2007). China has successfully mastered the manufacturing of wind turbines with generation capacity up to 750 kW and even produced the prototype of a 1.2 MW wind turbine on a massive scale, primarily based on domestic technologies. The rapid build-up of its wind capacity has ranked China as the fifth largest producer of wind power, after Germany, the U.S., Spain, and India. Most of the Chinese stakeholders involved in wind development strongly believe that the goal to install 30 GW wind power generation capacity by 2020 will be easily achieved, if not surpassed.

[82] Denmark is involved in this exercise through its WED programme with NDRC (Case 6).

Figure A.2.1: Wind resource map, China[83]



As with many industrial sectors in China, wind manufacturing capacity is much greater than its R&D capacity. In almost all cases, China has to import large-scale wind turbines, as its domestic technologies, albeit already developed, are not yet proven to be reliable in daily operation. Most of the wind projects based on Chinese technologies are facing the issue that real output is lower than what has been planned or what is desired which invariably affects the already fragile economic viability of most projects, while others are endangered or even destroyed by extreme weather conditions, such as typhoon. The real picture of the operational performance of large scale wind farms based on the most recent Chinese wind technology will not be revealed until at least the middle of 2008 when the first batch of concessionary wind farms has been operating for one full year (Shi 2007).

A large-scale wind power generation system/farm is far more complex than a small-scale, off-grid stand-alone system. At present, the gap between China and the world technology leaders is being reduced but is still considerably large.

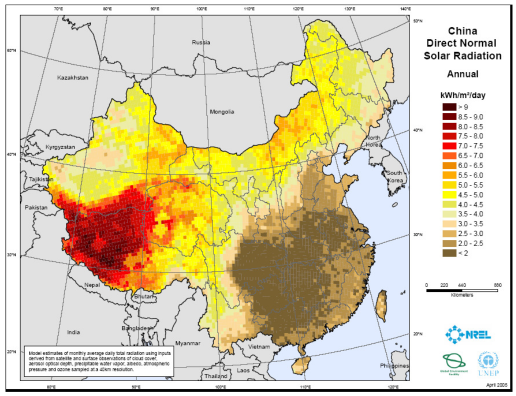
Solar energy

Compared to the wind sector, the assessment of solar energy potential is easier and more reliable. With its large territory and the low-to-middle range of latitude coverage, China captures a huge amount of solar energy as shown Figure A.2.2. The potential is greater than in other regions with a similar latitude range such as Japan and Europe. The nation-wide solar radiation ranges from 3340-8400 MJ/m2 (Luo et al. 2008).

There are about 100 companies of scale that produce solar technology in China today. They have pushed international players from having 12-15% of the market to having about 2%.[84] With its huge domestic market potential and solid resource foundation as well as a favourable political environment, China is expected to emerge as one of the greatest solar energy production bases in the world in the years to come. Over the past two decades, China's solar energy industry, having benefited from both R&D and a burgeoning domestic market, is now taking shape and making progress in technological development and innovation. China is the biggest producer and consumer in the world when it comes to solar water heaters. Both the output and consumption of solar water heaters account for over a half of the world total. With regard to solar PV productions, China has also been developing rapidly in the past 2-3 years. As an example, China initiated the demonstration of solar thermal power technology just recently and it is a quite promising technology, albeit it remains at a very initial stage. However, in general, the majority of the solar PV technologies and devices are currently imported from developed countries, a situation that also prevails in the wind industry.

[83] Source: Cambridge Energy Research Associates, 2006.
[84] Interview with Husayn Anwar, Independent Consultant (solar energy), Shanghai, 4.6.2008.

Figure A.2.2: Annual China direct normal solar radiation[85]



Biomass energy

China is rich with biomass resources. As the world's largest user of biomass as a source of energy, China has a huge potential of biomass resources, mostly from agricultural residues, logging scraps, husbandry wastes, industrial and municipal wastes, and energy crops. For example, annually there is about 600-700 million tons of crop residues from the agricultural sector that could be used, while 135-170 million tons of animal wastes are available from the livestock industry. In the mountainous areas, half of residential energy demand is supplied by burning forestry wastes of various kinds. According to FAO (2007), IEA, and the Ministry of Agriculture, one third of China's rural energy demand – primarily for cooking and heating – is supplied mostly by traditional biomass (Zhao and Tian, 2007; Bian, 2005).

The use of traditional biomass energy (bio-energy) is declining in China. However, along with growing rural household incomes, rapidly advanced urbanization, and developing commercial energy markets in rural areas, traditional biomass has been gradually replaced by modern forms of energy carriers, such as electricity, natural gas, liquefied petroleum gas, coal, and kerosene. With such a shift in energy choice, the share of bio-energy in the nation's total primary energy demand has been halved over the past two decades, accounting for 13% in 2005, and it would be further halved by 2030, as predicted by the IEA, if no major change takes place (IEA 2007).

It is likely, however, that modern bio-energy will take off in China. Having witnessed the recent revival of modernized use of bio-energy resources, particularly in industrialized countries, such as Germany, Italy, the US, the UK, and the Nordic countries, China now views bio-energy as a stone that could kill several birds, i.e. it could improve both rural economic development and environmental quality, enhance national energy security, and mitigate Greenhouse Gasses (GHG) emissions. China considers the following categories of bio-energy technologies as modern ones:

- **Efficient direct-combustion technology.** China is looking closely at the development of large-scale biomass boilers, biomass pelletization technologies, pressurized fluidized bed combustion (FDC), and blended coal-biomass combustion. In recent years, a growing number of biomass power plants have been built in China, taking advantage of abundant biomass resources and supportive policies. By the end of 2005, the installed capacity had reached 2 GW (EREC 2007). On average, the generation capacity of each facility is higher than 1 MW or even tens of MW. To be able to secure adequate feedstock is becoming an issue in many regions, particularly when a poor overall planning is made.
- **Biomass gasification technology.** By dint of its strong R&D capacity on coal gasification technologies, China is attempting to develop a 4 MW BIGCC[86] power generation system under the support of the nation's "863 Programme" which is focusing on high-tech R&D (see Section 3.4.1). In 10-15 years, BIGCC can be expected to be commercially applied and a number of

[85] Source: NREL, 2005
[86] Biomass Integrated Gasification Combined Cycles.

10 MW power generation systems can be built (Wang (ed.) 2007). In addition, China has seen hydrogen-from-biomass technologies as a promising technology to make sustainable production of hydrogen that can be used for future transportation fuel. A joint research programme on hydrogen production by biomass gasification in supercritical water is being conducted by Xi'an Transportation University and the Shanxi Coal Chemical Institute under the Chinese Academy of Sciences (CAS).

- **Biomass liquefaction technology**. Fast pyrolysis[87] technology is a promising biomass direct liquefaction technology which can, ultimately, produce a high yield of bio-liquids. It has been developed over the past decade, particularly in IEA member states. In China, the R&D in this area is already on the national energy R&D agenda especially within the support from the "863 Programme", albeit it is still at a very initial phase, basically limited to lab experimentation. East-China Engineering University and Guangzhou Energy Conversion Research Institute of CAS (Table A.4.2) are taking the lead in China in this area but they do recognize that they lag behind the world's cutting-edge environments, particularly in the study of reaction mechanisms and mathematic modelling. Biomass indirect liquefaction technologies for liquid biofuels, such as methanol and DMEs (dimethylether), are even at less developed state in China compared to the fast pyrolysis.
- **Bio ethanol Production Technology.** In response to the worldwide oil shortage, China has followed the United States and Brazil in quickly expanding its bio ethanol production capacity and become the world's third largest producer. However, much of China's bio ethanol production is currently grain-based, mostly from maize, i.e. the first generation of bio ethanol technology. After a heavy debate on which developmental pathway that a country with a large population and limited arable lands should take in terms of liquid biofuels production, the Chinese central government made it clear that the focus should be on non-grain biofuels to avoid the emerging conflict with food supply. This indicates that China needs to focus on the second generation of biofuels technology – cellulosic bio ethanol production – which is using woody feedstock rather than starch/sugar-based raw materials. Based on the research output from several "863" projects[88], a number of pilot facilities to produce ethanol from sweet sorghum straws have been built and are in operation.
- **Bio diesel production technology.** China is in the course of moving from small-scale to large-scale production, from cooking oil to dedicated oil-bearing seedy plantations as feedstock, from chaotic production and unfair competition to a regulated business environment. What is of most concern to the Chinese policy makers is probably not development of conversion technology *per se* but the implications on socio-economical development and the ecological environment due to competition for land use.
- **Biogas production technology**. As one of the earliest biogas users in the world, China has achieved great successes in biogas technology development and applications, particularly for rural households. This is thanks to strong support from the government at all levels. By 2005, more than 11 million households were equipped with a biogas digester that could produce an aggregate annual 7 billion m^3 of biogas (REDP 2005). To enlarge the scale of biogas production units, the design of highly efficient, large digesters need to be improved in addition to improved systems management. More importantly, basic research on anaerobic digestion mechanisms need to be better understood, whilst improved methods for selecting bacteria populations need to be further developed. Beyond the boundary of production, purification technology is also on of the focus areas of Chinese interest, as it could help open doors for more biogas applications, for example electricity generation by use of gas turbines, or long distance transportation by using a natural gas pipeline system. Compressed biogas as a vehicle fuel is quite popular in the Nordic region, while in China it is not on the table yet. This could

[87] Pyrolysis refers to a kind of thermo-chemical decomposition process through which solid biomass can be converted into liquid oils, charcoal, and non-condensable gasses in the absence of oxygen. Fast pyrolysis is a thermolysis of heating biomass rapidly in an oxygen-starved environment. The process is characterized by high heating rates varying from 1,000oC/s to 10,000oC/s, and short vapor residence times in the reactor usually ranging from 0.5-2 seconds.

[88] Conducted by, for example, the East-China Engineering University and the Process Engineering Institute of CAS. Cf. the efforts of Novozymes in China in this area (Case 11).

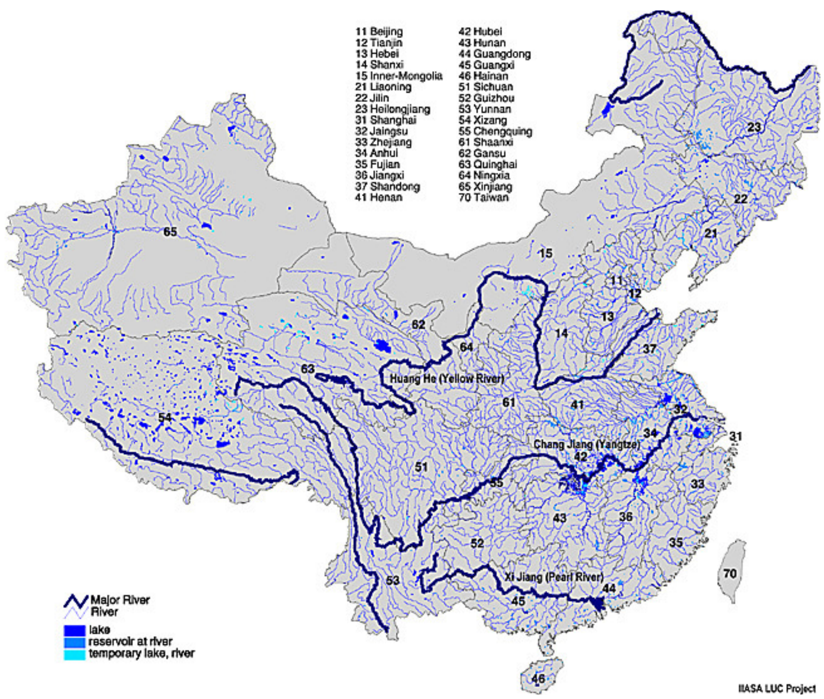
also be one potential area for R&D collaboration in view of the oil and gas shortages for both sides in the future.

Hydroelectric Power

With the world's greatest potentials in both theoretical and technically exploitable hydroelectric resources and as the second largest natural energy reserve after coal, China has given high priority to harness this "renewable"[89] energy resource which is still underexploited. Ambitious targets have been set in all the key Chinese energy policy documents, such as "Chinese Medium-and-Long Term Development Plan for Renewable Energy Sources" and "Chinese 11th Five-Year Development Plan for Renewable Energy Sources" (see Appendix 3). By 2010, the total installed hydroelectric power generation capacity will be doubled from the 2003 level and tripled by 2020, reaching 300 GW, which accounts for more than half of the nation's total technical potential of 542 GW[90] (NDRC 2008; C. Zhang 2005; Wang and Li 2008).

Although hydroelectricity generation is a well-established technology, hydro-engineering challenges vary greatly from site to site. As shown in Figure A.2.3, the majority of the Chinese hydropower potentials are located in the territories of several western or southern regions, where similar geological and topological complexities have never been dealt with anywhere before, and they require advanced and innovative technical solutions. For instance, improved earthquake survey technologies will help minimize significant risks to the selected dam sites in the long term as the lifespan of a project could be as long as 100 years. How to improve the performance of turbo-generators in high water-heads is also a critical issue for a reliable and efficient operation. China has already developed a strong capability in dam building, but it is still open to collaboration with other countries due to the significance, both in socio-economic and political terms, of risks and uncertainties embedded in the decades long hydro development process in China.

Figure A.2.3: Hydroelectric resource bases in China[91]



[89] Although it is debatable whether large hydropower should be considered a renewable energy source.
[90] Calculated by the Chinese water resources authority based on the latest survey on hydroelectric power potentials.
[91] Source: Heilig 1999.

The environmental and socio-economic implications are the most controversial issues in relation to hydropower projects in both China and worldwide. In many promotional schemes, this is also the key issue to determine whether or not hydropower could be considered a renewable energy source. For China, the concerns are even wider given that a small-scale hydropower plant is defined at 50 MW in China, five times higher than the European norm[92], and more scrutiny and efforts are required not only to minimize the negative environmental impacts, but more importantly to protect the welfare of local residents in the mountainous regions where normally greater hydroelectric power resources exist. The local residents are often poor and of minority origin.

These procedures should draw upon international experiences, especially from countries such as Norway and Sweden where hydropower is used extensively and takes up a significant proportion of the energy mix, and where expansion has been stopped since the 1960s due to the growing public concerns about the environment.

Ocean energy

Among the four types of ocean energy, i.e. tidal, wave, marine current, and ocean thermal, the first two offer greater prospects in terms of technological development while the latter two are at the initial R&D phase. In this sub-section, the focus will be on tidal and wave energy, although marine current and ocean thermal energy sources are also touched upon.

On China's near-shore, the exploitable potential of tidal energy represents about 21 GW[93] while wave energy may produce up to 13-15 GW (C. Zhang 2005; Xing and Tao 2007). More importantly, they are close to the Chinese economic locomotive, the south-eastern coastal region where electricity is badly needed, particularly in recent years. For example, 88% of the total tidal energy potential falls in Zhejiang and Fujian provinces, the most economically dynamic areas in China (Xing and Tao 2007). The financing capability for such projects is strong in these provinces, and, due to their location, the initial capital investment and operation costs for power transmission would be significantly reduced compared to electricity transmitted over long distances.

As yet, little progress has been made in development and deployment of technologically mature traditional tidal energy technologies, although traditional tidal lagoon technologies have proven feasible and reliable, based on more than 40 years of operational experience. Since the 1980s, deployment has essentially been stagnant in China as well as worldwide. The eight operating tidal power plants in China were almost all built in the 1970s and 1980s. This includes the world's third largest tidal power experiment plant, Jiangxia [94]. There are two reasons behind the slowdown. The first is economic; the per kW investment for the Jiangxia plant (in 1980 value) was two times higher than that for an equivalent coal-fired power plant, or on average 1.5-2 times higher than that of a hydroelectric power plant (C. Zhang 2005). In the French LaRance[95] case, unit electricity production cost ($/per KWh in 1973 prices) was two times that for the average hydroelectricity project (Wang 2007). More significantly, as traditional tidal lagoon power plants need to build a barrage across the opening to a tidal basin, similar to the reserve dam, the negative impacts on tide variations, local marine ecological systems, and navigation systems are far greater than that of a hydroelectricity reserve. Therefore, the focus has shifted towards the use of submerged turbines to capture and convert tidal current into electricity energy.

The prospect of wave energy development in China is still unclear. China would rather devote its own efforts to R&D rather than developing large-scale wave projects, primarily due to the low wave energy density in its near shore areas, the high investment costs, inadequate long term data measurements, and unclear impacts by wave energy device deployment on the marine environment. From 1990 to 2005, the Chinese government invested US$ 177 million in wave

[92] As there is no international standard to define the scales for hydropower plants, the defined scale of 50 MW does not seem unreasonable, but it does have implications for the possible negative impacts on the local environment, for the inhabitants, and for wild animals if no effective preventive measures are taken.

[93] Based on the "Survey Result of Tidal Energy Resources in China" conducted in 1982 by the former Design Institute under the Ministry of Hydroelectric Power.

[94] It was built for experiment and developed under the "Sixth Five-Year" Key Technology Development Programme in 1974 with its initial designed capacity of 3.2 MW which was upgraded to 3.9 MW by the end of 2007.

[95] The largest tidal power plant in the world, built in 1964, had a capacity of 240 MW and is still in operation.

energy R&D. In 1990, the first wave power experiment plant was built at Dawanshan Island in Guangdong Province. The capacity was 20 kW. In 2005, China developed a stand-alone wave power generation system, which is able to convert wavy mechanic energy into stabilized power energy.

Foreign investors and wave energy developers are exploring opportunities to develop the Chinese wave energy market by starting with a joint RD&D followed by a commercialization plan and strategy. Very recently, the Israeli company S.D.E. Energy has signed an agreement to build an initial model in Guangzhou Province by applying its developed wave energy technology. Should it be successful, a nationwide deployment programme will be launched as the company's scale-up plan is to sell its innovative technology throughout China. This on-going process is subject to the guaranteed purchase of all the KWh generated. From a long term perspective, it is as yet uncertain whether Chinese R&D and foreign investments will combine to tap China's wave energy potential. It probably depends on how successful the foreign investors are in demonstrating sensible returns on the initial investment to the Chinese government.

Geothermal energy

Up till this stage, extensive but low-temperature geothermal resources in China confine the major geothermal applications to space heating and recreation rather than to power generation. Geothermal resources are available in many areas, but the temperatures range from 30-90 C in most locations. Since 1990, use of geothermal energy for space heating, recreational bathing and spa, and cultivation has evolved quickly by application of developed technologies for exploration and utilization as well as increased demand from various sectors which follows rapid urbanization and a growing need for cleaner energy sources. By 1999, China had already made itself the world's largest geothermal non-electric user as shown in Table A.2.1. The momentum has been maintained over the last decade, with an average two-digit annual growth rate (B.M. Zhang 2005). According to the "2005 Chinese Geothermal Environment Bulletin" released by the Ministry of Land and Resources of China, the direct utilization of geothermal energy in China has reached 13.76 m^3/s, and in 2005, the installed capacity of geothermal energy reached 10,779 MW.[96]

Table A.2.1: Capacity and output of non-electric use of geothermal energy in the world[97]

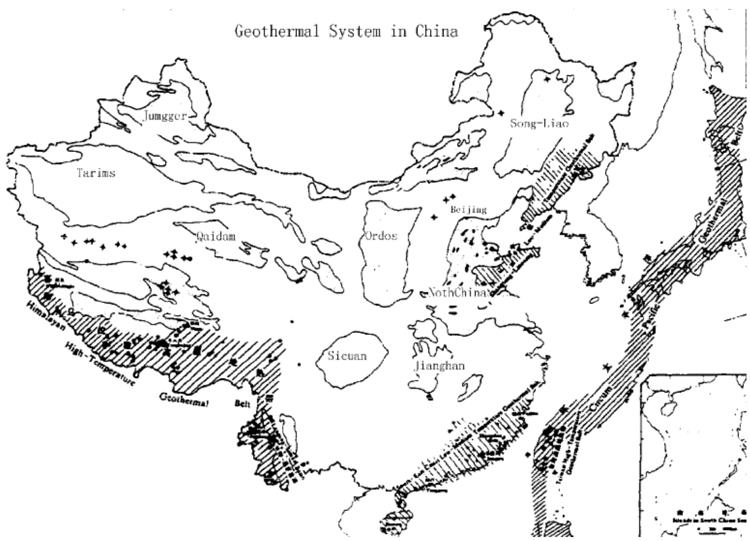
Country	Capacity/MW	Annual Output/GWh
China	2,282	10,531
Japan	1,167	7,482
USA	3,766	5,640
Iceland	1,469	5,603
Turkey	820	4,377
New Zealand	308	1,967
Georgia	250	1,752
Russia	308	1,707
France	326	1,306
Hungary	473	1,135
Sweden	377	1,147
Mexico	164	1,089
Italy	326	1,048
Romania	152	797

Combined with the wide spread of applications of district heating and ground heat pumps, geothermal energy may have an important role to play in satisfying the demand from the continued expanding heat markets in China.[98]

[96] Among which only 32 MW is for power generation (including that of Taiwan).
[97] Source: Liu 2005.
[98] See also Section 4.4.6 regarding the involvement of Glitnir Bank and its Icelandic technology partners in the sector.

High temperature geothermal resources do exist, but they are geographically limited to a few locations[99] in southern Tibet, western Yunnan and western Sichuan, as shown in Figure A.2.1. They are located on the Himalayan Geothermal Belt. Whether or not the resources could be exploited in an economically viable and environmentally benign manner depends on a number of complex factors. Thus far, there is only one commercial geothermal power plant in China, the Tibetan Yangbajing Geothermal Power Plant with 24 MW power generation capacity, albeit it has not bee in full operation in recent years[100] due to degrading geothermal resources (Liu 2005). In 2004, the Israeli Ormat Technologies Inc. proposed to develop a 48.8 MW geothermal power plant in Tengcong, Yunnan province. However, as the local government is concerned about the potential negative impact on geothermal tourism, this proposal has been stalled until now.

Figure A.2.4. Geothermal systems in China[101]



Carbon capture and storage (CCS)

As fossil fuels are still expected to dominate the world energy scenarios, the possibility to manage CO_2 contained in the fuels in a controlled way is becoming an attractive option, not only for China but for the world at large. In this context, CCS has a role to play if and when it proves mature and reliable. China has been actively engaged in the development of CCS in both R&D and applications as CCS could provide a strategic solution for the dilemmas of its power sector. Thanks to its strong coal industry and large geographical potential for CO_2 storage, China sees CCS as one promising option to solve both energy and climate issues.

Nevertheless, CCS is new to all, in technical as well as legal and regulatory terms. Scientifically, there is a need to study, for example, the physical character and performance of CO_2 in a highly concentrated form and under great pressure. Technically, it is still a challenge to devise methods and technologies to handle capture and transport of CO_2 in a safe and cost-efficient way. Those two factors determine how effective CCS would be as a climate solution. Some argue that CCS provides only a short term banking solution to CO_2 emissions that should have been cut off otherwise. If masses of stored CO_2 were to be released or leaked out, it would cause a huge catastrophe.

However, the Chinese petroleum industry has its own motivation to be the first mover, as injection of CO_2 back into the ground could increase the oil yield, which offsets the extra cost of developing

[99] Out of 1,028 geothermal systems in China, those with high temperature water/steam account for only 5.8%, although it accounts for 25.5% of the total reserve of heat energy (Liu 2005).
[100] Only 86 GWh generated in 2003, a ten year low.
[101] Source: Zhang 2005.

resources that are difficult to access or of low quality. It remains unclear how much storage capacity China would have as such data are politically sensitive and the Chinese authorities are not willing to provide accurate and precise information on that. It can be inferred from the active Chinese involvement that China sees a huge potential for CCS. Also, CCS was listed as a cutting-edge technology to be further developed in the National 2020 medium to long longer term science and technology development plan (Appendix 3), while strong support is being given to CCS development in both the 11th Five-Year Plan and the National High-Tech Programme ("863" Programme).

With regard to the academic regime, scientists and researchers have been closely monitoring and collaborating on clean coal technologies. As an example, the FutureGen project in the United States has been on the Chinese scientists' radar for a long while.

China moves fast from the lab to the field. On 31 December 2007, China decided to build its first coal-fired power plant with a CCS facility in two years under a joint-venture partnership, GreenGen Co., between a group of state-owned enterprises and American firm Peabody Energy.[102] It is reasonable to speculate that more such plants would be built in the decades to come if the first one works well.

[102] More about this project can be found at: http://pepei.pennnet.com/display_article/315797/6/ARTCL/Display/none/1/China

Appendix 3 - Appendix: Key policy and legal documents

Table A.3.1 – Key political and legal documents

Name of document	Organization responsible	Date	Source
POLICY DOCUMENTS			
Essentials of 2000-2015 development plan for new energy and renewable energy industry Chinese version: 新能源和可再生能源产业发展规划要点 2000-2015	NDRC 国家发展改革委员会	Dec. 2000 2000 年 12 月	Annual Report on China's New Energy Industry (2007), Beijing: China New Energy Chamber of Commerce, Norwegian Energy and Environment Consortium, 2007; http://www.ces.cn/html/2005-3/20053311413261.shtml http://www.stcsm.gov.cn/learning/lesson/jinrong/20010731/20010731-2.asp
10th 5-year plan for energy saving and comprehensive resource utilization Chinese version: 能源节约与资源综合利用"十五"规划	NDRC 国家发展改革委员会	Oct. 2001 2001 年 10 月 10 日	http://www.ces.cn/html/2005-3/20053311432211.shtml
Outline of National Medium and Long-term S&T Development Plan 2006-2020 Chinese version: 国家中长期科学和技术发展规划纲要（2006-2020 年）	State Council 国务院	Feb., 2006 2006 年 2 月	http://www.gov.cn/jrzg/200602/09/content_183787.htm http://www.gov.cn/jrzg/2006-02/09/content_183787_4.htm
National 11th 5-year plan S&T development program Chinese version: 国家"十一五"科学技术发展规划	MOST 科技部	Oct. 2006 2006 年 10 月 27 日	http://www.most.gov.cn/kjgh/kjfzgh/200512/t20051220_55485_5.htm
Development program for energy under 11th 5-year program Chinese version 能源发展"十一五"规划	NDRC 国家发展改革委员会	April 2007 2007 年 4 月	http://news.xinhuanet.com/fortune/2007-04/11/content_5960916.htm
Program for development of water management under 11t 5-year plan Chinese version: 水利发展"十一五"规划	NDRC Ministry of Water Resources Ministry of Construction 国家发展改革委 水利部 建设部	May 2007 2007 年 5 月	http://www.chinapower.com.cn/article/1081/art1081473.asp
China's National Climate Change Programme Chinese version: 中国应对气候变化国家方案	National Development and Reform Commission 国家发展改革委	June 2007 2007 年 6 月	http://en.ndrc.gov.cn/newsrelease/P020070604561191006823.pdf http://www.sdpc.gov.cn/xwfb/t20070604_139486.htm
China's Scientific and	Jointly Issued by:	June 2007	http://www.ccchina.gov.cn/WebSite/CC

Name of document	Organization responsible	Date	Source
Technological Actions on Climate Change	Ministry of Science and Technology National Development and Reform Commission Ministry of Foreign Affairs Ministry of Education Ministry of Finance Ministry of Water Resources Ministry of Agriculture State Environmental Protection Administration State Forestry Administration Chinese Academy of Sciences China Meteorology Administration National Natural Science Foundation State Oceanic Administration China Association for Science and Technology		China/UpFile/File199.pdf
Medium and Long-Term Development Plan for Renewable Energy in China (Abbreviated Version) Chinese version: 可再生能源中长期发展规划	National Development and Reform Commission 国家发展改革委员会	Sept. 2007 2007 年 9 月	http://www.frankhaugwitz.info/doks/policy/2007_09_04_China_RE_Medium_Long_Term_RE_Development_Plan.pdf http://www.china.com.cn/policy/txt/2007-09/04/content_9252708.htm
White Paper on Energy: China's Energy Conditions and Policies Chinese version: 中国的能源状况与政策	Information Office of the State Council 中华人民共和国国务院新闻办公室	Dec. 2007 2007 年 12 月	http://www.china.org.cn/english/environment/236955.htm http://www.gov.cn/zwgk/2007-12/26/content_844159.htm
Development program for renewable energy under 11th 5-year plan Chinese version: 可再生能源发展"十一五"规划	NDRC 国家发展和改革委员会	March 2008	http://nyj.ndrc.gov.cn/ggtz/t20080318_198288.htm
International Science and Technology Cooperation Programme on New and Renewable Energy. Beijing: Ministry of Science and Technology and National Development and Reform Commission, P.R. China.	MOST/NDRC	2007(?) undated	Hard copy

Name of document	Organization responsible	Date	Source
LEGAL DOCUMENTS			
节约能源法	全国人民代表大会常务委员会	2007 年 10 月	http://news.xinhuanet.com/newscentre/2007-10/28/content_6967159.htm
可再生能源法	全国人民代表大会常务委员会	2005 年 2 月	http://www.gov.cn/ziliao/flfg/2005-06/21/content_8275.htm
Renewable Energy Law 可再生能源法	全国人民代表大会常务委员会	2005 年 2 月	http://www.gov.cn/ziliao/flfg/2005-06/21/content_8275.htm
Electricity Law 电力法	全国人民代表大会常务委员会	1995 年 12 月	http://www.mwr.gov.cn/zcfg/fb/19960401000000514190.aspx
Law on Environmental Protection 环境保护法	全国人民代表大会常务委员会	1989 年 12 月	http://www.dffy.com/faguixiazai/xzf/200512/20051202105134.htm
Coal Law 煤炭法	全国人民代表大会常务委员会	1996 年 8 月	http://www.gov.cn/ziliao/flfg/2005-08/05/content_20916.htm
大气污染防治法	全国人民代表大会常务委员会	2000 年 4 月	http://www.envir.gov.cn/law/air.htm
Guiding Catalogue for the Development of the Renewable Energy Industry 可再生能源产业发展指导目录	国家发展和改革委员会	2005 年 11 月	http://www.china.com.cn/chinese/PI-c/1113291.htm
State Strategic Programme intellectual property rigths 国家知识产权战略纲要	国务院	2008 年 6 月	http://www.sipo.gov.cn/sipo2008/yw/2008/200806/t20080610_406106.html
Energy Saving Law 节约能源法	全国人民代表大会常务委员会	1997 年 11 月 1 日 (amended 2007)	http://www.ces.cn/html/2005-3/20053311434551.shtml
Management Methods for Energy Saving in Key Using Units 重点用能单位节能管理办法	国家经济贸易委员会	1999 年 3 月 10 日	http://www.ces.cn/html/2005-3/20053171348181.shtml
Management Regulations for Energy Saving in Private Construction 民用建筑节能管理规定	建设部	1999 年 10 月 28 日	http://www.ces.cn/html/2005-3/20053311433421.shtml
ADMINISTRATIVE GUIDELINES			
Guiding catalogue for development of the renewable energy industry	NDRC (Energy [2005] no. 2517)		
Renewable energy surcharge level regulation	NDRC (Price [2006] no. 28-33)		
Provisional regulation on renewable energy surcharge balancing	NDRC (Price [2006] no. 44)		
Regulation on the administration of power generation from	NDRC (Energy [2006] no. 13		

Name of document	Organization responsible	Date	Source
renewable energy			
Provisional administrative measures on the renewable energy development fund	MoF (Economic and Construction [2006] no. 237)		
Regulations governing the use of the renewable energy development fund to promote renewable energy integration in buildings	MoF (Construction [2006] no. 460)		
Regulation on the management of bio-ethanol projects	MoF (Construction [2006] no. 460)		
Regulation on the construction and management of wind farms	NDRC (Energy [2006] no. 1204)		
Regulations for the National Natural Science Fund 国家自然科学基金条例	国务院	2007 年 2 月	http://www.nsfc.gov.cn/nsfc/cen/gltl/02.htm
Provisional administrative regulations on pricing and cost sharing for renewable energy power generation	NDRC (Price [2007] no.7)		

The following websites cover almost all the policy and legal documents listed here

http://www.ces.cn
http://www.china.com.cn/economic/zhuanti/2007nyfz/node_7019899.htm
http://www.ccei.org.cn/zcfg.asp
http://www.cred.org.cn/zhengce.asp
http://www.crein.org.cn/view/ViewList_2.aspx?BC=zcfg
http://nyj.ndrc.gov.cn/ggtz/default.htm

Table A.3.2 – Nordic Asia and China strategies

Country	Title	Year	Address
Denmark	Denmark in Asia – Opportunities for the future	2007	http://www.um.dk/um_files/Publikationer/Danida/English/CountriesAndRegions/Asia/AsienUkWeb.pdf
Denmark	Strategy for Knowledge Based Collaboration between Denmark and China – Summary (Ministry of Science, Technology and Innovation; full version available in Danish; summary available in Chinese)	2008	Full Danish version http://videnskabsministeriet.dk/site/forside/publikationer/2008/strategi-for-vidensamarbejde-mellem-danmark-og-kina English version http://videnskabsministeriet.dk/site/forside/publikationer/2008/strategy-knowledge-based-collaboration-denmark-china-summary Chinese version http://videnskabsministeriet.dk/site/forside/publikationer/2008/strategy-knowledge-based-collaboration-denmark-china-chinese/strategy-knowledge-collaboration-denmark-china-chinese.pdf
Denmark	Danmark-Kina. Partnerskab til fælles gavn	2008	To be finalized during the autumn of 2008
Norway	The Government's China Strategy (Ministry of Foreign Affairs)	2007	http://www.norway.cn/NR/rdonlyres/7B68A4B6-32FC-4B6E-B623-A1877E84579A/77221/Kinastrategien_engelsk.pdf
Finland	Destination: Asia Towards goal-oriented educational, research and cultural cooperation with Asian countries (Ministry of Education, Finland)	2007	http://www.minedu.fi/export/sites/default/OPM/Julkaisut/2007/liitteet/opm34.pdf?lang=en
Sweden	Our Future with Asia - A Swedish Asia Strategy for 2000 and beyond (Ministry of Foreign Affairs)	1999	http://www.sweden.gov.se/content/1/c6/04/09/70/41cc9066.pdf
Sweden	Framtid med Asien - en uppföljning av regeringens Asienstrategien (Ministry of Foreign Affairs)	2002	http://www.sweden.gov.se/content/1/c4/04/41/346214e8.pdf
Sweden	Country Strategy for Development Cooperation with the People's Republic of China 2006–2010 (Ministry of Foreign Affairs)	2006	http://www.sweden.gov.se/content/1/c6/03/96/27/c21413bc.pdf

Appendix 4 - Actors in the Chinese energy sector

Note: (I) = Interviewed by authors

Table A.4.1 – Key actors in the energy sector at the central government level

Organization	Areas of competence
Energy Leading Group	A supra-ministerial coordinating body headed by the Premier of the State Council. It will be replaced by the new Energy Commission during 2008
National Energy Commission (under establishment)	To provide guidance to the development of the sector and be responsible for coordinating the "agendas" of the stakeholders in the energy sector
National Coordination Committee on Climate Change (ONCCCC)[103]	The committee is inter-ministerial and comprises 17 Ministry level organizations. The work of the Committee is coordinated as follows: - NDRC coordinates climate change policies and actions adopted by various departments - Ministry of Foreign Affairs takes the lead in international climate change negotiations - CMA takes the lead in participating in the IPCC The Office of the Committee is situated in the Department of Regional Economy under NDRC
National Development and Reform Commission (NDRC) (I)	Responsible for coordination of issues at the macro-level; responsible for development of national energy development strategies; has own policy and strategy research competence
National Energy Agency (under NDRC)	- Analysis of national and international energy development trends and developments; formulate policy and strategic proposals - To analyze and make proposals for energy development programmes and relevant reforms - Practical management of the oil, natural gas, coal, and electricity sectors; give guidance to local energy development and construction - To formulate policy proposals for energy saving and new energy development - Management of the national strategic oil reserve - To manage international energy collaboration and coordination of this
Ministry of Science and Technology (MOST), incl. Renewable Energy Department and "ACCA 21" Centre (I)	- To undertake policy research and formulate policies relating to basic energy research and high-tech development programmes ; formulation, organization, and management of basic science programmes and plans within energy research, high-tech development plans and programmes, S&T support programmes, and S&T platform programmes - To strengthen development and dissemination work in relation to the development and commercialization of high-tech and applied technologies in relation to energy
Ministry of Finance	- Formulation of tax rebate and other regulations on financial concessions or support mechanisms in support of R&D in energy organizations or companies - To decide on the basis of the national budget how much tax the energy sector is to pay on an annual basis and the size of the government's budgetary outlays - To put forward goals for new or elimination of old taxes or levies, for adjustment of tax rates and rebates regarding R&D projects and investment and for temporary tax holidays on investments that have considerable influence on national finances - To be responsible for allocations from the Special Fund for Renewable Energy
Ministry of Water	- To formulate plans and programmes for development of hydropower; prepare drafts for new relevant laws and regulations and monitoring systems - To elaborate policies for hydropower and plans for water saving , elaborate relevant guidelines and standards , organize and monitor activities relating to water saving in connection with hydropower generation - To provide guidance for work in the hydropower sector , formulates policy proposals regarding pricing, taxes. Credits, budgetary, and similar issues relating to economic coordination - To coordinate work relating to hydropower and electrification in rural areas Responsible for S&T work in relation to hydropower and development of the human resource base

[103] Pang & Zou 2008.

Organization	Areas of competence
Ministry of Construction	To be responsible for regulation of construction, and development of building codes and standards
Ministry of Communications	To oversee the planning and implementation of all transport infrastructure and proposes energy saving policies and standards for the transport sector, incl. the introduction of new and more fuel-efficient technologies
Ministry of Agriculture	- To be responsible for formulation of policies, plans, legal drafts, regulations and organizational interventions relating renewable energy development in the rural areas - To guide the development of a renewable energy system in rural areas - To be responsible for formulation of infrastructure projects within environment and renewable energy in rural areas - To organize and guide demonstration projects for comprehensive use of renewable energy as well as key technologies
Ministry of Education	- Plans and guides the programmes for energy research at the universities - Macro-control in relation to how the universities manage commercial applications of technologies and their dissemination as well as the coordination of commercialization, education and research - To coordinate and guide the implementation of key state energy research projects at the universities - To guide the construction and implementation of key state laboratories for renewable energy at the universities.
State Electricity Reform Commission (SERC)	China's regulatory authority in the power sector performs administrative and regulatory duties with regard to the national power sector. The major responsibilities are: - Overall regulation of the power sector including and development of a coherent system for the regulatory organization at the different administrative levels - To develop laws, regulations, and rules for the electricity market - Planning for the national and the regional power markets and electricity trading arrangements - To monitor electricity market operations, ensure orderly and fair competition in the market, regulate transmission, distribution, and non-competitive generation businesses - To develop and enforce of safety and technical standards; quantitative and qualitative codes for the electricity industry; to issue and monitor business licenses; enforcement of environmental laws, regulations, and standards for the sector - To propose and review tariff levels and regulate fees and charges for ancillary services - To monitor and act on violations of laws and regulations by market participants and resolve disputes among them - To supervise the implementation of service providers - To provide statistics and information on the electricity market - To organize and help implement sector reform programmes[104] The Commission was supposed to be independent in its activities, but its mandate is limited and it is still constrained by the NDRC due to overlapping competences.

[104] http://www.serc.gov.cn/english/index.htm# (accessed 18.9.2008)

Table A.4.2 – Key R&D organizations working with renewable energies

Organization	Areas of competence
Energy Research Institute (ERI) Belongs to NDRC (I)	The main tasks are to: - Undertake research on: major aspects of theory and methodologies in relation to energy economics; economic aspects of the energy situation at national and regional level, incl. coal, electrical power, oil, natural gas, resource exploration, development, extraction and production, transport, end use consumption, energy production and demand balance; energy security, regional and international collaboration - Provide the necessary policy research and scientific input to formulate energy strategies and development plans, associated policies and legislation, and proposals for reforms of the energy system on behalf of the central and local authorities
Guangzhou Institute of Energy Conversion under Chinese Academy of Sciences (CAS)	- High-tech engineering R&D in relation to clean and renewable energy and strategic technologies - The institute deals with all renewable and new energy fields (incl. geothermal and ocean) and has established key state energy laboratories for renewable energy and natural gas hydrates - The institute also has a research laboratory for energy strategy
Qingdao Institute of Biomass Energy and Bioprocess Technology	Main research areas include: - Cultivation, screening and engineering of plant species of bioenergy applications - Screening and reconstruction of functional microbial isolates and communities of bioenergy applications - Microbial catalysis and metabolic engineering of Biodegradation processes - Reaction, separation, scaling-up and integration in bioprocess engineering - Biotransformation processes and computational simulation - Safety assessment of emerging technologies
Energy Economy Research Centre under the Institute of Industrial Economics, Chinese Academy of Social Sciences (CAAS)	- Undertakes research on macro-level issues in relation to energy - Provides policy advice and consulting to government departments, sector organizations and companies - Exchange between academia and enterprises - Organization of and guidance to international research collaboration
North China Electrical Power University (I)	- Has been ranked as no.1 in electric power generation technology in China; no 100 on the overall ranking of universities in China - Established the School of Renewable Energy in 2007 on its Changping Campus outside Beijing. It is first school of this kind in China; focus on hydropower, wind, bioenergy and solar energy - Has a strong tie with electrical industry (according to their own information they have educated 60% of the top leaders in the electrical power industry in China - Specialized in electricity generation, transmission and distribution; - Education (B.Sc., M.Sc., PhD) and in-service training - Interested in joint PhD programs with the Nordic countries
Institute of Nuclear and New Energy Technology, Tsinghua University (I)	- Has a strong base in nuclear technologies - Specialized in hydrogen, solar energy and biofuels - Training and exchange researchers with other research institutes, including the cooperation with KTH - Conduct consulting work in design as well, particularly in nuclear facilities
Beijing Geothermal Research Academy	- Theoretical, technical and technological research relating to resource assessments and resource exploitation - Dissemination of new technologies - Consulting, e.g. geo-thermal project strategies and planning - Engineering projects in relation to geo-thermal projects

Table A.4.3 – China's major energy companies (following 2002 reform)[105]

Type of organization	Name and organizational structure	Comments
Grid corporations	State Grid with the following subsidiaries: - regional grid companies: Northeast Power Grid, North China Power Grid, East China Power Grid, Central China Power Grid, Northwest Power Grid - 25 provincial and municipal grid companies - 5 research institutes	Covers 26 provinces, autonomous regions, and municipalities covering 88% of China's territory; about 1.5 mill. employees. In 2006, State Grid invested 648 mill. RMB in R&D, up 77% as compared to 2003[106]
	China Southern Power Grid	Covers China's southern provinces
Electrical power producers	Huaneng	
	Datang	
	Huadian	
	Guodian	
	China Power Investment	
Oil companies	China has a number of oil and petroleum companies. The biggest are CNPC, incl. PetroChina, CNOOC, Sinochem, and Sinopec	In 2004, CNPC accounted for 89% of China's oil produced overseas at own foreign equity facilities[107]
Non-core business groups	China Power Engineering Consulting Group Corporation	
	China Hydropower Engineering Consulting Group Corporation	
	SINOHYDRO Corporation	
	China Gezhouba (Group) Corporation	

[105] Information gathered during interviews.
[106] http://www.sgcc.com.cn/ywlm/tjsj(new)/kph-e/default.shtml (accessed 18.9.2008).
[107] Downs 2006.

Table A.4.4 – Key national intermediary organizations

Organization	Areas of competence
NDRC, Global Environmental Fund, WB Renewable Energy Project Office	- Conducts energy policy research in support of the Chinese Renewable Energy Law
China Renewable Industries Energy Association (CREIA) (I)	Industrial association with corporate members and individual members covering all the sub-sectors of renewable energy, i.e. solar thermal, solar PV, wind, biomass (biogas plants), bagasse, hybrids, geothermal, small hydro and ocean energy. CREIA provides all-round services including: - Policy analysis and advice for government - Market development and market regulation - International cooperation between the industry and foreign investors - Training, education and outreach to raise both the professional level and public awareness - Technology development and industrialization - Environmental support to mitigate the pressure caused by climate change - Consultation and guidance in terms of technology, policy, market, investment and export/import for the industries, research institutions and the governmental officials
China Wind Energy Association[108]	- Serve as window of Chinese wind society to outside world, promote international academic and technical cooperation, perform a bridge between the government and institutions, establish good relationships with domestic and overseas wind societies, cooperate with similarly associations, communicate with scientists and engineers closely, and contribute to the development of wind energy technology and industry
China New Energy Chamber of Commerce	China New Energy Chamber of Commerce is under the guidance and supervision of All-China Federation of Industry and Commerce, with the main tasks as follows: - To regulate the behaviours of the enterprises, promote the self-discipline of the industry and help them actively participate in the deliberation and administration of state affairs; to promote national guidelines, policies among the members and guide the members to abide by national laws and regulations - To provide consulting service on economics, technology, information, production, management, financing, law and regulation - To organize the members to carry out exchanges and cooperation in China, and to visit, inspect, and hold exhibitions and trade fairs, with the aim of enhancing the communication and cooperation among the domestic enterprises of the industry - To establish contacts with the chambers of commerce or trade associations and institutions both overseas and in the regions of Hong Kong, Macao, and Taiwan; to organize the members to develop activities to exchange ideas, mutual visits and inspections in order to promote the communication and cooperation of international economy and trade of all the members - To safeguard the legal rights and interests of the members; to pay attention to any difficulties, opinions and requirements of the members, helping them allay their worries and tide over their difficulties - To carry out industry research, to compile industrial development report and to hold various industrial seminars and annual forums; to assist the members to set up brands, develop markets, etc. - To educate the members to actively participate in social services - To organize the members to participate in all the activities held by ACFIC - To undertake all matters consigned by the government and ACFIC. *(Source: http://www.cnecc.org.cn/ensite/index.htm)*
China Association of Comprehensive Resource Utilization (CARCU), Special Committee on Renewable Energy	- Belongs to Department of Resource Conservation and Environmental Protection, National Development and Reform Commission (NDRC), P.R. China. At present, the association has eleven sub-committees, incl. renewable energy. In addition to the sub-committees, it also has another 180 and more group members covering the following sectors: Metallurgy, Coal, Petrochemical, Ferrous metal, Electrical power, Environmental protection, Building materials, Automobiles, Recycling, Tertiary institutions, Research companies, Agriculture, Light industry. Of the above sectors, metallurgy, coal, electrical power, tertiary institutions and research companies constitute 60 – 70% of its members. In total, it has 750 group members.

[108] Similar organizations exist for other renewable energy sub-sectors.

Appendix 5 – Case studies

CASE 1: EU-China Energy and Environment Programme (EEP)

The EEP was established under an agreement between the European Union and the Chinese Government in 2002 and started in May 2003. The programme will finish in November 2009. The total budget is €42.9 million, of which €20 million is from the EU and €22.9 million is from China. The Chinese contribution has been calculated as the accumulated contributions from all involved Chinese partners/agencies and is mainly in kind.

The overall programme objectives are to improve environmental quality in China based on the following strategic priorities:

- To foster co-operation between Chinese and EU industries in China's energy markets
- To strengthen the security of energy supply in both Asia (China) and Europe
- To protect the global environment in line with international objectives, in particular in the context of climate change, and to ensure sustainable use of energy.

The EEP is conceptually represented by four components:

1. Energy policy development
2. Energy efficiency
3. Renewable energy
4. Natural gas

The main activities are:

- Policy advice to central and local authorities
- Awareness and capacity building (primarily training)
- Introduction of new technologies through feasibility studies and demonstration projects.

The national executing agency for the programme is the Ministry of Commerce of the People's Republic of China (MOFCOM). The Implementing Agencies are the National Development and Reform Commission (NDRC), the Ministry of Science and Technology (MOST), the Energy Research Institute (ERI), and the China National Petroleum Corporation (CNPC).

The programme has been off to a slow start and the main activities only started in 2006. The major activities in 2007 were:

- A workshop on renewable energy organized together with the EU Chamber of Commerce in China and Chinese Renewable Energy Industries Association. The aim was to help improve the wind energy market in China, and the focus was on regulatory policies and technical standards for wind power development in support of the regulatory agenda
- NDRC officials participated in the EU energy week, including a high level round-table on international cooperation on energy efficiency organized by DG TREN in Brussels
- A Chinese Government Delegation attended the European Wind Energy Conference in Milan (Italy), a full day Government and Industry Workshop in Denmark, a full day in Copenhagen at the Ministry of Foreign Affairs, and a study tour to off-shore wind technology sites in Denmark
- Co-sponsoring of an "International Symposium on China's Energy Law"
- EEP PMU staff and experts participated in a "Conference on Energy Efficiency in Motor Driven Systems" (EEMODS 2007), Beijing, June 2007, and in a side event discussing a proposal for a China Electric Motor Challenge Programme
- 8 tender procurement notices and 4 calls for proposals from renewable energy were launched (1: Development support for sustainable rural and renewable energy; 2: Agricultural biomass resource assessment; 3: Off-shore wind energy assessment and

feasibility study of off-shore wind farm development in China; 4: Training support for the dissemination of the Chinese renewable energy law (energy efficiency and natural gas components published)

- 2 service contracts were signed: a 'Study on the Improvement of Energy Efficiency and Reduced Environmental Impact of Industrial Boilers in China' (€ 0.8 million) and a 'Feasibility Study of Coal Bed Methane in China' (€ 0.5 million)
- EEP's natural gas component continues to provide a Vice Chairman for the Working Group on Energy and Utility Policy of the EU Chamber of Commerce in China and is contributing to the Chamber's 2007 Position Paper. Through the meetings with the EU Chamber an additional platform is provided for contacts between the European industries represented in the workgroup and the NDRC
- Cooperation with the Office of the National Energy Leading Group in four energy policy studies (China auto-traffic energy saving, energy intensive products research, the development of new energies, climate change issue and energy strategy adjustment)
- Cooperation with the National Climate Change Office for studies on technology transfer needs assessment in ten major industries
- Production of dissemination materials on the implementation of the energy conservation law, and workshop for the dissemination of the revised National Energy Conservation Law
- NDRC study tour on EU Energy conservation legislation and policy with the aim to learn lessons from Eastern European countries to improve China's policy for sustainable energy development
- Review of a feasibility study for the Donghai Off-shore Wind Farm
- Support to the drafting of a natural gas law framework.

In 2008, EEP will launch a study into EU experiences with feed-in tariffs/cost sharing arrangements for RE. The study will combine Chinese and EU experts. Conditions under which the study will be awarded are currently under discussion.

3 service contracts have been signed: Development support for sustainable rural and renewable energy (€ 0.5 million); agricultural biomass resource assessment (€0.6 million); off-shore wind energy assessment and feasibility study of off-shore wind farm development in China (€0.7 million).

The programme uses two main instruments to identify partners for implementation activities: (1) Calls for tenders (public procedure) and (2) calls for proposals (public procedure / bidders identified by PMU). Amongst the two, NDRC is in favour of the latter, which still needs at least three bids that are in compliance with the bidding document/TOR. It is generally acknowledged that it has been difficult to implement the project, the main reason being that the two bureaucracies have different rules that are difficult to harmonize.

Two new initiatives are under way:

1. EU is planning to set up an EU-China Institute for Clean and Renewable Energy (ICARE). The initiative would contribute to filling the gap between the growing demand for specialized clean and renewable energy experts and the limited offer of currently available skills and expertise in that area. The project will consist of a master's degree course, a research platform for post-graduate students and an exchange of researchers and energy professionals. European professors from three or four European universities will be selected to join the ICARE project, which will include subjects such as wind power, solar, and bio fuel. The first renewable energy master's degree is likely to start in September 2009. The EU side will contribute 80 to RMB 100 million to the project, complemented by a financial or in-kind contribution from China. The Chinese counterpart university has not been selected as yet.
2. The EU-China Clean Energy Centre (ECEC), the second of the recent initiatives between China and the EU, is jointly supported by the EU and the National Development and Reform Commission. It aims to promote an increased use of clean energies through improved

access to European policy, regulatory framework, technology experiences and best practices.

It will become a partner for European stakeholders involved in Clean Energy-related projects in China and plans to deal with sustainable coal including carbon capture and storage and biofuels.

A consortium composed of European and Chinese non-profit organizations will be set up to establish and run the centre as a legally registered, non-profit entity in China. The EU Commission will contribute RMB 100 million to support the ECEC project within five years.

A feasibility study/programme mission has been undertaken, but the documents are not available.

Sources: Interview with EEP 4.6.2008; Zhang Qi. Masters at Work, China Daily, 2 June 2008; EU web sites

CASE 2: IVA-CAE exchange programme on renewable energy

Under the auspices of the Swedish Energy Agency (STEM), the Royal Swedish Academy of Engineering Sciences (IVA) established a research exchange with the Chinese Academy of Engineering (CAE) in 2004. Focusing on renewable energy, in particular bioenergy, this project is aimed at identifying mutual interest in R&D collaboration, for example coal-biomass blended combustion in industrial boilers to reduce CO_2 emission and improve the boiler's performance. Due to initial lack of information and mutual unfamiliarity, the project was designed initially to exchange information and to gain experiences through staff exchange programmes and a series of workshops.

Under the project, a number of exchange visits have been made between the two partners including short-term (1-3 months) staff exchange component (5-6 people from the Swedish side and around 10 from the Chinese side). It is difficult to assess the effectiveness as an evaluation has not been conducted. However, the Chinese partners seem satisfied with the results as they strongly believe the researchers will learn more though being involved in the daily research operation in a given foreign institute. Most of the researchers from the Chinese side are selected among a dozen of candidates, who have quality research skills and quick-learning capacity. CAE also believes that without such an in-depth understanding of each other's interest and research capacity, it is difficult to identify appropriate research topics, in which both sides are really interested and, moreover, could collaborate on a solid and long-term basis.

Although CAE is the representative partner from the Chinese side, it does not mean it will work on its own within China. CAE actually acts as a platform where researchers from other research institutes and universities are invited to join in the project. About a dozen members of CAE are involved in the project. Each of them has an excellent network in China. This has made it easier for the Swedish side to identify who is doing what in China in a given subject.

By the same token, researchers at Swedish universities are also invited every year to apply for a grant for contact and initial visits to Chinese research institutes within the framework of the exchange programme. This has consolidated the Swedish capacity on China's energy issues. The important role that Swedish researchers originally from China can play in this type of collaboration has been recognized.

In May 2007, a large Swedish environmental delegation visited China. Researchers from a number of Swedish universities and institutes took part in a workshop with their Chinese colleagues and visited several research centres in Beijing and Zhejiang. In mid-June a Chinese delegation travelled to Sweden for a conference on the theme "Environmental and Climate Change." The conference was arranged in conjunction with the International Green Energy Conference held at Mälardalen University in Västerås.

After a long period of exchanges only, there is evidence of some frustration on both sides. China is not clear about what they can get out of this type of programme and Sweden is also eager to move on to more substantial collaboration. Chinese researchers clearly expressed that China is at the stage of developing all forms of energy sources. The question is what Sweden can provide. Although bio-energy is a promising option, it does take time and effort from both sides to narrow down a couple of specific sensible research topics. On 15-20 June 2008, a CAE delegation was invited by IVA to visit Sweden in order to identify areas and topics in which substantial collaboration on R&D could be carried out in the years to come.

In addition, the Royal Academy of Sciences (KVA) sponsors about five to seven projects annually, but the grants cover only travel and accommodation costs, mainly on the basis of exchange with Chinese Academy of Sciences (CAS).

The combination of scientific reputation (*in casu* IVA's) and the good Nordic image, expressed through sincerity, frankness, and friendliness, makes the collaboration with Nordic countries attractive, despite the fact that the funding that the Swedish side can provide is rather small compared to the much larger amounts being involved when the big OECD countries like UK or the EU (Case 1) are involved.

Source: Authors' personal information.

CASE 3: Norwegian academic research with China in environment and energy

Excerpt from: Buan, I.F., 2008. Norwegian Actors in the Fields of Energy and Climate Change in China. *FNI Report 1/2008*. Oslo: Fridtjof Nansen Institute. http://www.fni.no/doc&pdf/FNI-R0108.pdf, accessed 24.9.2008, p.2.

"… what we see is that on the one hand, Norwegian actors do research in China on their own and that, on the other, scientific institutions and individual scientists from the two countries are involved in cooperative research partnerships. The research institutes presented here include important policy-informers such as CICERO, ECON, the University of Oslo's Centre for Interdisciplinary Environmental and Social Research (CIENS) and more. These are actors that have spent years establishing relationships with Chinese counterparts such as the Chinese Academy of Sciences (CAS) and the Chinese Academy of Social Sciences (CASS). CAS and CASS are important national academies belonging to the Chinese State Council, the chief administrative authority of the People's Republic.

In 2006, CIENS established the Sino-Norwegian Centre for Interdisciplinary Environmental Research (SINCIERE), which is cooperation with CAS and even has an office on the CAS campus. The Nansen-Zhu International Research Centre (NZC) is another notable example of Sino-Norwegian cooperation. Also at CAS, NZC is a joint venture between the Nansen Environmental and Remote Sensing Centre (NERSC), CAS and others. Yet another example, the consultancy ECON has entered into an agreement on cooperation on energy and environmental issues with the Counsellor's Office to the Chinese State Council. ECON will function as a think-tank for the Office on issues of energy, climate and environment, a position with real potential to influence outcomes.

Smaller cooperation activities also exist, with researcher from the two countries joining forces on research projects and contributing to each other's articles and books. Norwegian actors also increasingly hold expertise crucial to these relationships, such as knowledge of Chinese language and culture. They may seem abundant, but the existence of such cross-border, cross-cultural Sino-Norwegian relationships must not be taken for granted. Unlike twenty or as little as ten years ago, it is now increasingly obvious that the Chinese do not in any significant way need Norwegian funding in order to realize their projects. Rather, many admit that they are now in a position to pick and choose; indeed, quite a few of them have far too much to do already. It has become a matter of quality as well as quantity, because the financial aspects may not be the most crucial part anymore. This means that in order to continue the work that already exists as well as expand and develop it further, cooperation needs to be based both on good relationships and on project proposals being attractive to the Chinese."

CASE 4: KTH-China Energy Centre initiative

The teaming up of universities to strengthen research and teaching capability requires a solid common ground on which mutual interest in collaboration should be based and developed. KTH has been pursuing such an approach for some years. With a coordinating centre at KTH, a number of sub-centres and other partnerships have been established with Chinese universities. The aims are to:

- Send Swedish persons to China to become acquainted with the Chinese system and come back with the experience that can be of interest to KTH and Swedish companies
- Develop a functional structure at high level within KTH so that the China-links in the energy sector become highly visible on the KTH agenda
- Supply the KTH President and leadership with statistics related to KTH-China activities in energy and environmental technology
- Identify potential sources for the individual programmes as well as for the overall centre.

Nuclear energy was the initial area for KTH and Tsinghua University to look at, as Tsinghua, traditionally engaged in nuclear science and technology development, possesses a physical facility for nuclear experiments and runs it at an affordable cost. This is what KTH needs in order to sustain its nuclear knowledge updating.

Back in the 1950s, one of the best nuclear reactors for experiments in the world was set up at KTH. With the possibility of welcoming nuclear back in Sweden as a strategic energy source in the current climate friendly environment, Sweden (more specifically, lead nuclear scientists and engineers at KTH) needs to keep up with innovative nuclear technologies. China is an excellent place to go, since it is speeding up its nuclear energy capacity to secure enough energy in the future to fuel its continued GDP growth without escalating global warming by emission of GHGs from coal-fired power plants. Therefore, it is fair to say that the marriage between KTH and some of the strongest Chinese universities is a potential win-win strategy for both sides.

Indeed, KTH has gone much further than nuclear in China with its sub-centres and other partnerships. A quite broad spectrum of scientific collaboration, mostly financed by external funds, is being carried out, while more new ideas are being explored. These are examples of such collaboration:

- *EU-China Campus for Energy and Environment (EEC)*

The EC Programme is an Asia-Link project, "An EU-China Campus for Energy and Environment". It has two partners from KTH (Department of Physics and Department of Chemical Engineering), two partners from China (Tsinghua University and Harbin Engineering University), and one partner from Italy (Politecnico di Torino). The kick-off meeting was held at KTH on January 16 -17, 2006. The main objective o the programme is to educate future talents and leaders with multi-cultural and multi-national backgrounds and competences in the fields of sustainable energy (hydrogen and fuel cells) and nuclear engineering. The target groups include: Master and PhD level students; young teachers, joint faculty members, and administrative staff.

- *Joint Research Centre of Clean Energy Programme (JRCCE)*

JRCCE was established by the Department of Energy Technology of KTH and the Institute for Thermal Power Engineering at Zhejiang University in China. The programme started by a kick-off meeting in Zhejiang in 2005. The programme comprises collaboration in research, undergraduate and graduate education in the area of clean and sustainable energy generation, including: co-supervising MSc thesis students (two students from each side every year); co-supervising PhD thesis students; organization of joint research projects; organization of joint courses, conferences, symposiums and other scientific meetings on subjects of common interest; exchange of teaching and research personnel; exchange of academic information and materials; exchange of summer training students.

- *Sino-Swedish Fuel Cell (FC) network (SSFC)*

The SSFC Programme was established in 2003. The programme comprises workshops and research collaboration, joint research proposals to various national funding agencies in Sweden and China, EC FP, and EC-China programmes, and, finally, undergraduate and graduate education in the area of fuel cells and hydrogen energy. Two of workshops under the programme have delivered ISBN numbered formal publication proceedings. The network has involved 20 Swedish and Chinese universities, institutes and industries/companies. Based on the successful Sino-Swedish FC network, an EC-China NANOCOFC (nano-composites and low temperature solid oxide fuel cells) network involving 8 European partners from 7 countries throughout Europe, one United Nations partner, and 4 Chinese partners have joined forces in an on-going project financed by the EC.

- *Enhancement of Research Capabilities on Multi-functional Nano-composites for Advanced Fuel Cell Technology through EU-Turkish-China Cooperation (NANOCOFC)*

The project aims to enhance research capacities on nanotechnology, multi-functional materials, and advanced applications. The project is based on existing Sino-Swedish IT/LTSOFC (intermediate and low temperature solid oxide fuel cell) cooperation and includes research institutions in the EU and Turkey as well. It aims at: networked research cooperation and joint activities; development of the centres' infrastructure and research or innovation strategies; exchange and sharing of personnel, information, resources and research methodologies; organizing seminars and EC-China NANOCOFC (nano-composite LTSOFCs) workshops; raising public participation and awareness; promoting the trans-technology and research achievements to industry and to establish new ways of production

The main centre at KTH serves as a hub for exchange and knowledge sharing between Sweden and China on innovative thinking. Professors and researchers from the centre are actively involved in inter-governmental cooperation by providing expertise on both China and energy technologies. Such a collaborative framework can be seen as a good example for inter-university collaboration, but less so if cooperation proves to be unsustainable. This is probably too early to comment on.

The integration of such a centre into the overall institutional setup and development strategy has helped stimulate cooperation within the KTH, thus allowing the knowledge brought and generated from the collaboration with Chinese colleagues to reach out on the campus in Sweden as well. With high-level KTH leaders being involved, it is helpful not only to increase the efficiency but also to enhance the visibility of the centre and its activities in both Sweden and China. As Sweden has pulled back its developmental support to China in almost all areas but environment-related issues, this collaborative centre can also serve as a think-tank for Swedish governmental agencies.

Thus far, the centre is receiving positive feedback from both governments and it is recognized by the EU that has funded a number of projects organized and implemented by the Centre.

It is worth emphasizing that this centre is collaborating with a number of Chinese universities, Tsinghua being one of them. Recently, an open call for Post-Doc candidates at KTH in nuclear energy engineering specifically made for applicants from Tsinghua University and Harbin Engineering University is another example of the means adopted to stimulate collaboration.

Sources: http://www.energy.kth.se/proj/Projects/KCEC/index.htm; personal contacts.

CASE 5: Danish University Centre in China

On 24.9.2008, the Danish Ministry of Science, Technology and Development announced an agreement with China to establish a Danish University Centre in Beijing. The aims of the Danish University Centre are: to make Danish research and education more visible in China; to intensify research collaboration between Denmark and China; to improve the opportunities for Danish students to study in China; and to increase the number of Chinese researchers and students recruited for studies in Denmark.

The University Centre will provide the framework for joint research and post-graduate education (Master and PhD levels). It will be established in 2009 and will be fully developed in 2013. It is expected to host 100 researchers and 300 students, of which half will be from Denmark. A new building will be built on the new campus of the Graduate University of CAS (GUCAS) 60 km. from the centre of Beijing.

The Centre will focus its activities in the following areas: biotechnology, health, and bio-medicine; nano-science and nano-technology; renewable energy, climate and environment; ICT; agriculture and food sciences; business management, social science research and learning; design and architecture. All the Danish universalities will be involved in the Centre.

Sources: VTU China strategy
http://videnskabsministeriet.dk/site/forside/nyheder/pressemeddelelser/2008/danmark-faar-universitetscentre-i-beijing (accessed 24.9.2008)

CASE 6: Danish-Chinese Wind Energy Development Programme (WED)

The WED is a 3-year development programme funded with DKK 45 million from Danish international development assistance funds. The Chinese side provides a contribution in kind. The MOU was signed in 2007. The programme has an exclusive focus on wind energy, and the main aim is to provide capacity development through technical assistance. Three government agencies have been appointed to execute the project: China Meteorological Administration (CMA), China Electric Power Research Institute (CEPRI), and China Hydropower Engineering Consulting Group Company (CHECC). The programme has four components of which two have elements of research:

1. CMA: Meso- and microscale modelling. This component is implemented through a twinning arrangement with RISØ in Denmark under the rules of the Danish Ministry of Finance regarding twinning. This means that both parties are supposed to benefit from collaboration and therefore certain rules can be waived, e.g. the size of the overhead. The idea of the component is to develop better models to assess wind resources so that decisions about where to place the wind parks and where to roll out the necessary infrastructure will be increasingly better informed.

   Both sides are supposed to develop their numerical models through their work. Through the project, the models are supposed to become more accurate and will be able to offer better analysis as compared to what is currently available in China. CMA and RISØ are supposed to appear with joint papers at two international conferences and publish joint articles in two international journals. They have set up a joint PMU. This is the only research based component under the project.

2. CEPRI: Grid code for wind turbines, grid absorption studies, grid connection study, and WindPro training. CEPRI is the research arm of the state grid corporation. The component covers six sub-projects. China issued provisional rules for grid connection in 2005. They are still considered preliminary and must be improved. The studies under this component are supposed to provide an empirical basis for the update. The projects are all running and are implemented by joint Sino-international partners (which are not necessarily Danish).

Three provinces have been appointed pilot areas: Liaoning, Jilin, and Heilongjiang.

The WED will be completed at the end of 2009. In the meantime the Danish government is preparing a new programme: "The Danish Renewable Energy Development (RED)" (Case 7). It took two years to make the WED programme operational due to different perceptions about goals, collaborative formats etc. The project is now doing what it was intended to do.

Source: Interview with WED Coordinator, 6.6.2008; Interview with S. Kristoffersen, BFT, Danish Ministry of Foreign Affairs 28.4.2008.

CASE 7: Danish Renewable Energy Programme (RED)

As a follow up to the Danish involvement with wind energy (see Case 6), a new and more substantial programme is being negotiated during the time of writing this report. According to current plans, RED will have two components:

Component 1: Institutional development of the Government of China's strategic planning institutions

The aim is to enhance the capacity in China to manage the renewable energy sector and the focus is on (1) the preparatory work needed before the Chinese Government makes a decision on the actual establishment of a national Renewable Energy Centre under the National Energy Agency and on (2) interventions in the renewable energy sub-sectors, excluding hydropower. Effectively, the component will also support the development of sub sector strategies for wind, biomass and solar energy. Further, the component will (3) support the preparation and establishment of an RE Information and Support Centre to provide sector-wide information and knowledge.

What remains to be done is a more detailed conceptualisation of the Renewable Energy Centre, its role and functions, its size, its budget, its mandate, and its responsibilities.

Component 2: Development and implementation of innovative renewable energy technologies

The aim is to exploit the large potential for renewable energy development in China by introducing new and innovative technologies through Danish-Chinese institutional and business partnerships. The component will support the transfer and development of innovative RE technologies through cooperation between research and development (R&D) institutes, universities and private sector enterprises in Denmark and China, primarily in the applied R&D part of the innovation chain. The expected outputs are market analysis of potential areas for Danish-Chinese R&D cooperation within RE and Danish-Chinese partnerships for RE technology innovation.

The National Energy Agency under NDRC will be the counterpart agency and the framework estimated budget will be around 100 mill. DKK from the Danish side. The Chinese contribution has yet to be quantified.

The RED will also look at how synergy can be created between the programme and relevant business initiatives, incl. the Danish B-2-B programme. This initiative is supposed to have a strong focus on poverty alleviation, i.e. a "Go-West" perspective. However, RED will attempt to gather key resource centres from all over China in a common effort.

The WED (Case 6) and RED programmes as well as the B-2-B business programme (Case 10) are funded under the Danish environmental allocation for China under the official Danish development assistance budget. The ambition of the RED programme is clearly to engage in both policy research and technological research. It seems clear that a part of the research will deal with framework conditions, but it must be expected that the programme can also test formats for R&D undertaken by partnerships between companies and research institutes.

Not surprisingly, the development of an effective Danish-Chinese platform for cooperation (this Case and Case 6) has been challenging due to the lack of experience in the field on both sides. But the authors of this study are of the opinion that Denmark's experience with working with the NDRC and the National Energy Agency could be an important resource for the development of a Nordic Framework Programme for R&D in relation to renewable energy. At the same time, the Danish platform inside the NDRC could be seen as a key resource for other Nordic stakeholders.

Denmark is also interested in exploiting synergy with the proposed EU Clean Energy Centre (Case 1) which will have some overlap with the Danish programme. There is a clear interest in discussing interfaces and avoid overlaps.

Interview with S. Kristoffersen, BFT, Danish Minsitry of Foreign Affairs 28.4.2008; Interview with M. Bregnbæk, BFT, Danish Minsitry of Foreign Affairs, 24.9.2008.

CASE 8: ECO-cities in China

To deal with the challenges of urbanization and the stress that it puts on the environment, a movement has started in China to build or develop eco-cities all over the country. It is estimated that 30-40 are on the way and that 500 will be developed within 15-20 years. At this stage, it is far from clear what a city needs to do to become an eco-city and there seem to be differing views between Chinese planners and authorities and their international advisers.[109]

The most prominent eco-city at this stage appears to be the "Sino-Singapore Tianjin Eco-city" which is being established on the basis of an agreement signed in 2007 between the Governments of the People's Republic of China (PRC) and the Republic of Singapore. The PRC and Singapore will

[109] Chinese Eco-Cities. *WorldChanging*, September 22, 2008. http://www.worldchanging.com/archives/008674.html, (accessed 1.10.208).

collaborate to share their expertise and experiences in the formulation of policies and programmes to create social harmony, to develop formats for sustainable urban planning, focusing on environmental protection and resource conservation, recycling, ecological infrastructure development, and use of renewable energy resources, and the reuse of wastewater. The Eco-city will be developed by a joint venture company formed by a Singapore Consortium, which is led by Keppel Corporation, and a PRC Consortium which comprises companies such as the Tianjin Binhai New Area Urban Infrastructure Construction Investment Co. Ltd, Tianjin TEDA Investment Holdings Co. Ltd, and the China Development Bank.[110] One of the aims of the eco-city is to stimulate and facilitate energy related R&D, directly through incorporating or collaboration with local high-tech business parks or indirectly through working with external R&D partners.

The Finnish FEEC (Case 10) has implemented an eco-city in Mentougou outside Beijing. The city is a tourist area that used to have heavily polluting industries. It has 190,000 inhabitants in the city proper and 17 surrounding villages. FEEC was involved with a feasibility and planning study for turning the city into an eco-city. FEEC worked with Mentougou S&T Department. The idea was to integrate projects relating to "green" buildings, renewable energy, eco-planning, and rehabilitation of polluted areas and of water resources. The project was financed by the local government. The chief planner on the Finnish side is now working with some Chinese and Finnish experts on projects regarding clean energy. The equipment to be procured for these projects should primarily be bought in China, but from any type of enterprise. Mentougou wants to be a model for the rest of China.

FEEC has also been active in soliciting projects and partnerships in relation to the China-Singapore eco-city in Tianjin and Finland will provide a small part of the design. Finland is also a technology partner of the project. According to the Finnish VTT representative in Beijing, many issues in Tianjin would have warranted research, but no Finnish research organizations have become involve until now.

Sources: http://www.tianjinecocity.gov.sg, accessed 10.9.2008; Case 10; Interview with Mr. Ning Liu, General Manager, Sino-Finland Huineng Science & Technology (Beijing) Co. Ltd., and VTT Representative in Beijing, 6.6.2008; "China, Singapore build eco-city in Tianjin". Xinhua News Agency, 8 May 2008.

CASE 9: Science parks in China

The example of Baoding City in Hebei Province south of Beijing demonstrates how a city can use high-tech and other types of business parks as well as international partners to pursue a low carbon agenda. The "Baoding National High and New technology Industrial Development Zone" was established by Baoding City in the early 1990s as a key National Science and Technology Industrial Park (STIP). It was set up under the auspices of MOST and with support from its "Torch" programme. The zone has a strong focus on renewable energy.

Since January 2008, the zone has been undertaking a low-carbon development initiative which is a pilot project in collaboration with the WWF.[111] This initiative is in alignment with Baoding's strategy for developing a renewable electricity industry with the goal of becoming China's "electricity valley", particularly by focusing on PV and wind power. The programme will assist Baoding in moving into a low-carbon development trajectory. In the opinion of its Director, the Baoding Zone is the only STIP that has multiple renewable electricity industries (primarily solar and wind), including China's first poly-silicon solar cell manufacturer (Tianwei Yingli Company) with a complete industrial chain that includes research, manufacturing, and application of PV and optoelectrics.

In relation to wind, a so-called Wind Power Industrial Park has been set up in the Baoding STIP. Three wind turbine manufacturers, Guodian United Power (Baoding) Co. Ltd., Huide Wind Power Equipment Co. Ltd., and Tianwei Wind Power Science and Technology Co. Ltd. are located there. In addition, Huiteng Wind Power Equipment Co. Ltd., specializing on blade manufacturing technologies, is also located in the Park. All in all, there are about 50 enterprises in the wind power industry

[110] Press release: Agreements to develop eco-city in China signed" (Singapore, Ministry of National Development, 18.11.2007 (http://www.mnd.gov.sg/Newsroom/newsreleases/2007/news181107.htm, accessed 11.9.2008).
[111] The initiative is supported by the WWF in UK, the Netherlands, Sweden, Norway, and Denmark (http://www.wwfchina.org/english/sub_loca.php?loca=1&sub=96accessed 11.9.2008).

chain in the wind park. According to the Director, the development of the Huide Wind Company is an example of how the Chinese energy power industry is catching up. Huide has imported wind turbine manufacturing technology from the German Flender Group Co. Ltd. and now produces 1 MW wind turbines (with 90% of the parts manufactured locally).

When it comes to R&D development on wind power, the Zone and its companies plan to operate three R&D Centres for wind power focusing on: 1) turbines; 2) control systems; 3) blades. The blade centre is already in place under the name of "Huayi Blade R&D Centre". It consists of one member from CAS and 18 other researchers with doctoral degrees. It is supported by an expert committee lead by Prof. He Dexin, President/Chief Engineer of the Chinese Wind Energy Association, and a consultation committee consisting of 15 members from CAS. The centre is jointly established by the Baoding Zone and the Institute of Engineering Thermo-physics of CAS. Currently, it focuses on blade manufacturing for 2 MW wind turbines. A prototype has already been produced and will soon be tested on a wind turbine. The centre covers all the aspects from basic theoretical research to prototype manufacturing, entirely based on "indigenous" knowledge and technology according to the Director of the Zone.

A Sino-Dutch Wind Technology Development Centre is being discussed by Baoding Development Zone, ECN, and the Institute of Engineering Thermo-physics of CAS. The Agreement of Intent has already been signed and the proposal will be submitted to the government of each side to seek financial support.

Finally, under the auspices of MOST, Kenuo Corporate from Baoding, which produces control systems, Huayi Blade R&D Centre, and Tianwei Wind Equipment (turbines) are developing a R&D programme on 3 a MW near-shore wind turbine manufacturing technology. It has also been planned to build three testing platforms/facilities for wind turbines, blades and control systems.

The interactions between the initiatives in the Zone and at the city level are numerous. In 2007, Baoding started a solar energy programme, a so called "Solar City", focusing on both manufacturing and application of PVs. Baoding has also been named the First Demo City of Solar Energy Comprehensive Utilization in China by MOST. According to the Baoding Zone Director, the first integrated PV 5-star hotel in the world was built in Baoding, intended to start generating surplus electricity for the grid on July 15, 2008. Its economic viability has not been fully documented, as the application is still at the stage of technology demonstration rather than for actual economical operation. If this type of application is proven feasible, the aim is to reduce the manufacturing costs along with the scaling up of the application in buildings. With regard to electric power saving, Baoding has developed a number of innovative technologies reducing the power consumption in the high-voltage motor systems and cutting off the energy loss in the electric power distribution systems.

Baoding Development Zone has a strategic partnership with North China Electric Power University (see Appendix 4) and they have set up a number of collaborative projects. Finally, Baoding has set up a professional training school to provide technicians for the renewable energy industry in Baoding that has about 160 enterprises and 30,000 employees.

The Director of the Zone is also a high-tech entrepreneur himself. He started his career in the zone in 1992. He had a strong government background and set up Tianwei Yingli Company (solar energy) in the beginning of 2000 when energy supply was not really an issue. In June 2007, Yingli was listed on the New York Stock Exchange as YGE (Yingli Green Energy) Ltd.

Source: Interview with Director Ma Xuelu, Baoding National High and New technology Industrial Development Zone, 20 May 2008

CASE 10 - Commercial promotion and Nordic innovation centres in China

All of the Nordic countries have strong public commercial promotion teams in China. The authors interviewed commercial officers from Finland, Denmark, Sweden and Norway. Finland and Demark also have innovation centres that have been set up to facilitate bilateral collaboration between business and the R&D communities. Representatives of both of these were interviewed as well. Finally, a representative of Innovation Norway was interviewed.

In recent years, the commercial promotion offices have increasingly focused on environment, energy, and – most recently – business related to climate change. The innovation centres are following suit.

NORWAY

- Innovation Norway

Innovation Norway supports the companies that want to enter the Chinese market or that are already there through provision of services throughout the business development process, i.e. analysis, strategy, business planning, establishment, and expansion. Innovation Norway is part of the Norwegian Embassy. It has combined resources from the Commercial Section, the Design Council, the Tourist Council, and the Regional Development Bank. Its primary mandate is to promote Norwegian technologies.

There are not many Norwegian companies in China working on renewable energy, and, surprisingly, little is happening in the hydropower sector. There is a strong wish to promote activities in the energy sector, however, and Innovation Norway works closely with NEEC (see below).

Source: Interview with Innovation Norway, Beijing, 21.5.2008.

- Norwegian Energy and Environment Consortium (NEEC)
NEEC has been created to use Norway's energy and environmental capacities to promote a sustainable future for China and, as a consequence, the rest of the world. Through combining Norwegian energy and environmental competences, NEEC wants to turn the challenges in the Chinese energy, environmental and building sector into an opportunity for Norwegian companies. They will be able to provide solutions through business partnerships and by identifying feasible funding mechanisms for the benefit of both countries by promoting existing Norwegian technologies and competence. As with other similar Nordic initiatives, the idea is to line Norwegian companies up behind a set of joint promotion activities and to provide tools that will help the companies operate in the Chinese market. Key services are workshops, seminars, and matchmaking events both in Norway and China.

Sources: http://www.neec.no/home.php, accessed 24.5.2008

SWEDEN

- Centre for Environmental Technology (CENTEC)

In order to increase the visibility of Swedish environmental policy and technology solutions in China, the Swedish government decided to finance CENTEC at the Swedish Embassy in Beijing through the Swedish International Development Agency (SIDA). CENTEC focuses on areas where Sweden and Swedish companies possess unique competence and where China is looking for solutions. This is specifically in areas such as urban development, climate emission reduction, industrial pollution control, energy efficiency, renewable energy, waste-water treatment, water-supply, air monitoring, waste management, chemical control, urban transports and consultancy services. CENTEC arranges high-level delegation visits in both directions, seminars and workshops on relevant themes, participates in exhibitions, identifies relevant demonstration projects and stitches together financial solutions. The budget for the three-year project phase is SEK 6 million. CENTEC is a resource to Swedish agencies and organizations as well as to businesses involved with environmental and technological co operations in China. CENTEC began operation on 1 September 2007.

CENTEC has a strong commercial focus and, until now, mainly on environment, although it has promoted a few initiatives in the energy sector. There has not been a focus on R&D in the activities until now.

Sources: Interview, 21.5.2008; http://www.swentec.se/upload/Nyheter/CENTEC_press%20release.pdf, accessed 18.5.2008

- Science Week and Science Centre

In November 2007, a Swedish Science Week was held in Beijing as the first of a series of activities to promote S&T cooperation between Sweden and China. The event had 200 participants from the Swedish side, including many rectors and scientists. This event was organized under the bilateral framework for S&T cooperation between Sweden and China. Energy, climate, and environment were the focus areas.

Sweden intends to set up a centre for collaboration in S&T in China, but the scope of centre etc. has not yet defined.

Source: Interview with Magnus Breidne, Counsellor Science andTechnology, Embassy of Sweden Science Office (ITPS), 19.5.2008.

FINLAND

- Finnish Environmental Cluster for China (FECC)

FECC was a project started in 2006 that aimed to build a network involving Finnish environmental businesses in the Chinese markets. The project was launched in June 2006 with the Finnish Ministry of Trade and Industry appointing a working party to investigate how to boost Finnish environmental and energy technology exports to China.

The project aimed at engaging companies, investors and public-sphere actors in co-operation to create an operating model that would support environmental business operations and that would be suitable for the Chinese operating environment.

The funding for the project comes mainly from the Finnish Funding Agency for Technology and Innovation (TEKES, see Case 12), SITRA and the Technology Industries of Finland, as well as the regional business development organisations Lakes (Lahti Regional Development Company), Jykes (Jyväskylä Regional Development Company) and Oulu Innovation.

FEEC now wants to organize technical exchange through creating a platform for the future. Effectively, FEEC primarily served to brand Finnish stakeholders, expertise, and technologies, and it did not result in many concrete projects.

Source: http://www.sitra.fi/en/Programmemes/CompletedProgrammemes/environment/projects/fecc/fecc.htm (accessed 20.5.2008).

- FinChi

FinChi is a business incubator established as a non-profit organization in 2003 in the Pudong area in Shanghai by the Ministry of Trade and Industry of Finland together with Finpro and TEKES (see Case 12). It is dedicated to supporting Finnish high-tech companies in entering and expanding their activities in China. FinChi provides a range of services, resources (e.g. labs), and office solutions. The innovation concept pursued by FinChi is supported by the Pudong local government. The strong local connections enable FinChi to promote networks and partnerships between Finnish high-tech companies and Chinese partners.

The community at the incubator is designed to foster a culture of innovation, wealth creation and lucrative business ventures. To date, FinChi has served more than 30 Finnish organizations ranging from government agencies to research institutes, from the traditional paper industry to venture capitalists. Apart from housing new entrants, a number of services are provided, such as legal services and marketing strategies. There is also a recruitment agency in FinChi that helps clients to identify suitable staff.

FinChi is the host of VTT and TEKES (Case 12).

Source: Delman and Madsen, 2007, p. 24.

DENMARK

- Green China

Green China is an initiative by the Danish Export Council to promote Danish energy companies already in China or planning to enter the market. The initiative will help companies make a strategy for China and do business in the market via three elements: (1) overview of the policies, laws, and regulations in China, (2) promotion of Danish companies via joint branding of Danish energy technologies/solutions, and (3) networking in six selected provinces in China (Beijing, Liaoning, Tianjin, Hubei or Shaanxi, Chongqing or Sichuan). Finally, the initiative will build a network among the participating Danish companies where they can share experiences. The initiative will develop a toolbox for the members of the programme to use when elaborating and implementing their business strategies in China.

- Danish B2B ENVIRONMENT PROGRAMMEME

The world-wide Danish Business-to-Business Environment (B2B ENV) programme has been made available in China from mid 2008. Through financial support, the B2B ENV Programme encourages companies in China and Denmark to establish environmental, long-term business partnerships. The overall objective of the programme is to contribute to reducing poverty by promoting economic growth and social development in China. B2B ENV focuses on transfer of know-how and technology from the Danish to the Chinese company and can support matchmaking, feasibility studies, and technical assistance and training in partnership projects. The types of environmental business partnerships that will be eligible for support are under definition.

- Danish innovation centre in Shanghai

In September 2007, a Danish Innovation Centre was established in Shanghai by the Export Council of Denmark under the Ministry of Foreign Affairs and the Danish Ministry for Science, Technology and Innovation. The innovation centre aims to strengthen Denmark's innovation and competitiveness by coupling Danish companies and knowledge institutions with leading innovation environments in China.

The innovation centre provides services to Danish companies, knowledge institutions, public bodies and interest organizations in their activities in China in the following areas: monitoring of innovation; establishment of an incubator facility; conducting technology searches; facilitating innovation partnering; acting as a so-called "Biz innovation review board"; providing venture capital; promoting investment in R&D and high-tech; branding Denmark.

The innovation centre is open to Danish companies and institutions wishing to do business with China. The financing of the centre is partly based on customers paying for the services and partly on government funding for non-commercial activities, e.g. university-to-university contacts.

Sources:
http://www.asien.um.dk/da/menu/MiljoEnergi/MiljoSamarbejdeKina/B2BEnvironmentProgrammeme/?WBCMODE=PresentationUnpublished, accessed 24.9.2008;
http://www.dtcchina.um.dk/en/menu/InfoAboutChina/Marketopportunities/News/generalnews/NewInnovationCentreInShanghai.htm, accessed 13.7.2007.

CASE 11: Corporate R&D Centres

It has been difficult to locate Nordic companies that have outsourced R&D in relation to renewable energy technologies to China. The first case below describes how Novozymes is engaged with R&D in relation to second generation biofuels. Grundfos, which is described in the second case, works with pump technology and not with renewable energy technologies. However, Grundfos works with energy efficiency issues and the company's operation in China is interesting as a case of how an R&D unit develops once it has been located in China.

Novozymes

The Novozymes Company produces enzymes for bio fuel production. The R&D Unit in Beijing has 60 people working in the laboratory. They are integrated into the global Novozymes R&D system, while they also carry out adaptation projects for the Chinese market. 7-8 % of the company's global research, covering all of the company's products and not only enzymes for biofuels, is conducted in Beijing.

Novozymes has an exclusive agreement for the Chinese market regarding second generation biofuels with the big Chinese company, COFCO. A pilot plant has been Located in Zhaodong, Heilongjiang Province, which can produce about 500 t/year. Novozymes is involved in the fermentation process, process optimization, and the scaling up of trial production to commercial scale. There is already a first generation ethanol plant in Zhaodong.

There has been a lot of interest for this project in China, but Novozymes has said no to other potential partners. The agreement with COFCO is to share IPR on normal commercial conditions and COFCO has accepted that.

Currently, Petro-China is active in both the national and the international market for first and second generation biofuels (e.g. through Henan Hengtian) but Novozymes does not have any plans at this stage with COFCO to go beyond the Chinese border.

Other Chinese organizations and companies and foreign companies are trying to set up projects for commercial scale production of second generation biofuels. At this stage, Novozymes estimates that it has an 8-9 year technological lead. The company has 100 people working on this in R&D worldwide. No other companies have invested the same resources in this field.

Novozymes is committed to commercializing enzymes for second generation biofuels within two years through proving both its technological and financial viability. It is estimated that this will not be possible for any of the competitors.

There is considerable interest in the Zhaodong plant and lots of Chinese scientists are invited there by various Chinese organizations to study the technology. Many scientists from around China claim that they can do the same, but they have to prove it. Novozymes has not seen anybody doing it as yet. However, Novozymes is fully aware that there is a lot of scientific capacity in the field all over the country. Chinese scientists are doing a lot of good basic research, but they are not as yet as strong on the application side when it comes to commercialization. However, new commercial players are emerging with a strong R&D capacity.

Novozymes sponsors some research in Chinese laboratories. If the research done is promising and if an agreement to share IPR is reached, then Novozymes can invest in research undertaken by Chinese research teams. About 6-7 such agreements are set up per year.

Many Chinese scientists take out Chinese patents only, and they are not aware that they should also take out international patents, which in itself is an expensive process. Novozymes encourages the Chinese scientists to take out the international patents and offers to help them do it. However, Novozymes want to make sure that the process is validated before the description of the process is ”leaked” through a patent description.

The main challenge in working with Chinese R&D teams is to build mutual trust. Novozymes is well known and respected in China which helps it a lot, but many Chinese scientists are still uncertain where collaboration with a foreign company will lead them and whether they will gain or lose from it.

Much of the work that Novozymes does with the universities is also meant to build networks and attract the interest of future staff. For example, Novozymes has just financed and conducted the 3rd Novozymes-Tsinghua Festival for Life Sciences with 8.000 students participating.

Source: Interview with R&D Director, Beijing, 23.5.2008.

Grundfos

Grundfos produces and sells high-quality pumps and pumping systems worldwide. 20% of all energy in the world is used by pumps and therefore energy is a major issue for Grundfos. The company has several manufacturing units in China but the one in Suzhou is the biggest, and it is expanding fast. There is also a plant (an acquisition) in nearby Wuxi. There are 250 employees in sales in China and the company is rapidly opening representative offices around China to test whether sales and service units should be established there. The annual turnover in China is about 1 billion RMB. The company’s vision for 2025 is to have 75,000 employees worldwide, up from 17,000 now, and probably about 10,000 in China.

The Grundfos R&D network is global and a node was established in Suzhou in 2006. The R&D unit was set up for a number of reasons: proximity to production, customers in a major growth market; competitor supervision; access to highly educated employees; support to project sales and extension of the value chain services; financial advantages. Now, the China Unit is the largest outside Denmark. In 2007, Grundfos had 500 R&D employees in Denmark and 150 globally. The figure will remain the same for Denmark in 2010, but there will be more than 250 worldwide. 35 worked in R&D in China in 2007 and the figure is expected to rise to 70 in 2008 and 160-200 in 2011.

The China R&D unit is working within Grundfos areas of core competences and contributes to the mother company's "Innovation Intent" on par with other R&D departments. It is also assigned projects like the other R&D units. Energy efficiency is high on the R&D agenda. The unit is interested in renewable energy, but does not work on it itself. Grundfos can provide sunk pumps that are driven by e.g. solar or wind. The energy producing units are bought from other companies (solar panels, small wind turbines), but these technologies are not a competitive solution for pumps in the current market environment. 4.4% of turnover was used on R&D in 2007. It is expected that the figure will be stable, 4-5%, in the years to come

When asked if there is a specific Chinese contribution to innovations, a special innovative gene, the R&D Manager responded that the Chinese employees are very innovative and have lots of ideas. For example, one suggested an "i-fluid" Innovation Forum where staff should come up with 100 new ideas for fluid pumps. They did that, and afterwards the ideas were reduced to 20 and then to five with a commercial potential. This a state-of-the-art approach to innovation. The Chinese staff are extremely keen on learning. They read a lot and are able to apply what they learn. Danes are more inclined to learn while doing, once they are employed. The Chinese staff knows the market well and can use their knowledge in the adaptation process. The R&D Unit also organizes "sandbox" projects where everybody is allowed to play. Any idea that comes up will be tested and it is required that staff should come out with more questions than they brought in. User driven design processes are also being explored increasingly.

Grundfos is working extensively with the Chinese universities to create networks, to recruit staff, and to undertake joint projects to test competencies. A tour to universities around the country will be a next step to cast the net wider. Plans are also underway to conduct a Grundfos Challenge (like in Denmark) where university teams compete on innovative projects.

At the R&D Unit of Danish Grundfos, IPR is not considered a major issue, but extra precautions have been taken to protect the proprietary knowledge of the company. Employment contracts are very specific on the issue and technical precautions are implemented so that proprietary knowledge cannot leave the organization unnoticed. Grundfos has also employed a patent-engineer to follow the state-of-the-art knowledge, to assist in implementing internal measures, and to supervise what is happening in China in general. Grundfos would be ready to take cases to court, if necessary. There have been a few cases of serious infringement as several Chinese companies copy Grundfos products, the logo, etc. Effectively, more than 50 companies are under supervision. In the opinion of Grundfos, however, the best way to handle copycats is always to be a step ahead through innovation. Copies of the products will always exist. The most important thing is to be careful to protect products and product concepts under development.

Source: Interview with R&D Manager, Grundfos R&D, China, 3 June 2008.

CASE 12: Public Finnish R&D organizations in China

TEKES is the Finnish Funding Agency for Technology and Innovation. In Shanghai, TEKES is based in the Finnish innovation centre/incubator, FINCHI, and the local counterpart agency is the Shanghai Science and Technology Commission. One of the programmes in China focuses on environmental and energy technologies. Until now, the programme has mainly been undertaking studies. The focus is on sustainable communities, e.g. energy sustainability. TEKES has signed a framework agreement with Tongji University in Shanghai and projects with Finnish partners are supposed to be rolled out very soon. The first project will focus on energy efficiency in the construction field. Tongji is supposed to join up with VTT (see below). It is a spin-off from an ongoing VTT initiative called: "Global eco-solutions".

One of the current priorities of TEKES is to support the initiatives of the FEEC – Finnish Environmental Cluster for China which focuses on the development of Eco-cities in China, a high priority for many local governments (see Case 7).

Most Finnish partners in the current portfolio of research projects are universities. TEKES seeks matching funding for these projects from China. It is possible to obtain, but it is also difficult as China has its own procedures and time schedules. Usually the period for calls is very short and it is never announced in advance when calls will be made. It is somewhat easier in Shanghai, though, due to long-standing collaboration. When forthcoming, Chinese funding is mostly for exchange, travel, conferences etc. There is no intention to make joint calls at this stage.

TEKES has a very successful programme in nano-technology. This project has a preparatory fund to provide seed money. If the preparatory activities are successful, it will lead to research projects. However, there is still some uncertainty about how China projects can be funded. Yet, MOST seems to be able to come up with 70% of counterpart funding.

Source: Interview with Finnish S&T Counsellor, Shanghai, 2.6.2008; websites.

VTT Technical Research Centre of Finland is a technology research complex that primarily works with clients to commercialize research. They work with strategic research, customer focused contract research and development of business processes, tailored product development, consulting-testing-certification services, and licensing of existing patents. VTT has strong competences in wind energy for cold climates and in biomass and biofuels. All their projects require the involvement of commercial partners from the beginning. Often several companies from different stages of the R&D and business development process are involved. VTT can form a joint venture between Finnish and Chinese companies and with itself as a minor partner, normally by investing its technology. A good model has not been found for China as yet. VTT can also help elaborate contracts and also assist in dealing with the IPR issue

VTT provides technical support to Finnish companies in China and is intended to act as a facilitator of research collaboration between Finnish and Chinese research institutions and companies. VTT is also part of the FEEC - Finnish Environmental Cluster for China (Case 8). VTT involvement with energy in China is limited to its involvement in the Eco-city project (Case 7).

Both TEKES and VTT work on the basis of standard international contracts that have clear provisions regarding confidentiality and protection of proprietary knowledge.

Source: Interview with Chief Research Scientist, Managing Director of VTT China, 2.6.2008; websites.

CASE 13: The World Bank

It is nearly impossible to make *a* WB case on Chinese energy, given both the scale of investment and the long, now declining contribution, in monetary terms, to development in China, including the energy sector. The WB has to compete with other financial institutions to lend to China. In this context, the investment in energy infrastructure particularly coal-fired energy plants using clean coal technologies has become increasingly justifiable. Drawing upon the bank's strong technical expertise pool, the Bank has an excellent record and reputation in China, and the Bank is still an attractive partner for most Chinese institutions.

Traditionally, there are two lines of business that the Bank is involved in China, i.e. developing energy infrastructure and improving the capacity in energy policy making. Recently, carbon financing/trading is another area that the bank is trying to practise with China, although some issues regarding the mechanism need to be solved.

The Bank's overall goals for its energy programmes are to help China develop a reliable and sustainable energy system to support the – likely - continued rapid economic growth while at the same time addressing the whole range of energy-related environment issues. The near term goals include helping the Chinese government achieve its targeted 20 percent reduction in energy intensity by 2010.

The Bank's energy conservation programmes featured by projects with ESCOs in China have achieved significant success. In 2006 and 2007 alone, the ESCOs helped China save as much as the total energy consumption of France for the same period. Clearly, the mainstream of the bank's energy business in China is infrastructure investment, which is implemented on the basis of a development project model.

On the policy side, the Bank is actively involved in the process of building policy making capacity through a number of cooperation programmes. Obviously, to deal with the world's second largest energy consumer, the most effective leverage point is probably to get the energy policy right. The GEF, albeit heavily criticized for its operational inefficiency, is still the main means along which the Bank's directs its grants to China.

Just as an example, through the World Bank's "China Renewable Energy Scale Up Programme" (CRESP), which was kicked off by the end of 2005 and planned to last for 10-12 years and which is supported by NDRC, the WB and GEF wants to promote scaling up of renewable energy in China as a key contributor to the current renewable energy boom in China. The Chinese leaderships need to know the policy implications of different options in policy design and implementation. Such programmes feed their needs. Currently, the programme is providing support to the following areas:

- The main focus now is now on capacity building, and at the national level, the programme is focusing on energy policy studies in the following areas:
  - Providing support to the Government with regard to mid-to-long term planning by updating data for renewable energy sources, for example the distribution of resources and their use and application
  - Studying renewable energy power pricing and cost-sharing mechanisms
  - A renewable energy portfolio standard with Chinese features (applicable only for the five big electricity producers and three petroleum companies, see Table A.4.3)
  - Developing management schemes for renewable energy technologies, meaning who is doing and managing what and how?
  - How to support rural energy development by advancing renewable energy technologies in rural China
- Supporting NDRC in developing technological policies, fiscal policies and taxation instruments
- At the provincial level, providing assistance to elaboration of development plans for renewable energy at a provincial level
- Studying the mechanisms of tradable green electricity certificates
- Evaluation of the implementation of the Renewable Energy Law: in February 2008, a call for expressions of interests was made and consulting firms were to be selected
- Supporting the Ministry of Water Resource on developing methods for managing small-hydros
- Helping NDRC and Ministry of Finance to develop specific implementation regulations/rules under the Renewable Energy Law
- As for R&D in the wind sector, the programme supports technology transfer and the building of domestic manufacturing capacity up to 2-3 MW wind turbine; wind testing and certification are also areas that this programme is working on.

Source: Interview with CRESP programme, 22.5.2008.

CASE 14: Glitnir Bank and the geothermal project in Xianyang

Glitnir Bank is based in Iceland and has Iceland and Norway as its home markets. The bank is specialized in projects within seafood, renewable energy (hydro and geothermal), and offshore oil supplies, mainly vessels. The bank has a strong focus on geothermal energy projects in China, but not on hydro where China seems to be rather self-sufficient. The Chinese geothermal resources are described in Appendix 2.

Iceland is foremost in the world in using geothermal and has world class engineering and project development and management skills, which China is interested in. Glitnir's view is that it is "the best technology in the world". However, the technology is not an off-the-shelf commodity; it has to be adapted to the local environment every time, in particular the quality and nature of the geothermal resource. Glitnir only has a representative office in China. Therefore, it can only carry out investment projects and not normal banking.

Glitnir is involved in a major project in Xianyang City near Xian, where geothermal energy is used for heating. Icelandic ENEX-Kina *ehf* (comprising ENEX Iceland, Reykjavik Energy, and Glitnir Bank) and Shaanxi Geothermal Energy Development Corporation (CGCO), which is backed by SINOPEC (see Table A.4.3), are the owners of a joint-venture company, Shaanxi Greene Energy Geothermal Development Co., in the city of Xianyang, 25 km. from Xi'an, capital of Shaanxi Province. The Chinese partner owns 50.5% of the company and the Icelandic partner owns 49.5%. The company owns and operates the geothermal project in Xianyang which is now completed. It covers 170.000 m^2 of floor space which used be heated by coal. In the 2007/2008 heating season, the plan was to expand the district heating system to cover 1,000,000 m^2 and the ultimate goal is to expand the DH system to cover 15 million m^2. The project has the potential to become the largest of its kind in the world. The overall investment is expected to be around US$ 100 million.

The project has developed very fast and the technology and the project management approach is now being recognized across China since the area covered by geothermal now has reached a scale and viability that makes it interesting for other major cities.

Glitnir would support the idea of Nordic collaboration in China.

Source: Interview with Glitnir Bank, 2.6.2008, Shanghai.