Renewable Energy Development in China:

Policies, practices and performance

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Jingyi Han

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Preface

Four years ago when I touched upon the topic of renewable energy, it was already widely discussed in China. At that time, China – the biggest consumer of fossil fuels in the world – had established a series of policies and had carried out a considerable amount of demonstration projects to exploit the renewable energy resources within its territory. However, I did not expect it become such a hot topic as it is today. The concepts of “Green Energy” and “Low-Carbon Economy” are now involved within the conversations between politicians, researchers and the public everyday. Therefore, it is a golden opportunity for me to carry out my doctoral research on renewable energy development in China during the past four years. I tried to evaluate the performance of renewable energy development in China by applying the theories and methodology of policy evaluation in this research. This doctoral research could not cover all the aspects of the renewable energy development in China due to the limited time and experiences of research I had. But it is already cheerful for me to be one of the researchers who study the problem of renewable energy in China from a sociologist’s point of view.

This research has been carried out in the framework of the “Innovative Methodology for Governmental Environmental Audit in China” project, a collaborative research program between The Royal Netherlands Academy of Arts and Sciences (KNAW) in the Netherlands and Chinese Academy of Sciences (CAS) in China. I am sincerely grateful to the financial supports from both KNAW and CAS.

It is my great honor to be a student of Professor Arthur Mol, chair of Environmental Policy Group (ENP), Wageningen University, the Netherlands. He helped me open the window of Environmental Sociology. He gave me invaluable supervisions at every stage of my PhD program. This doctoral thesis can not come into being without his great enthusiasm and angelic patience during the past four years. The doctoral thesis is an important milestone of my research career and I will benefit from his supervision in the future.

I highly appreciate the supervision of Professor Yonglong Lu, head of the Environmental Policy and Management Group, Research Institute for Eco-Environmental Sciences (RCEES) in CAS, and the director of the Bureau of International Cooperation in CAS. He led me the way to the world of scientific research. He encouraged me when I was depressed. He enlightened me when I was confused. He helped me get the opportunity to study in Wageningen and gave me essential directions in designing and carrying out fieldworks. I have been his student for seven years since the beginning of my Master program. I wish I can be his student for the whole lifetime.

I own many thanks to Dr. Lei Zhang. She helped me through the most difficult stage designing the research. She commented on the research proposal, articles and all chapters of my doctoral thesis. She, like an elder sister, also took care of me in daily life. The delicious foods from her made my life in Wageningen much more joyful.

I am grateful to Nathan Johnson, who accompanied me on the fieldwork in Shandong Province. I also want to thank Mr. Li Sun, Ms. Min Xu, Mr. Yuping Dong, Mr. Zongming Li, Mr. Guangli Zhang, Mr. Shupeng Zhuang, Mr. Zhisheng Xia, Mr. Guoguo Zhang, and all the other people who helped me during my fieldworks.

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Many thanks go to all ENP colleagues and fellow PhD candidates. I learnt a lot from the courses, colloquiums and discussions with them. Special thanks go to Ms. Corry Rothuizen, who was always being there and helping me. I am particularly grateful to Drs. Sarah Stattman and Mr. Alexey Pristupa for their kindly helps on the Dutch translation and the arrangement of thesis defense.

I want to express my profound acknowledgement to my families for their support. I am in great debt to my wife Feiyue Yao, for her love, understanding and endurance over the years.

Hangzhou/Wageningen, October 2009

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Abbreviations

CDM	Clean Development Mechanism
CERs	Carbon Emission Reduction credits
COP	Conference of the Parties
EEA	European Environmental Agency
EIA	Environmental Impact Assessment
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
LPG	Liquefied Petroleum Gas
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NEC	National Energy Commission
NELG	National Energy Leading Group
NIMBY	Not-In-My-Backyard
NOC	National People's Congress
NREL	US National Renewable Energy Laboratory
OBM	Original Brand Manufacturer
ODM	Original Design Manufacturer
OEM	Original Equipment Manufacturer
PCDM	Programmatic Clean Development Mechanism
PPA	Power Purchasing Agreements
PV	Photovoltaic

SC	State Council
sce	Standard coal equivalent
SH	sunshine hour
SR	sunshine radiation
SWH	Solar Water Heater
UNESCO	United Nations Educational, Scientific and Cultural Organization
VAT	value-added tax
L	Liter
t	ton
Mt	10^6 ton
J	Joule
MJ	10^6 Joule
PJ	10^{15} Joule
W	Watt
MW	10^6 Watt
GW	10^9 Watt

Chapter 1 Introduction

"China's economy has a high energy intensity. The country uses 20-100 percent more energy than OECD countries for many industrial processes. Automobile standards lag behind European standards by ten years. And China has 20 of the world's 30 most polluted cities, largely due to high coal use and motorization."

– World Bank (2007)

1.1 Background Information

China is an economy in transition with a population exceeding 1.3 billion and economic growth over the past three decades averaging around 8%. China's demand for energy has surged to fuel its rapidly expanding industrial and commercial sectors as well as households experiencing rising living standards. During the last 30 years, not only aggregate but also average per capita energy consumption in China has increased sharply (Figure 1.1). China is now the second largest consumer of energy products in the world behind the United States (Chang et al., 2003; Crompton and Wu, 2005; Fan et al., 2005). According to the development objectives for China's national economy in 2050, the average annual growth rate of energy demand in China will be roughly 2.8% for the coming years (Wang and Lu, 2002). In other words, its energy demand in 2050 will reach 3.5 times that in 2005.

However, the production of conventional energy in China cannot significantly increase due to the limited reserves. By the end of 2007, in total 3.26×10^{11} t coal, 2.83×10^{9} t oil and 3.21×10^{12} m^3 natural gas of recoverable energy reserves had been proven in China. Their production lives were 129 years, 15 years and 46 years, respectively[1]. In addition, the energy efficiency of China is lower than that of the most advanced countries. World Bank (2008) revealed that China's energy consumption per unit of GDP in 2007 was 1.160 t sce per 10^4 yuan GDP, 4.5 times higher than that of EU, 3.8 times higher than that of Japan and 2.4 times higher than that of US. As a result, China became a net energy importer after 1992 and the gap between energy production and consumption has kept increasing since then (Figure 1.2).

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[1] Source: adapted from China Statistic Yearbook 2008.

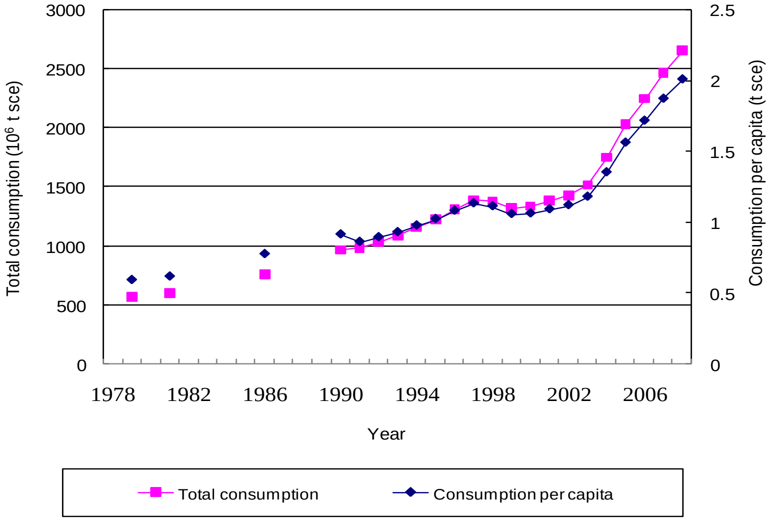

Figure 1.1 Total and per capita consumption of primary energy in China

Adapted from China Statistic Yearbook 2008

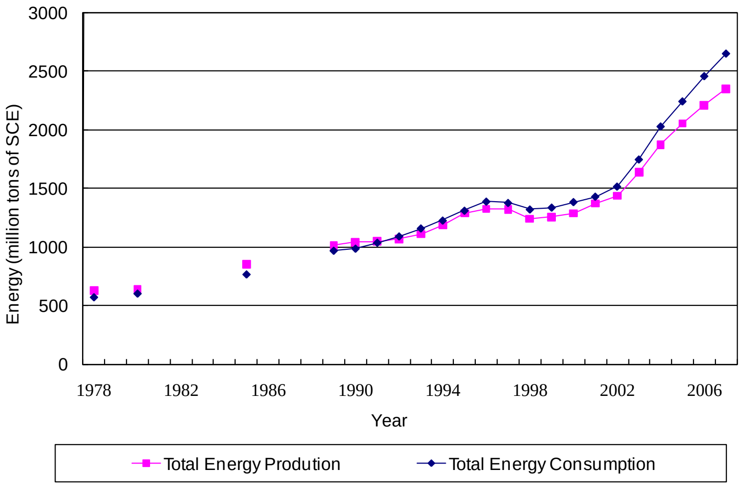

Figure 1.2 Energy production and consumption in China

Adapted from China Statistic Yearbook 2008

China is a so-called "fossil-fueled civilization" as its energy system demonstrates unsustainable patterns of development, characterized by heavy dependence on fossil fuels (International Energy Agency, 1999; Lewis, 2007). Coal and oil accounted for 89.2% of China's total primary energy consumption in 2007 (Figure 1.3). This energy consumption structure has a particularly acute impact on the atmosphere in China (Zhou, 1996; Chang et al., 2003; Smil, 2003). China has overtaken the United States as the world's biggest CO_2 emitter (Vidal and Adam, 2007). Most cities in China are suffering air pollution caused by SO_2 and NO_x emissions from fossil fuel combustion.

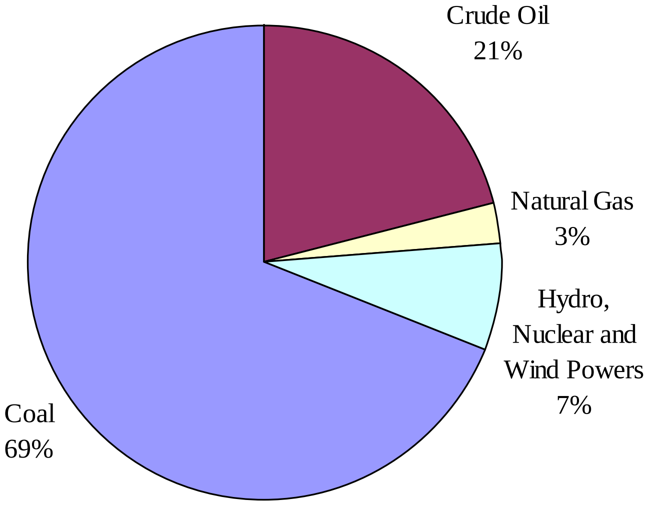

Figure 1.3 Structure of China's total primary energy consumption in 2007
Adapted from China Statistic Yearbook 2008

It is clear that China is now facing serious challenges as it attempts to meet the rising energy demand to fuel its economic growth, at the same time as it strives to reduce its reliance on coal and imported oil to relieve the environmental impacts. Previous researches suggested developing renewable energy resources as a sustainable solution to these challenges. Sorensen (2000) predicted the takeover of fossil and nuclear energy resources by renewable energy resources, due to the finiteness of fossil and nuclear energy resources. Janssen (2002) analyzed the contribution of renewable energy to energy security, environment, economic growth, employment, and trading technologies and services. Smil (2003) foresaw an extraordinary scale of transition from conventional fossil fuel to renewable energy resources in world energy consumption in the future.

Renewable energy refers to the energies that are generated from natural resources and can be replenished in a short period. Currently bioenergy, wind energy, solar energy and hydro energy are widely developed on large scales in the world (Box 1.1). Besides, there are also other renewable energy resources such as geothermal and ocean energy, which have great energy potential but have not been developed on a large scale. Utilization of renewable energy instead of fossil fuels can reduce carbon emissions and subsequently clean the air. It also provides benefits in energy security and economic development. Therefore, China aims to significantly increase the proportion of renewable energy in its domestic energy consumption: 10% by 2010 and 15% by 2020 (National Development and Reform Commission, 2007). Renewable energy is of particular importance for China in ensuring security of energy supply, transforming to a green economy and alleviating climate change effects.

1.2 Development of Renewable Energy in China

Development of renewable energy resources in China can be traced to the 1950s, shortly after the foundation of the People's Republic of China. From 1958 to 1960, in total 41 tidal power stations were built in coastal provinces such as Fujian, Guangdong and Zhejiang. In 1971 the photovoltaic (PV) panels were installed on Dongfanghong-2 Manmade Satellite[2]. However, pressures of energy shortage and energy related environmental pollution at that time were not as significant as they are today. Development of renewable energy in China remained at experiment level with immature technologies and limited scales for about 30 years (Chang et al., 2003).

[2] Source: China Renewable Energy Website: http://www.cres.org.cn/index.asp, retrieved on March 22, 2009

Box 1.1 Different types of renewable energy

- **Bioenergy** is produced by photosynthesis and stored in biomass, such as trees, crops, algae, as well as other organic wastes, in the form of chemical energy. Most biomass energy resources are burned directly for cooking and heating in rural areas of developing countries. However, it is technically feasible to transform biomass into electricity, solid fuel, liquid fuel and gaseous fuel by physical and chemical methods that create little buildup of greenhouse gases (GHGs) in the atmosphere. Therefore, biomass is regarded as one type of renewable energy if it is produced in such clean and sustainable ways.

- **Wind energy** is the kinetic energy that is present in moving air. Wind energy is widely used for power generation. It is a pollution-free, infinitely sustainable form of energy because it does not use fossil fuel, nor does it produce greenhouse gasses, or toxic waste. Modern wind power technologies can convert kinetic energy that is present in the wind into a more useful form – electric power.

- **Solar energy** is energy from the sun in the form of heat and light. This energy drives the climate and weather, and supports virtually all life on earth. Solar energy is the world's largest and most important energy resource. For thousands of years, human beings have used both heat and light directly from the sun for daily life. Modern technologies harness the sun's heat and light for more useful ends such as electricity and hydrogen generated by photocatalysis.

- **Hydro energy** is the force or energy of moving water. In ancient ages, hydro energy was used mainly for irrigation, transportation and operation of various machines, such as watermills, textile machines and sawmills. At the end of the 19th century, human beings started to use hydro energy for electricity generation (hydropower). Soon it became the most important renewable energy resource used for large-scale electricity generation.

China, following some advanced countries, started its nationwide development of renewable energy resources from the end of the 1970s and especially after the reform and opening-up in 1978. Rising concern of environmental protection[3] and the two oil crises in 1973 and 1979 stimulated China's determination to reduce its reliance on coal and imported oil. From 1978 to 2000, the Chinese government involved renewable energy development into its Five-year Plan and national laws such as the *China Electric Power Act* in 1995 and the *China Energy Saving Law* in 1998. As a result, renewable energy consumption in China increased steadily. About 7 million household biogas pools and more than 70,000 centralized biogas stations were constructed in China in this period. Two single crystalline silicon solar cell production lines were introduced in the mid 1980s. In 1989 China built its first grid-connected wind farm in Xinjiang (Zhou, 1996; Lew et al., 1998; Li, 2003).

From the beginning of the 21st century, the Chinese government used market incentives, in addition to command and control management and direct subsidies, to stimulate renewable energy production. The Chinese government started numerous renewable energy demonstration projects such as Integrated Rural Energy Development Program with Rural Economic Development, the China Brightness Program and the China Renewable Energy Scale-up Program. Activation of the *Renewable Energy Law* in 2006 provided legal authority and created a new era for renewable energy development in China. International cooperation via Clean Production Mechanism (CDM) transferred both financial and technical resources from developed countries to China. These policies and programs resulted in great development of renewable energy utilization, especially small hydro, wind power, solar thermal and bioenergy, in China (Figure 1.4).

In 2007 China invested 12 billion US dollar in renewable energy development, second only to Germany's 14 billion US dollar. In 2007 the amount of renewable energy utilization in China equaled to about 220 Mt sce, which accounted for 8.3% of China's total primary energy consumption (Howard and Wu, 2008). By the end of 2008, China had the largest small hydropower capacity (60 GW), the largest solar water heater installation (140 million m^2 collector areas), the third largest bio-ethanol production (1.9 billion L), and the fourth largest wind power generation capacity (12 GW) in the world. All these data prove the fact that China is going to overtake developed countries to be a leading producer and "a pioneer leading the way" in developing renewable energy resources (REN21, 2009).

[3] Labeled by the United Nations Conference on the Human Environment in 1972

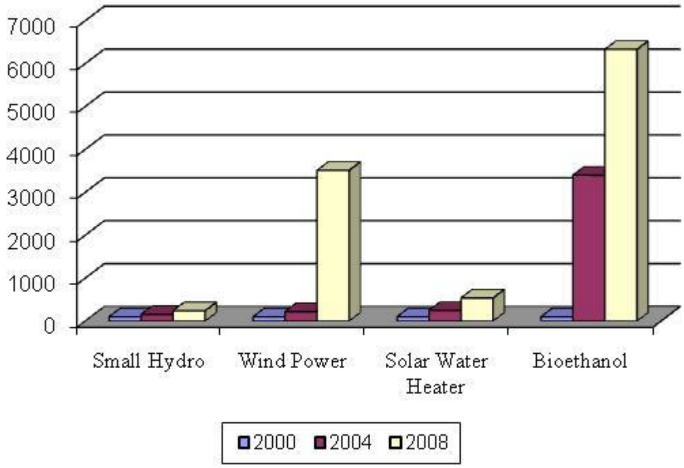

Figure 1.4 Development of renewable energy installed capacity in China

(the Year 2000=100)

Adapted from REN21 (2005; 2009)

1.3 Major Problems of Renewable Energy Development in China

Above discussion showed the tremendous efforts and great achievements of renewable energy development in China. However, there are still some widely discussed problems in relation to the implementation of renewable energy in China[4].

First, the policy stimulation is insufficient. Currently the costs for developing most renewable energy resources in China are much higher than conventional energies, which results in less competitiveness of renewable energy. Therefore, policy stimulation is a vital factor to improve renewable energy development in China. However, the renewable energy policy framework in China lacks stability and coordination. It can not provide sufficient stimulation for long-term development of renewable energy resources.

Second, the market mechanism is immature. In comparison with western countries, China has a relatively shorter history of its market economy. It is still under reform in several aspects. In relation to renewable energy development, there lacks a stable market

[4] Source: the *11th Five-Year Plan for Renewable Energy Development*

demand. The markets of most renewable energies are organized by the government.

Third, the technology R&D capability is weak. Except perhaps for hydropower and solar heating, the technological level of renewable energy production is much lower than western countries. Most technologies and key equipments are imported from other countries. The domestic system of production, quality assessment and labeling of renewable energy products falls short. In addition, China lacks experience with renewable energy resource investigation.

1.4 Research Objectives and Questions

As Barry (1999: 116) argued, "it is not terribly difficult to know what needs to be done, though it is of course immensely difficult to get the relevant actors (government and other) to do it". Against the ambitious development planning and fast technology R&D, China is surprisingly weak in monitoring and evaluating the performances of renewable energy policies, programs and projects. A rich literature has been introducing renewable energy resources, policy arrangement and technology innovation in China (Lew et al., 1998; Lin, 1998; National Energy Laboratory, 2004; Xiao et al., 2004; Li, 2005; Li et al., 2005). However, few researches on renewable energy policy implementation and performance have been conducted in China. The question whether the objectives of renewable energy development in China are reached in an efficient and effective way remains unanswered.

Against this background, the main objectives of this study are to evaluate the performance of renewable energy policies and practices in China. To be more specific, the following research questions will be answered through this study:

- Has the implementation of renewable energy policies and practices in China achieved good performance?
- What are the driving forces behind the successes/failures of renewable energy development in China?
- What reforms can be recommended for further renewable energy policies and practices in China?

1.5 Organization of Thesis

This thesis is organized in seven chapters. Chapter 1 has so far overviewed the incentives, history and status of renewable energy development in China. In addition, the research objectives and research questions have been introduced in this chapter. Chapter 2 estimates the total amount of renewable energy resources, and overviews the institutional structure and policy framework of renewable energy development in China. Chapter 3 develops an analytical framework for performance evaluation of renewable energy development in China. This analytical framework is built on theories and methodology of policy evaluation. In between the theoretical and empirical parts of this study, there is also a methodological section which clarifies the choice of case study research as the major research approach and elaborates the methods for data collection. Chapter 4, 5 and 6, in which the designed analytical framework is applied in three cases at different administrative levels with different renewable energy resources, constitute the empirical part of this study. Chapter 4 evaluates performance of biomass gasification projects in Shandong to learn lessons for rural bioenergy development in China. Chapter 5 assesses onshore grid-connected wind farms in Inner Mongolia to find out challenges behind this success story. In Chapter 6 an investigation on Solar Water Heater development in Zhejiang is carried out to indicate necessary policy revisions and market reforms for solar thermal utilization in China. Chapter 7 provides overall conclusions and recommendations for further renewable energy development and research in China.

Chapter 2 Renewable Energy in China: Resources, institutions and policies[5]

"By developing local sources of energy such as hydro, wind, solar, geothermal and modern biomass including liquid biofuels, countries can create diversified energy portfolios that are less vulnerable to wide price fluctuations."

-Beijing Declaration[6]

Abstract

China, the largest economy in transition, is making great efforts to increase the proportion of renewable energy in its total energy consumption to 15% by the year 2020. However, except for the ambitious development targets, the overall picture of renewable energy development in China is not much familiar to the external world. How much renewable energy resources does China have? Who have the authorities in developing these renewable energy resources? What policies have been formulated to support the development of these renewable energy resources? In this paper, the authors estimate the amount of various renewable energy resources in China by reorganizing and calculating secondary data, and analyze the institutional arrangement and policy framework of renewable energy development in China from their own point of view.

Keywords: China; Renewable energy; Overview

2.1 Introduction

China has the third largest territory (about 9.6 million km^2) and the largest population (above 1.3 billion) in the world. Its topography diversifies from mostly plateaus and mountains in the west to lower lands in the east. The climate of China also varies greatly from the north to the south. Due to its topographical and meteorological characteristics, China has plenty renewable energy resources.

[5] This chapter contains an article submitted to *China & World Economy* as Han J., A.P.J. Mol and Y. Lu. Renewable Energy in China: Resources, institutions and policies.

[6] The resulting documents of the Beijing International Renewable Energy Conference in 2005

In comparison with developed countries such as the United States, the Netherlands and Germany, the Chinese government has not yet carried out a systematic assessment of its total renewable energy resources and their spatial distribution. Only several fragments of this work have been done, e.g. the nation-wide solar energy investigation at the end of the 20^{th} century, or are just in process, e.g. the nation-wide investigation and assessment of agricultural residue resources started in January 2009, through government-supported research projects.

In order to increase renewable energy utilization in its total energy consumption, China has built up a regulatory framework of renewable energy development. China has reformed its institutions and established new governmental departments to manage renewable energy development. Meanwhile a series of renewable energy policies have been formulated in succession by the Chinese government since the end of the 1980s. The Chinese government also carried out a lot of demonstration programs to promote its renewable energy development during this period (Lew et al., 1998; Li, 2003; NREL, 2004; Fan et al., 2005).

This paper aims to estimate China's renewable energy resources and to overview China's regulatory framework in relation to renewable energy development. In doing so, we reorganize and calculate secondary data gained from statistical materials, governmental reports and documents, as well as scientific publications. We also interview governmental departments and research institutes in relation to renewable energy development in China.

2.2 Renewable Energy Resources in China

Since the definition of renewable energy is still under debate and there lacks a clear list of renewable energy resources, this paper does not aim to calculate the amount of all renewable energy resources reserved in China, but to estimate the potential of the main renewable energy resources with developed technologies to utilize. These renewable energies include bioenergy, wind energy, solar energy, hydro power, geothermal and ocean energy.

2.2.1 Bioenergy

Bioenergy is an important energy resource comparable to oil and coal in China. In 2000, bioenergy accounted for about 13% of total primary energy consumption in China. Its proportion within rural household energy consumption can be as high as 42% (Li et al., 2001). Currently most bioenergy resources produced in China are directly used in inefficient ways for cooking and heating.

Although no detailed investigation of biomass production has been successfully conducted in China, previous studies proved that China was abundant in biomass energy resources (Li et al., 1998; Li et al., 2001; Li and Hu, 2003). These studies estimated that the energy value of annual biomass production in China was about 600 Mt sce and could reach 800 to 1,000 Mt sce by 2020. There are five important types of bioenergy resource in China: agricultural residues, forestry residues, human and animal manure, municipal solid waste, and industrial wastewater. Annual production of each bioenergy resource is estimated as follow:

2.2.1.1 Agricultural residue resources

Agricultural residue refers to agricultural products' residue and processing wastes. Crop straw, rice husk, cornstalk and corncob are several good types of agricultural biomass for energy generation. Bridgwater (1999) made an experimental research of biomass production and stated that "production of crop residues is related to amounts of crop-products and rates of residues produced from crops". According to his research, the energy value of residue from a specific crop can be estimated by the following formula:

$$E=BR \times c=G \times r \times c$$

E means the available energy from a specific crop residue;
BR means the amount of crop residue;
G means the production of this crop;
r means the ratio of residue to production of this crop;
c means energy coefficient of crop residue.

Thus, we can estimate that in 2005 total production of agricultural residue in China was approximately 708.01 Mt and it could provided 353.26 Mt sce energy (Table 2.1)[7]. Although agricultural residue is also used as important animal feedstock, industrial material, and useful fertilizer in China, this estimation shows the great energy potential of agricultural residue in China. If all the wasted agricultural residues are used properly, it can provide families in rural areas with reliable energy resources.

Table 2.1 Estimation of crop residue production in China, 2005

	Rice	Wheat	Corn	Soy-bean	Tuber	Cotton	Peanut	Rape	Others
Area (10^6 ha)	28.85	22.79	26.36	12.90	9.50	5.06	4.66	7.28	N/A
Yield (kg/ha)	6,260	4,275	5,287	1,672	3,650	1,129	3,076	1,793	N/A
G (10^6 t)	180.60	97.43	139.37	21.57	34.68	5.71	14.34	13.05	12.29
r (kg/kg)	1	1	2	1.5	1	3	2	2	1
BR (10^6 t)	180.60	97.43	278.74	32.36	34.68	17.13	28.68	26.10	12.29
c (t sce/t)	0.43	0.50	0.53	0.54	0.49	0.54	0.53	0.54	0.50
E (10^6t sce)	77.66	48.72	147.73	17.47	16.99	9.25	15.20	14.09	6.15

N/A: data not available
Source: China Yearbook 2006

[7] Li et al. (2005) estimated that China's total agriculture residue generation in 2005 is 750.9 Mt, a little higher than the estimation made in this study mainly because they took different *r* values.

2.2.1.2 Forestry residue resources

Production of forestry residue in a specific region is even more difficult to estimate than that of agricultural biomass. According to studies conducted by the Food and Agricultural Organization of the United Nations (2006), only half of forestry products are used for industrial products at mills and manufacturing facilities. That is to say, another half, in the form of branches, barks, chips and sawdust, can be utilized for their energy value. Results of the Sixth National Forest Resource Survey showed that China had in total 800 to 1,000 Mt forest biomass available, of which 400 to 500 Mt can be used to provide about 200 Mt sce energy (Li et al., 2001; Li et al., 2005). With the rapid process of afforestation projects implementation in China, a much larger amount of forestry residue can be expected in the coming years.

Unlike agricultural residue, which is available in almost any rural area in China, production of forestry residue is much higher in several specific regions than the others (Figure 2.1). About 70% of China's total forestry residue resource is available in six provinces, while only 30% in the other 25 provinces. This spatial unbalance to some extent decreases unit cost and increases the possibility to utilize forestry residue in large scale[8].

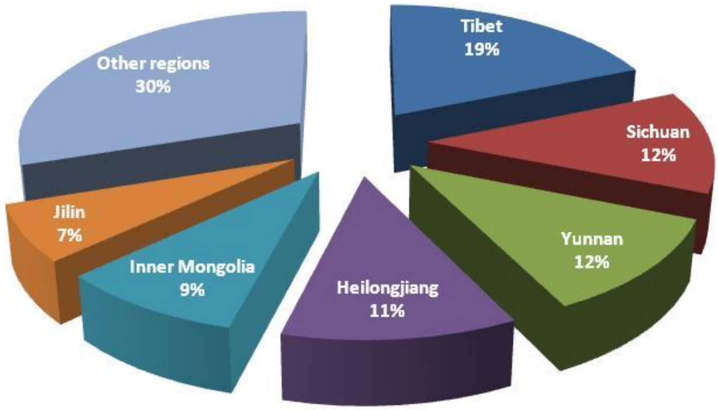

Figure 2.1 Distribution of forestry residue availability in China, 2005

Source: adapted from China Yearbook 2006

[8] It is mainly because the cost of biomass collection and transportation will be sharply reduced since large amount of forestry residue is produced in a small region.

2.2.1.3 Human and animal manure

Human and animal manure refers to excrement of human and animals that is available for energy value. In this study, only manure of human, cattle, pig and chicken are estimated. The manure of other animals, such as sheep, horses and ducks, are ignored because they are too dispersed to collect.

The amount of manure per head per day depends on various factors such as body size, kind of feed, physiological state (lactating, growing, etc.), and level of nutrition (Wang et al., 1998). In order to estimate human and annual animal manure production in China, the formula developed by MOA/DOE Project expert team (1998) is used in this study:

$$E=\sum E_i=\sum n\cdot u\cdot f\cdot p\cdot v$$

Where, E is annual energy potential of human and animal manure in China; E_i is annual energy potential from manure of one specific animal/human (i = human, pig, cattle, chicken); n is number of animals/humans; u is the generation of manure per day per head of animal/human; f is the fraction recoverable, which represents the proportion of the manure that is recoverable for energy generation; p is the proportion of dry matter in manure; v is energy value of dry matter when it is converted into biogas.

By using the above formula, it is estimated that China's energy potential of human and animal manure in 2005 was 1,352.0 PJ, or 46.1 Mt sce (see Table 2.2)[9]. Within the four sources, pig and cattle manure have more energy potential than human and chicken manure. It is easy to understand if one notices that most Chinese families in rural areas raise livestock (although in small number) at home, and more and more large and medium-sized animal farms have been established in China (Li et al., 2005). As a result, the standing stock at the end of the year kept increasing during the last decade. Although the amount of animal manure per head per day has decreased due to improvement of feed in recent years, the total energy potential from animal manure generation increased from 1,102.5 PJ in 1997 (cf. Li et al., 2005) to 1,352.0 PJ in 2005.

[9] Li et al. (2005a) predicted that China's energy potential of animal manure was 1,598.5 PJ in 2005. It is mainly because the total amount of pig and cattle was overestimated.

Table 2.2 Energy potential from China's human and animal manure in 2005

	Human	Pig	Cattle	Chicken
Number (10^6 head)	1,307.6	503.3	141.6	8047.2
Unit generation (kg head^{-1} d^{-1})	0.6	2.0	20.0	0.1
Total generation (Mt)	286.4	367.4	1,033.7	293.7
Fraction recoverable	1.0	1.0	0.6	0.6
Proportion of dry matter (%)	13.0	20.0	18.0	20.0
Dry matter (Mt)	37.2	73.5	111.6	35.2
Energy value of dry matter (10^6 J kg^{-1})	4.2	6.3	4.2	7.5
Energy potential (PJ)	156.2	463.1	468.7	264.0

2.2.1.4 Municipal solid waste resources

Along with rapid economic development and urbanization, municipal solid waste is becoming a major environmental problem in China. Every day about 0.5 Mt foods, paper, plastics, fabric and other types of solid wastes are generated in China's cities. These wastes can be useful energy resources if they are properly disposed. In China, more than 80% of municipal solid wastes are disposed through landfill. For this reason, energy potential from municipal solid waste is calculated in the form of landfilling gas, which consists of methane and carbon dioxide. In 2005, in total 155.8 Mt municipal solid wastes were produced, and 82.4% of this waste was disposed through landfill. According to Li et al. (2005), disposing every t of municipal solid wastes can produce 25.6 m^3 landfill gas, and the energy value of landfill gas is 19.5 MJ per m^3. Therefore, it is estimated that total energy potential from municipal solid wastes in 2005 is 64.1 PJ, or 2.2 Mt sce.

2.2.1.5 Industrial wastewater resources

Industrial wastewater, especially black liquor[10], is another important bioenergy resource in China. The quality of wastewater (most importantly the concentration of organic matter) differs among various industrial sectors, which influences the energy potential of wastewater. In calculating energy potential, organic matters in wastewater are converted into amount of CH_4 available (Table 2.3). We use the same rates of wastewater production and CH_4 generation as Li et al. (2005) used in their study. Taking the energy value of CH_4 as 18.2 MJ per m^3, the total energy potential from industrial wastewater in 2005 is 457.5 PJ, or 15.6 Mt sce.

Table 2.3 Energy potential from China's industrial wastewater production in 2005

	Product output (Mt)	**Wastewater production** (m^3 t^{-1})	**CH_4 generation** (m^3 CH_4 /m^3 wastewater)	**Energy potential** (PJ)
Alcohol	3.90	15.00	22.23	23.70
Sugar	10.34	7.00	0.56	0.70
Beer	29.48	20.00	0.24	2.60
Yellow wine	2.20	15.00	4.44	2.70
Starch	4.20	20.00	12.42	19.00
Lemon acid	0.63	14.00	17.75	2.80
Yeast	0.08	125.00	10.66	1.90
Modern medicine	1.03	1,130.00	7.34	155.50
Traditional medicine	1.46	396.00	0.06	0.60
Monosodium glutamate	1.35	25.00	22.27	13.70
Fiberboard	4.67	68.00	0.58	3.40
Slaughterhouse	77.43	16.00	0.81	18.30
Vegetable oils	16.83	0.10	6.66	0.20
Canned food	5.34	55.00	0.35	1.90
Pulp	30.96	119.00	3.14	210.50

[10] Wastewater discharged from papermaking industry.

Table 2.4 shows the total energy potential from different biomass sources and its distribution over different sources in 2005 in China. The total energy potential was about 617.16 Mt sce in 2005. Agricultural residue is the most important bioenergy resource in China, accounting for 57.24%. However, its energy potential is expected to shrink in the future due to the increased amount of biomass utilized for other purposes. Forestry residue (32.41%) is also an important and promising biomass energy source. Energy potential of human and animal manure accounts for 7.5% of total bioenergy potential and will rapidly increase due to expansion of large and medium-sized animal farms in China. Municipal solid waste (0.36%) plays a very limited role in total bioenergy potential in China, and is not suitable for large-scale bioenergy development. Industrial wastewater plays a moderate role, accounting for 2.49% of the total energy potential.

Table 2.4 Bioenergy potential in China in 2005

	Energy potential (Mt sce)	**Percentage** (%)
Agricultural residue	353.26	57.24
Forestry residue	200.00	32.41
Human and animal manure	46.10	7.50
Municipal solid waste	2.20	0.36
Industrial wastewater	15.60	2.49
Total	**617.16**	**100**

2.2.2 Wind energy

With its large land mass and long coastline, China is rich in wind energy resource. Three national wind energy resource surveys have been conducted in China to establish an overall database of wind resources in China. The first two surveys were conducted by the China Meteorological Administration in the 1970s and the 1990s respectively. These two surveys collected meteorological data at an altitude of 10 m, while wind power rotors are normally installed at 50 m above the ground. Moreover, the number of meteorological stations for data collection in the western and northern parts of China, where wind energy resources are abundant, was too limited to get a reliable estimation. As a result, the actual amount of wind energy resources available for electricity generation throughout China remained unclear at that time. The third national wind resource survey was co-conducted by the China Meteorological Administration and provincial meteorological departments from 2004 to 2006. It collected 486,000 data from 2,384 meteorological stations. Results of this survey showed that onshore wind energy resource available for development was 253 GW at an altitude of 10 m, and more than 500 GW at an altitude of 50 m. China also has about 750 GW offshore wind energy resources available for development (Yang, 2004; Li et al., 2005; Li et al., 2007).

Wind energy resource in China has an important characteristic of spatial imbalance (Zhang, 2005; Ni, 2008). Inland areas with rich wind energy resource in China are located mainly in Inner Mongolia Plateau, some parts of Northeast China, the northern part of Xinjiang, the Qinghai-Tibetan Plateau, and the Hexi Corridor in Gansu (Figure 2.2). These areas account for about 25% of China's territory. In these areas, the average wind energy density ranges from 200 W/m^2 to more than 300 W/m^2. The annual hours of effective wind speed (3~20 m/s) in these areas exceed 4,000 h. China is also abundant in wind energy resource in its southeast coastal areas and islands in Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong and Hainan. The average wind energy density also exceeds 150 W/m^2 in these areas.

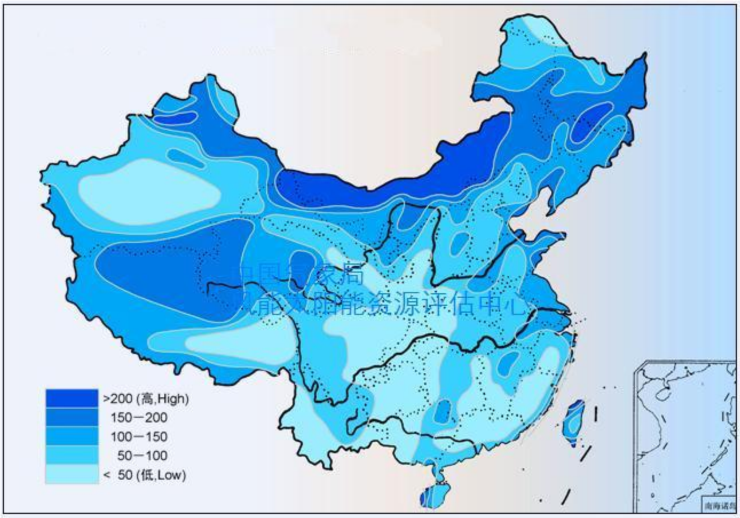

Figure 2.2 Average onshore wind energy density in China (W/m^2)

Source: http://cwera.cma.gov.cn

2.2.3 Solar energy

Total radiant energy density from the sun is about 3.75×10^{26} W. Within this tremendous amount of energy, only a very small proportion can reach the earth. It is estimated that the total amount of sun radiation reaching earth surface is about 1.7×10^{16} W. In other words, solar energy the earth surface received every year equals 35,000 times the whole world's annual energy consumption. China has great potential of solar energy resource. Two thirds of its territory receives over 2,200 hours of sunlight every year. On average, China has 5,852 MJ/m^2 of annual solar radiation with a maximum over 9,000 MJ/m^2 (Luo et al., 2005).

The amount of solar energy a specific area receives is influenced by six factors: height-angle of the sun (the bigger it is, the more solar energy received), air mass (the more it is, the less solar energy received), air transparency (the bigger it is, the more solar energy received), geographic latitude (the higher it is, the less solar energy received), sunshine hours (the more it is, the more solar energy received) and altitude (the higher it is, the more solar energy received). Spatial distribution of solar energy resource in China represents trends of north>south and west>east (Figure 2.3). The western part of Tibet, the western part of Qinghai, the southeastern part of Xinjiang, the northern part of Gansu, and the northern part of Ningxia are in the group with the most abundant solar energy resources. Especially the Qinghai-Tibet Plateau, with an average altitude over 4,000 m, thin, clean and transparent air, low geographic latitude, and annual sunshine hours over 3,000 h, is technically the most suitable region for developing solar energy in China. In comparison, Sichuan, Guizhou and Chongqing are among the areas with least solar energy resource in China (Luo et al., 2005).

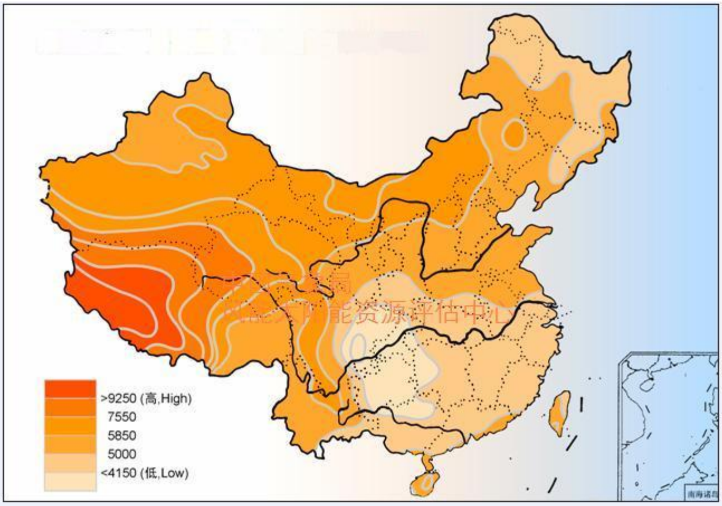

Figure 2.3 Distribution of solar energy potential in China (GJ/m²·yr)

Source: http://www.cnjlc.com/h2o/8/2007071812118.html

2.2.4 Hydropower

From 2001 to 2005, a nationwide survey of hydropower resource named "Reexamination of Hydro energy Resource in China" analyzed 3,886 large rivers (with theoretical installed capacity above 10 MW) in China (Figure 2.4). Results of this survey showed that national installed capacity of hydropower is 694 GW, ranking first place in the world. The technical annual power generation capacity is 5.42×10^{12} kWh. By the end of 2004, about 100 GW of installed capacity had been developed, which brought China an annual electricity production of 3.31×10^{11} kWh. Besides these large-scale hydropower resources, this survey also showed that China has plenty of rural small hydropower resources (< 50 MW), with a technical installed capacity of 128 GW.

Figure 2.4 Airscape of China's water system

Source: http://www.cnjlc.com/h2o/8/2007071812118.html

There are three important characteristics of hydropower resources in China.

First, hydropower resources in China show an imbalanced spatial distribution. In general, plenty of resources are available in undeveloped, southwestern areas, while limited resources are available in developed, eastern areas, where energy demand is relatively large. Sichuan (120 GW), Tibet (110 GW) and Yunnan (102 GW) are the top three provinces with most abundant hydropower resources in China. As a result, large amount of electricity generated from hydropower resources need to be transported from west to east.

Second, hydropower resources in China show a seasonal imbalance. Caused by the monsoon climate, the amount of precipitation and runoff varies largely among different seasons. About 70% of runoff in major rivers happens from July to October every year, while a minimum runoff happens in winter period. In order to utilize hydropower regularly in all seasons, it is crucial to build reservoirs to regulate runoff.

Third, most hydropower resource in China is distributed in large-scale rivers. Hydropower resources in Yangtze River Watershed (47%), Brahmaputra River Watershed (13%) and Yellow River Watershed (7%) account for about two thirds of the national installed capacity. This to some extent makes the large-scale hydroelectric power stations, e.g. the Three Gorges Hydro Power Station, more favorable than the small-scale ones in China. Currently, about 70% of hydropower in China is generated by power stations larger than 300 MW.

2.2.5 Other renewable energies

All the renewable energy resources discussed above are developed on a relatively large scale in China. There are several renewable energy resources, which have great energy potential but have not yet been developed on a large scale in China.

2.2.5.1 Geothermal

Geothermal is energy generated by heat stored beneath the earth's surface or the collection of heat absorbed in the atmosphere and oceans. Geothermal energy comes from high-temperature liquid matter in the interior of the earth, or from the disintegration of radioactive elements (U, TU and K^{40}). There are four types of geothermal resources available on earth: 1) heat water and vapor from the shallow interior of the earth; 2) high-pressure gases, consisting of large amount of methane, located in deep sedimentary basins; 3) Hot Dry Rock Geothermal Energy (HDR) from rocks just a few kilometers below the surface; and 4) magma fluid.

China has a great potential of geothermal energy. The total geothermal resource in China can reach 7,360,000 PJ and technically 973 PJ is available every year. Geothermal resources are distributed unevenly within China’s territory. High-temperature geothermal resources (> 150 °C) are located mainly in the southern part of Tibet, the western part of Yunnan Province and the western part of Sichuan Province (Taylor and Li, 1996).

2.2.5.2 Ocean energy

Ocean energy is generated due to sunlight radiation and the gravitation of sun and moon. It is stored by the movement of seawater. It is estimated by United Nations Educational, Scientific and Cultural Organization (UNESCO) that the total amount of ocean energy in the world is 76,600 GW, within which 6,400 GW can be harnessed (Takahashi and Trenka, 1995). Main forms of ocean energy include tidal energy, wave energy, ocean thermal energy, and salinity energy.

Tidal energy is formed by tidal currents or the rise and fall in sea levels due to the tides. Tidal energy is used mainly for electricity generation. Its working mechanism is quite similar to hydro electricity generation, while the energy density and efficiency are lower than that of hydropower. In general, the larger the tide range is, the more power can be generated in a given period. Theoretically, it is worth developing electricity generation where the average tide range is larger than 3 m. Total installed capacity of tidal energy in China is 21.8 GW, which can provide the country 6.24×10^{10} kWh electricity every year[11]. These tidal energy resources are located in the southeast coastal areas, where the average tide range is larger than 4 m. Total installed capacity of tidal power plants in Fujian and Zhejiang accounts for 88.3% of the national capacity.

Wave energy refers to the energy of ocean surface waves. The total energy potential of waves around the world's coastlines is estimated to be 2,000 – 3,000 GW. Wave energy is captured to do useful works including electricity generation, desalination, and the pumping of water. Wave power generation is not a widely employed technology, and no commercial wave farm has yet been established. It is estimated that the theoretical installed capacity of wave energy in China is 12.8 GW. This energy resource is distributed unevenly around China's coastal areas: 33% around Taiwan Island, 55% in Zhejiang, Guangdong, Fujian and Shandong, while only a small proportion in other areas.

Ocean thermal energy is formed due to the temperature difference that exists between deep and shallow waters. The ocean surface is continually heated by the sun, which causes temperature difference between deep and shallow waters. This temperature difference contains a vast amount of solar energy, which can potentially be harnessed for human use. The total energy available is one or two orders higher than other ocean energy options such as wave power, but the energy extraction is comparatively difficult and expensive, due to low thermal efficiency. China has a great magnitude, 1,321 – 1,476 GW, of ocean thermal energy, mostly in the South China Sea.

Salinity energy is the electronic energy difference between freshwater and saltwater, or between seawaters with different salt concentration. Salinity energy is normally abundant at the sea-river boundaries. This energy resource can be extracted by using the difference in vapor pressure above freshwater and saltwater, and using the difference in

[11] Source: website of New Energy in China: http://www.newenergy.org.cn/html/00310/20031112.html

swelling between freshwater and saltwater by organic polymers. However, the most promising method is the use of semi-permeable membranes. China has about 1.7×10^{12} m^3 of annual water flux into the sea, which brings the country about 125 GW of installed capacity. Salinity energy resources in China are characterized by spatial and seasonal unevenness. On the one hand, 70% of the resources are distributed at river entrances to the East Sea. On the other hand, 60% of the resources can be explored in flood seasons (normally 4 to 5 months).

2.3 Institutional Structure of Renewable Energy Development[12]

In China, renewable energy development is supervised by a complex of governmental departments. The National People's Congress (NPC) and the State Council (SC) provide general direction, guidance and the Chinese government's standpoint about development of renewable energy. The ministries and commissions under the SC take responsibilities of renewable energy resource assessment, policy formulation, market regulation, technology development and financial resource allocation. Some state-owned energy companies also have administrative power in the energy sector (Lew et al., 1998).

2.3.1 Central roles of the NPC and the SC

The NPC is the organization with the highest state power in China. Current NPC is composed of the Chairman, 13 Vice Chairmen, the Secretary-General, 9 Deputy Secretary-Generals, 161 members of the Standing Committee and 2,987 NPC deputies from the provincial People's Congresses. The NPC is the only organization who can amend the Constitution. It has the power to amend all basic laws, such as the *Criminal Law*, the *Environmental Protection Law* and the *Renewable Energy Law*. It has the power to elect, appoint and depose key members of central government, such as the President of the People's Republic of China, the Prime Minister of the SC and the Chairman of the Central Military Commission. It is also responsible to examine and approve plans for national development, central and local government budgets, and establishment of administrative regions. In developing renewable energy resources in China, the NPC is the top leader that issued the *Renewable Energy Law* in 2005, approved the *Medium and Long-Term Development Plan for Renewable Energy* in 2007 and the *Eleventh Five-Year Plan for New*

[12] Information in this section is partly adapted from China's central government website: http://www.gov.cn.

and Renewable Energy in 2008, and annual budgets on renewable energy basic research, technology R&D and demonstration projects.

The SC is the central government in China. Current SC is composed of the Prime Minister, four Vice Prime Minister, five Councilors, 22 Ministers of ministries, 5 Ministers of Commissions, the Auditor-General and the Secretary-General. The SC is the highest executive of state power, such as economic coordination, market supervision and administration, social administration and public services. In developing renewable energy resources in China, the SC and the ministries and commissions under the SC are the most important national level executives of renewable energy development laws, plans and projects. Functions of key ministries and commissions which have impact on renewable energy development will be discussed below.

2.3.2 Functions of ministries and commissions under the SC

The National Development and Reform Commission (NDRC, formerly State Planning Commission) under the SC has broad administrative and planning control over economic and social development, and the restructuring of the economic system in China. In developing renewable energy resources in China, the NDRC is the major actor in drawing up and organizing the implementation of strategies, mid-long term planning, and annual plans. It approves, evaluates and adjusts the implementation of renewable energy projects. It deals with and balances the relations between renewable development and other national economic activities. It studies and analyzes both domestic and overseas economic situations to give predictions and pre-cautions on financing, banking, investment and pricing of renewable energy utilization. It is also the coordinator of other ministries and commissions in developing renewable energy resources. Arguably, it is the most powerful ministry-level administrative organ in developing renewable energy resources in China.

Besides the NDRC, other ministries and commissions under the SC also have functions in developing renewable energy resources. The Ministry of Science and Technology (MOST) takes the major administration of renewable energy technology innovation and diffusion. The Ministry of Environmental Protection (MOEP, formerly State Environmental Protection Administration) is responsible for environmental protection and pollution treatment in developing renewable energy resources. The Ministry of Agriculture (MOA) gives supervision to utilization of rural renewable energy resources, especially agricultural biomass. The Ministry of Water Resources (MOWR) is mainly in charge of managing nationwide use of hydro energy resource. The Ministry of Finance (MOF) is responsible for the financial budget, state-owned assets, finance and accounting in developing renewable energy resources. The State Electricity Regulatory Commission (SERC) is responsible for the reform of China’s power sector and pricing of renewable energy fueled electricity. The State Forestry Administration (SFA) is in charge of developing and managing fuel wood and other wood energy resources. The Ministry of Land and Resources (MOLR), the Ministry of Commerce (MOC), the Ministry of Transportation (MOT) and the State-owned Assets Supervision and Administration Commission (SASAC) have also indirect influences on renewable energy development in China.

2.3.3 Administrative power of state-owned energy companies

In China most energy companies in oil industry, coal industry, hydropower industry, nuclear industry and power grid industry are state-owned. Within these state-owned energy companies, some large companies such as the China National Petroleum Corporation (CNPC), the China Petroleum & Chemical Corporation (SINOPEC), China National Offshore Oil Corp (CNOOC), the China Shenhua Energy Company Limited (CSEC) and the State Grid have ministry level administrative powers. On the one hand, they take responsibilities to fulfill government planned production quota and growth rate. On the other hand, they desire additional government support to become more competitive in the world market[13]. These companies have substantial influences on development and reform of the energy sector in China. Sinton et al. (2005) believed that the shift of power and resources from centralized planning agencies to state-owned energy companies characterized China’s transition from plan to market in energy sector.

However, also the high level administrative power of state-owned energy companies has negative impacts on renewable energy development in China. First, interests of state-owned energy companies diverge from that of the ministries such as MOEP and NDRC. They are reluctant to invest in renewable energy as long as it is not cost-effective. Second, involvement of state-owned energy companies can disperse the management of renewable energy development in China. It is difficult for energy regulators to prevent state-owned energy companies from exerting monopoly powers. Third, different state-owned companies

[13] For example the CNOOC received government support in their trial in the buyout of American Unocal Company in 2005.

stand for the benefits of their own energy industries, which results in struggle in policy making and resource allocation between these energy industries.

2.3.4 Integration of renewable energy management in China

As discussed above, the management functions on renewable energy development in China are dispersed over more than 10 national governmental departments and more state-owned energy companies. As a result, development of renewable energy is confronted with a lot of bureaucratic hassle in China. On the one hand, the renewable energy developers need to deal with numerous governmental departments when they are applying for and operating new projects. On the other hand, development of different renewable energy resources are supervised by different governmental departments, which causes conflicts between administrative stakeholders (Han et al., 2008). In the long term, this will lead to administrative inefficiency and unreasonable energy allocation of financial resource.

In order to deal with the problem of dispersed management in the energy sector, the National Energy Administration (NEA), a bureau attached to the NDRC, was established in 2008[14]. The NEA integrates functions on energy management of NDRC, the National Energy Leading Group (NELG)[15], the MOST and the administration of nuclear energy of the Commission of Science, Technology and Industry for National Defense (COSTIND). This significant institutional reform aimed at centralizing the management of energy sectors. The NEA is composed of nine departments with 112 staff. It is responsible for drafting energy development strategies, proposing reform advice, implementing management of energy sectors, putting forward policies for exploring new energy and carrying out international cooperation. The NEA is also influential in energy price management. It suggests the NDRC upon energy product prices and then submits it to the SC for approval. The NDRC consults the NEA on any price adjustment of energy products.

The establishment of the NEA to a certain extent reduces the negative impacts of the dispersed energy management and subsequently benefits the development of renewable energy utilization in China. However, there are still some problems when it is in operation. First, the NEA has only a deputy-ministry administrative status, which is lower than most

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[14] Source: *Plan on Reform of State Council Organs*, approved at the 1st Session of the 11th NPC on March 15, 2008. Available online: http://www.chinalawandpractice.com/Article/1926907/Search/Results/Plan-on-Reform-of-State-Council-Organs.html?Keywords=National+Energy+Commission accessed on May 29th, 2009.

[15] This is a deputy-ministry-level team established in 2005, aiming to research national energy development strategies and plans and to advise the SC on energy reservation, security and international cooperation. The NELG was dissolved after the establishment of the NEA.

nation level governmental departments in relation to renewable energy development and state-owned energy companies in China. Notably a high level authority named “the National Energy Commission (NEC)” was established at the same time with the NEA. The NEC was designed to be a deliberation and coordination authority, while work of the NEC General Office is undertaken by the NEA. Theoretically the NEC can help the NEA coordinate problems and relations that the latter can not deal with, while in practice one will wonder whether the NEC is not the same institution as the former NELG, with only a different name, and thus limits the NEA’s full authority. It is doubtful whether the NEA can fulfill its full functions under this circumstance. Second, one and a half year after its establishment, the NEA was found to have only the function of approving energy-related projects. It is far away from what this authority was expected to be, i.e. an integrated administration of the energy sector. Therefore, the establishment of a full scale Ministry of Energy (MOE) is advocated by more and more political experts (Zhou, 2003; Sinton et al., 2005; Zha, 2006; Kahn and Yardley, 2007).

Such an MOE is not something novel in China. The former MOE was established in 1988 in order to integrate the functions of the Ministry of Coal Industry (MOCI), the Ministry of Petroleum Industry (MOPI), the Ministry of Hydropower (MOH) and the Ministry of Nuclear Industry (MONI). However, the function of the MOE largely overlapped with the former State Planning Commission. State-owned energy companies also shared the function of governmental departments at that time. This new ministry was not accepted by the petroleum and nuclear energy sectors. As a result, the former MOE could not perform well and was dissolved in 1993. After that energy management in China was dispersed again in individual sectors.

The establishment of the NEA implicates that the Chinese government has realized the necessity of a high level authority with integrated energy management functions. The NEA is not a compromise between stakeholders but a step of gradual reform. A full-authority MOE can be expected to emerge in near future.

2.4 Policy Framework of Renewable Energy Development in China

Although the history of renewable energy development in China is short, the Chinese government has formulated and executed a series of policies and specific policy measures for the purpose of renewable energy development. In the *Sixth Five-Year Plan* (1981-1985), renewable energy technology was for the first time included into the *National Key Technologies R&D Program*, although the program allocated only 3 million yuan[16] to renewable energy technology R&D. From then on, renewable energy development started to gain more and more importance in the national development strategies. A series of policies were issued, covering a wide range of renewable energy resource management, renewable energy technology R&D, as well as its commercialization. These policy documents created a solid foundation and powerful support for the boom of renewable energy utilization. According to their main contents, these policies can be classified into general policies and specific policies, while the latter can be further classified into total volume objective, priority grid access, differential prices, cost allocation, special fund, low-interest credit loan, and favorable tax rate (Lew et al., 1998; Li and Wang, 2005).

2.4.1 General Policies

General policies mainly clarify the importance of renewable energy development. From the *Eighth Five-year Plan* (1991-1995) until the *Eleventh Five-year Plan* (2006-2010), China has given the development of renewable energy strategic importance in its long-term national developing plans. In the *China Electric Power Act* (1995), the first Chinese law that discusses energy policy, it was declared that the Chinese government “encourages the development and utilization of new and renewable energy resources”. This principle was reaffirmed in the *China Energy Saving Law* (1998), the *Medium and Long-Term Development Plan for Renewable Energy* (2007), and the *Eleventh Five-Year Plan for New and Renewable Energy* (2008). *China Renewable Energy Law* (2005) set developing renewable energy as priority in the national energy strategy, aiming to establish capacity and infrastructure for rapid renewable energy development, and to create sustained markets for renewable energy as well. It also emphasized that research and commercialization of

[16] Unit of Chinese currency, 10 yuan ≈ 1 Euro

renewable energy technologies were regarded as priority of modern technology and high-tech industry development at the national level.

General policies also clarify key areas of renewable energy development in China. In most policies mentioned above, biomass[17], small hydro, wind energy and solar energy are given priority in the long-term renewable energy development plan. For developing strategies, policy emphases are laid on three aspects:

- Expanding financial resources;
- Developing production capacity; and
- Establishing renewable energy markets.

2.4.2 Specific Policies

Besides these general policies, China also formulated specific policies focusing on mid- to long-term objectives, policy instruments and resource allocation of renewable energy development. These policies can be classified into seven categories: total volume objectives, priority grid access, differential prices, cost allocation, special funds, low-interest credit loans, and favorable tax rates.

2.4.2.1 Total volume objectives

Renewable energy is a new industry with relatively high costs, high risks and low profits, which reduce investment incentives of renewable energy developers. Therefore, it is difficult to promote renewable energy exploitation and utilization by simply depending on a market mechanism. Command-and-control policies from the national government are essential at an early stage of developing renewable energy resources. Total volume objectives, and portfolios in some fields, are most commonly used policy instruments by the Chinese government. Governmental supervision on total volume objectives directs total amount and proportion of renewable energy the country should develop during a certain period. It serves as market guarantee and steers investments in renewable energy development. The Chinese government defines its total volume objectives of renewable energy development in two ways: as proportion of renewable energy in total energy consumption and as quantitative objectives for individual renewable energy resources.

[17] Low-efficiency combustion of biomass is excluded.

In the *Eleventh Five-Year Plan for New and Renewable Energy* and the *Medium and Long-Term Development Plan for Renewable Energy*, NDRC set renewable energy development objectives of 10% in total energy consumption by 2010 and 15% by 2020. In the *Medium and Long-Term Development Plan for Renewable Energy*, NDRC also announced portfolio mandates in power generation sector. For the whole sector, the share of electricity generated from non-hydro renewable energy resources should reach 1% of total electricity generation by 2010 and 3% by 2020. For any power producer with installed capacity greater than 5 GW, the mandatory share is raised to 3% by 2010 and 8% by 2020. Proportion objectives are much easier for decision makers and the publics to understand. Setting proportion objectives of renewable energy in total energy consumption also makes it possible to carry out horizontal comparison (with other countries) and vertical comparison (with previous years in China).

However, there are two challenges in defining and implementing these proportion objectives. First, it is difficult to define provincial objectives. Although it is required in the *Renewable Energy Law* that the national administration "sets middle and long-term targets of the total volume for the development and utilization of renewable energy at the national level" and "on the basis of the target of total volume, as well as the economic development and actual situation of renewable energy resources of all provinces, autonomous regions and municipalities, cooperate with People's governments of provinces, autonomous regions and municipalities in establishing middle and long-term targets and release it to the public" (Article 7), in practice there is no satisfactory solution to decide the shares of development objectives, and more importantly financial resources, among provinces. Article 7 clarifies authority of provincial objective formulation without providing a feasible method to calculate disaggregated objectives. As a result, there is not any provincial objective up till now[18]. Second, proportion objectives have problems in defining development planning of individual renewable energy resources. China's renewable energy proportion objectives are accounted by proportion of all renewable energy resources in total primary energy consumption. It is not disaggregated into individual renewable energy resources. As separate authorities supervise the development of different renewable energy resources in China, there will be unavoidable conflicts in planning development strategies for individual renewable energy resources

[18] After browsing all provinces' energy development plans in China, the authors could not find any proportion objective of renewable energy development.

Considering the second challenge mentioned in the previous paragraph, the Chinese government also announced quantitative objectives for bioenergy, hydropower, wind power, solar energy, geothermal and tidal power in its *Medium and Long-Term Development Plan for Renewable Energy* (Table 2.5). Quantitative objectives are meaningful for financial resources allocation, market planning and stage evaluation. However, quantitative objectives for individual renewable energy resources in China also have big challenges in implementation. First, most quantitative objectives are set in installed capacity instead of actual amount of energy consumption. In practice, this has caused low efficiency in project management and facility operation (Shi, 2008). This problem creates great uncertainty to fulfill the national proportion objectives, even when the quantitative objectives are fulfilled. Second, quantified objectives are sluggish to respond to technology improvement and change in prospective energy consumption. Once the amounts have been decided, they are hard to change[19].

Table 2.5 Quantitative objectives for individual renewable energy resources

Energy resource	Utilization method	Objective in 2010	Objective in 2020
Biomass	Power generation	5.5 GW	30 GW
	Biomass briquette	1 Mt	50 Mt
	Methane	19×10^9 m^3	44×10^9 m^3
	Bio-ethanol	2 Mt	10 Mt
	Bio-diesel	0.2 Mt	2 Mt
Hydro	Large and mid hydro	120 GW	225 GW
	Small hydro	50 GW	75 GW
Wind power	Onshore	10 GW	30 GW
	Offshore	0.2 GW	1 GW
Solar energy	Power generation	0.3 GW	1.8 GW
	Water heater (collector)	150×10^6 m^2	300×10^6 m^2
Other	Geothermal	4 Mt sce	12 Mt sce
	Tide power	-	0.1 GW

[19] In the *11th Five-Year Renewable Energy Development Plan*, the Chinese government doubled its 2010 onshore wind power objective from 5 GW to 10 GW. This is the only example of quantitative objective adjustment.

2.4.2.2 Priority grid access

Electricity generated from renewable energy resources, such as wind energy, is not seasonally stable, which makes it unwelcome for grid companies. Therefore, obtaining priority in grid access is necessary for protecting and promoting the immature renewable electricity industry. In China, priority grid access policy is implemented mainly in wind power and biomass electricity sectors. For promoting wind power development, the former Ministry of Power issued *Opinions on Wind Power Farm Construction and Management* in l994, in which power grids were compelled to purchase all electricity generated by nearby wind farms. In the *Plans Regarding the Power Price Reform* issued by the General Office of the State Council in 2003, it was further clarified that wind power did not participate in market competition. All grid companies should purchase electricity generated from renewable energy at prices decided by the government or in bids. In the *Medium and Long-Term Development Plan for Renewable Energy*, the grid companies' compulsive purchase of wind power was reconfirmed, and petroleum selling enterprises were also compelled to purchase all bio-ethanol and bio-diesel produced in China.

2.4.2.3 Differential prices

Development costs of different renewable energy resources vary greatly. In order to develop diversified renewable energies, it is necessary to set different prices for different renewable energy resources to ensure the developers acceptable profit levels. It is allowed in the *Renewable Energy Law* that on-grid prices of renewable energy generated power differ among different energy resources and different regions. Currently, the average price of wind power is about 0.6 yuan/kWh, while the average price of small hydropower is between 0.20-0.35 yuan/kWh (Li and Wang, 2005). The pricing mechanism of renewable energy is more flexible than of conventional energy. Taking wind power for instance, the price mechanism works as follows: during the time that equals 30,000 hours of full capacity electricity generation, wind farms sell the produced electricity to the grid at the price pre-established in the original bid. After this initial period and until the end of the project period, electricity is sold at a uniform on-grid price. The *Medium and Long-Term Development Plan for Renewable Energy* emphasized that on-grid prices of renewable energy can be adjusted according to the development level of renewable energy technology.

2.4.2.4 Cost allocation

Currently the production costs of most renewable energy resources are much higher than that of traditional energies. In addition, geographical distribution of renewable energy resources is always uneven. It is impossible and unfair to make local enterprises and residents pay the additional cost of renewable energy development. Therefore, in China's policy documents these costs are allocated within the whole society, virtually to all end users. It is stated in the *Renewable Energy Law*, the *Medium and Long-Term Development Plan for Renewable Energy* and the *Opinions on Wind Power Farm Construction and Management* that if grid companies purchase renewable electricity at a price higher than the price of power generated from other sources, the price difference should be allocated within the whole power grid in the form of higher retail prices to the electricity end users. Additional costs caused by purchasing renewable electricity, such as constructing connection to the grid system, can also be compensated by higher retail prices.

2.4.2.5 Special fund

Insufficient funding is always an important barrier for developing renewable energies. If the cost allocation policy is a solution to the problem of high generation cost, then special fund policy is the most effective solution to the problem of lack of funding. In China, special funds for renewable energy development are set by both the national government and local government. The *Renewable Energy Law* and the *Medium and Long-Term Development Plan for Renewable Energy* require that the national fiscal system installs special funds, and that the local fiscal system allocates budget for supporting renewable energy development. The specific policy of special fund management in China, elaborated in the *Interim Measures on Special Fund Management for Development of Renewable Energy*, requires that special funds are mainly used for projects that are unprofitable and for public goods. Recipients of these funds should provide self-complementary funds of at least equal size to the special funds. This specific policy lists the following priority fields that the special funds should be spent on:

- Technology R&D, standard establishment and demonstration projects;
- Renewable energy projects for daily use in countryside and pastoral areas;
- Independent renewable electricity systems in remote areas and sea islands;

- Renewable energy resources prospect, assessment and information systems;
- Localization of equipments for renewable energy production and utilization.

2.4.2.6 Low-interest credit loans

Besides the special funds provided by national and local governments, low-interest credit loans from "policy banks"[20], such as China Development Bank and Agricultural Development Bank of China, is another important solution to the problem of lack of funding for renewable energy development. In l999, the NDRC and MOST issued the *Notice on Several Problems for Promoting Renewable Energy Development*, in which certain favorable policies for power generation by renewable energy were set forward, including bank loans with 2% interest subsidy. In 2006 the national government provided low-interest loans for projects that are listed in the *National Renewable Energy Industrial Development Guidance Catalogue*[21] and qualified for the credit conditions. The discount rate is offered for a period of 1-3 years, with the ceiling rate of 3%. The *Renewable Energy Law* also stated that "Financial institutions may offer preferential loans with financial interest subsidy to renewable energy development and utilization projects that are listed in the national renewable energy industrial development guidance catalogue and conform to the conditions for granting loans."

2.4.2.7 Favorable tax rates

A favorable tax rate is helpful in stimulating investments on renewable energy development because it expands the profit margin for investors. It is the major financial incentive applied in China today for renewable energy development. The *Renewable Energy Law* stated that "The Government grants tax benefits to projects listed in the renewable energy industrial development guidance catalogue, and specific methods are to be prepared by the State Council". In the *Medium and Long-Term Development Plan for Renewable Energy,* it is also emphasized that "The national government grants a favorable tax rate to renewable energy technology R&D and equipment manufacture".

There are three important favorable tax rate policies. The first one is favorable value-added tax (VAT) rate on several renewable energies. In China, the normal VAT rate for

[20] Not-for-profit banks that are founded, shared or secured by government. These banks serve for governmental policies or intents on macro-economic control by policy financing activities.
[21] Issued by NDRC in 2005

enterprises is 17%, while it is 13% for methane, 6% for small hydro and 8.5% for wind power developers. The second one is refund of custom tariffs. From January 2008, custom tariff imposed on imported materials and components for manufacturing wind turbines is refunded by tax exemption or rebate. The third one is reduction in income tax rate. For power plants using renewable energy resources, income tax is exempted during the first 5 years of operation. For all enterprises developing renewable energy resources, the income tax rate is 15%, which is lower than the income tax rate of normal enterprises (33%).

2.5 Conclusions

China has plenty of renewable energy resources within its territory. The estimation shows that the total potential of bioenergy was about 617.16 Mt sce in 2005. The wind energy resource available for development exceeds 1,250 GW. The average annual solar radiation in China is 5,852 MJ/m^2. China has also 694 GW installed capacity of hydropower and large amount of other renewable energy resources. However, renewable energy resources in China show great imbalance. A large quantity of renewable energy resources is available in remote and rural areas in Western China, while the areas with large energy demand are located in Eastern and Southeastern China. The amount of available wind and hydro energy resources varies also between seasons. It makes the production of renewable electricity fluctuating, which is an important reason why renewable electricity is not welcomed by power grid companies.

The development of renewable energy in China is co-supervised by various governmental departments. The NPC and SC take the key role while the responsibilities of management are shared by several ministries, the NDRC and some state-owned energy companies. This institutional arrangement functions in organizing renewable energy projects, regularizing the renewable energy market and dealing with all the other issues in relation to renewable energy development. However, the authority of renewable energy in China is dispersed among too many governmental departments. It should be centralized by the establishment of a Ministry of Energy full-authority of renewable energy development.

The Chinese government has set clear development targets of renewable energy and policy measures to achieve these targets. However, there are various problems and shortcomings with the policy framework if it is compared with the renewable energy policies in Western countries. First, China does not apply wind power feed-in tariff (a fixed price per unit of renewable electricity that a utility company or supplier has to pay for) that functions well in other countries. It results in major barriers in wind power development. Second, most policies focus on command-and-control or governmental subsidies. Insufficient efforts have been taken in stimulating the maturity of renewable energy market. Moreover, performance of these policies is highly uncertain. China lacks both actors and a methodology for systematically evaluating the implementation of renewable energy policies. This forms important motivation for future studies.

Chapter 3 Analyzing Renewable Energy Development in China: a framework

"There is no shortage of literature ... (which) tell the story of disciplines capable of collecting massive amounts of empirical data but lacking systematic methods for exploring the normative frameworks which give these data meaning."

- Fischer (1995: 1-2)

3.1 Introduction

This study aims to answer the questions how renewable energy resources have been developed in China and what are reasons for the successes/failures, and to provide policy recommendations based on the answers to these questions. In evaluating renewable energy development in China, the core task is to evaluate the implementation of various renewable energy policies and the driving forces behind it. Therefore, theories of policy evaluation are taken as the theoretical basis of this study. The main purpose of this chapter is then to establish an analytical framework, including both the theoretical part and the methodology, for policy evaluation of renewable energy development in China.

It is difficult to give a standard definition of policy evaluation, notwithstanding the fact that many definitions have been given in previous studies. For example, policy evaluation is defined as "an applied endeavor which uses multiple methods of inquiry and argument to produce and transform policy-relevant information that may be utilized in political settings to resolve public problems" (Dunn, 1990), or policy evaluation is seen as "a scientific analysis of a certain policy area, the policies of which are assessed for certain criteria, and on the basis of which recommendations are formulated" (Crabbé and Leroy, 2008: 1), or policy evaluation is "designed to supply information about complex social and economic problems and to assess the processes through which their resolution is pursued" (Fischer, 1995). Policy evaluation can focus on policy outcomes expected to be achieved from a policy (*ex ante* evaluation); is can focus on the actual outcomes from the implementation of a policy (*ex post* evaluation); or – more commonly – it has a focus in between the two (*ex nunc*).

The key elements of a policy evaluation strategy include the policy to be evaluated, the process of evaluation, the criteria for evaluation and the policy recommendations derived from it. The policy evaluation strategies differ between different understandings of policies. In this chapter the discussion on policy evaluation is built upon three different perspectives on policy: “policy as a control loop” (Section 3.2), “policy as a political interaction” (Section 3.3) and “policy as an institutional phenomenon” (Section 3.4). In Section 3.5, I discuss the characteristics of the evaluation of renewable energy development in China and define an analytical framework for such an evaluation, mainly based on the discussion of the three perspectives on policy. The research methodology is elaborated in Section 3.6. This section describes the general methodological design of this study, the main reasons for using mainly qualitative research methodologies and the logics of case sampling in this study. Subsequently, three cases are selected for empirical study. And finally the methods for data collection are determined.

3.2 Policy as a Control Loop

3.2.1 Definitions of policy and policy evaluation

In this perspective of policy as a control loop, policy is seen as a rational problem-solving process. Policy starts from a policy problem with a clear problem definition and consequent goal-setting, based on which different policy options are developed. One or a combination of these policy options are selected and implemented after the options have been compared and weighed against each other. In this view, policy is like a control loop. It resembles a fully scientific and operational process. When the policy problem appears, adequate policy options are assessed and implemented. If the problem has been solved, the policy process stops. Should the problem reappear, the policy process will be repeated.

Few policy scientists adhere to this view of public policy literally. Definitions of public policy from this point of view can only be traced in some early-stage policy research, such as *The Policy Orientation* (Lasswell, 1951: 71). Within this rational problem-solving process, on the one hand the motives and the nature of the parties involved are considered rational, and on the other hand and more importantly the policy strategies are sought on the basis of scientific methods. Therefore, policy evaluation in this perspective is a “goal-achievement model”, which assesses whether, or to what extent, the policy results are in line with the policy objectives (Schriven, 1991; Vedung, 1997). In achieving these purposes of policy evaluation, policies must be assessed by pursuing criteria of goal attainment only or mainly (*ex nunc* or *ex post*).

3.2.2 Policy evaluation strategies

3.2.2.1 EEA framework

There are numerous strategies to perform policy evaluation from this perspective. One representative strategy is the environmental policy evaluation framework developed by European Environmental Agency (EEA). EEA (2001) defined a number of key elements of the design and implementation of policy evaluation:

1) *needs*, of the society;
2) *objectives*, stage or ultimate targets of the policy;
3) *actors*, which include those implementing the policy instrument and target groups of the policy;
4) *inputs*, resources dedicated to designing and implementation of the policy;
5) *outputs*, the tangible results of policy measures;
6) *outcomes*, the response of target groups to policy outputs; and
7) *impacts*, ultimate effects of the policy on environment and human health.

Based on the above definitions of these key elements, EEA provided an evaluation framework for environmental policies, which focuses on policy effects and the related questions of effectiveness (Figure 3.1). In this framework, policy “effects” refers to the impacts of the evaluated policy on the outside world (in terms of policy outcomes and impacts) while policy “effectiveness” is defined as whether and how far the observed effects of a policy measure live up to the explicit objectives set for it. Assessing policy effectiveness is considered the central task of policy evaluation. Gysen et al. (2002) further define different types of policy effectiveness: *institutional effectiveness*, which means the extent “to which the output of the policy matches the objectives of the policy”; *target group effectiveness*, which means the degree “to which the outcome of the policy corresponds with the policy objectives”; *impact effectiveness*, which refers to the linkage between the impact of the policy and the policy objectives; and *societal effectiveness*, which indicates whether or not the impact of the policy satisfies societal needs.

The "goal attainment" policy evaluation is tempting because it provides a straightforward way to assess and optimize policies by simply compare the policy objectives and actual results after policy implementation. However, there are obvious problems with the "goal-attainment model": it does not consider the side effects of policy measures or the influences of other impact factors; and it has a difficult time estimating the influences of other factors that impact on outcomes. These problems imply the difference between "policy effectiveness" and "goal attainment". It prove constantly difficult to build the causal link between policy objectives and results, mainly because: 1) policy goals are sometimes too vague to measure; 2) a policy normally consists of multi measures, making it difficult to assess the effectiveness of a single measure; 3) the causal chains of a policy are too long, i.e. the policy process passes along many links and through numerous actors, to identify; and 4) side-effects are beyond the scope of goal attainment assessment. One option to move beyond some of these problems is to apply a "goal-free" evaluation.

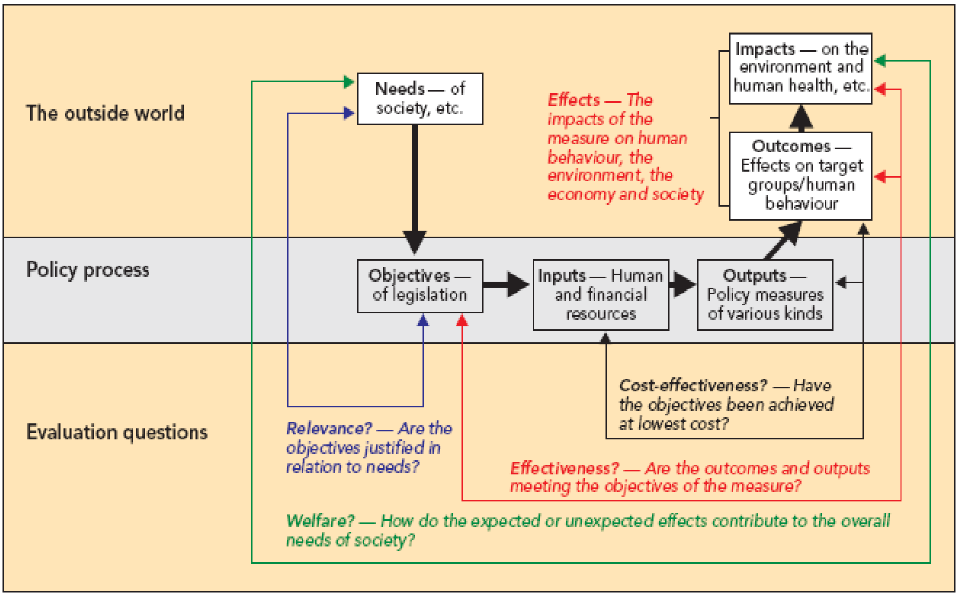

Figure 3.1 EEA Environmental Policy Evaluation Frameworks

Source: EEA, 2001

3.2.2.2 "Goal-free" model and intervention theory

Whereas the "goal attainment" evaluation starts from policy goals, a "goal-free" evaluation starts from policy results. Policy goals can either show up among the effects or they are irrelevant. Evaluators can even carry out the evaluation without knowing the policy objectives. This "goal-free" evaluation model addresses the side-effect critique of "goal attainment" evaluation without solving the problem of causal links.

The assumptions, based on which the causes of the policy problem are addressed, the solutions are pursued and hypotheses between policy and effect are made, are normally equivocal. In order to understand how policies are related to effects evaluators need to reconstruct policy theories, i.e. to make the assumptions underlying the relation between policy and effect more explicit. The *intervention theory* as suggested by Mickwitz (2002) is an example of such a reconstruction.

An *intervention theory* is a model of the causal path from policy intervention to ultimate outcomes. It is defined as "a specification of what must be done to achieve the desired goals, what other important impacts may also be anticipated and how these goals and impacts would be generated" (Chen, 1990; Rogers et al., 2000). Normally one intervention in relation to outcomes can be explained based on several intervention theories because different stakeholders hold different expectations on the same intervention. Intervention theories are not intended to describe how the intervention actually works, but to describe how the intervention is expected to function in a complex social setting. Therefore, intervention theories can perform an instrumental role in the process of evaluating public policies. First, they can be used to determine the anticipated effects of the evaluated policy and further to determine the data that need to be collected. Second, because intervention theories are built partly on scientific theories, they can be used to evaluate policy instruments based on scientific knowledge in situations that final effects of a policy cannot be identified due to long time periods or complex interdependencies.

3.3 Policy as a Political Interaction

3.3.1 Definitions of policy and policy evaluation

In this perspective, policy is seen as the product of interaction between various social and political actors, each with their own interests and power. The policy problem is dependent on how the various social and political actors push through their own issues and problem definitions. The policy goal is no longer purely the ambition to solve a problem, but rather a reflection of the power balance between the actors. The selection of policy options also involves negotiations and struggles between different actors.

There are numerous examples of policy definitions following this perspective: public policy is "whatever governments choose to do or not to" (Dye, 1984: 1); public policy "is, in its most general sense, the pattern of action that resolves conflicting claims or provides for cooperation" (Frohock, 1979: 11); public policy is "a set of interrelated decisions taken by a political actor or group of actors concerning the selection of goals and means of achieving them within a specific situation where these decisions should, in principle, be within the power of these actors to achieve" (Jenkins, 1978: 15). In this perspective, the strategies for policy evaluation are totally different from those in a "control loop" view of policy. A "goal attainment" evaluation is no longer sufficient.

3.3.2 Strategies of policy evaluation

3.3.2.1 Stakeholder-oriented evaluation

Stakeholder-oriented evaluation takes as its starting point neither the policy goals nor the final results, but the different "stakeholders" (not) involved in the policy making process. The term "stakeholder" refers to a person, group, organization, or system who affects or can be affected by a policy, program or activity and therefore has responsibilities towards it and an interest in its functioning (Hughes, 1998). Stakeholders were initially discussed in theories of organizational management and business ethics, to widen the conventional category of shareholders. Freeman (1984) argued that in addition to investors, employees, suppliers, and customers[22], other parties including governmental bodies, political groups, trade associations, trade unions, communities, associated corporations, prospective

[22] The conventional input-output model saw firms as converting investor, supplier, and employee inputs into customer outputs

employees, prospective customers, the public, and sometimes even competitors should be counted as stakeholders. Although the concept of stakeholders was criticized, for instance by Charles Blattberg (2004) for assuming that the interests of different stakeholders are negotiable, stakeholder have remained a strong concepts and a commonly discussed topic in policy sciences.

The major task of stakeholder-oriented evaluation is *stakeholder analysis*, that is, the process of identifying who can be impacted by or cause impacts on a policy, program or activity, and what these (potential) impacts are. Donaldson and Preston (1995) argued that the fundamental basis of stakeholder theory is normative and stakeholders can be identified by their "intrinstic interests". Mitchell et al. (1997) derived a typology of stakeholders based on the attributed power to influence, the legitimacy of each stakeholder's relationship with the organization, and the urgency of the stakeholder's claim on the organization. Guba and Lincoln (1981) identified three broad classes of stakeholders, each with subtypes:

1) The *agents*, those persons involved in formulating and implementing a policy, program or activity. These agents include:
    a) The policy makers;
    b) The local, regional and national funders;
    c) Local need assessors who identify the need that the policy, program or activity aims to improve or remove;
    d) Decision makers who determine to utilize or develop the policies locally;
    e) The providers of facilities, supplies and materials;
    f) The client for evaluating the policy, program or activity;
    g) The personnel engaged in implementing the policy, program or activity.
2) The *beneficiaries*, those persons profit from the implementation of the policy, program or activity. These beneficiaries include:
    a) The direct beneficiaries, the "target group", the persons for whom the policy, program or activity is designed;
    b) Indirect beneficiaries, persons whose relationship with the direct beneficiaries is mediated, eased, enhanced, or otherwise positively influenced;
    c) Persons who gain benefits by the fact that the policy, program or activity is in use.
3) The *victims*, those persons negatively affected by the implementation of the policy, program or activity. These victims include:

a) Groups systematically excluded from the use of the policy, program or activity;
b) Groups that suffer negative side effects from the use of the policy, program or activity;
c) Persons who are politically disadvantaged by the use of the policy, program or activity;
d) Persons who suffer opportunity costs for forgone opportunities as a result of the use of the policy, program or activity.

This policy evaluation strategy guides the evaluators to seek answers to questions "who are impacted by the evaluated policy or posing impacts on the implementation of the evaluated policy" and "how much are these impacts". Specific policy recommendations can also put forward partly based on the answers to these two questions.

Arguably, network analysis is a more advanced, theory-based and scientific methodology for analyzing the stakeholders around policies to be evaluated. In sociological research, a network means a social structure made of nodes (which are generally individuals or organizations) that are tied by one or more specific types of interdependency, such as resources, values, visions, ideas or financial exchanges (Wellman and Berkowitz, 1988)[23]. There are numerous network theories that operationalize network analysis. Most of them share many commonalities. I will elaborate on one example, which is relevant for the current research.

The *triad-network* model developed by Mol (1995) and elaborated by Koppen and Mol (2002) is an analytical framework suitable for analyzing actors and stakeholders around complex social problems in a systematic way (Figure 3.2)[24]. It can help to understand and analyze the institutions and actors constituting the policy, economic and social environment on the one hand, and the relations between the institutions and actors on the other hand. The triad-network model consists of three basic networks, viz. *policy network*, *economic network* and *societal network*. Each network constitutes a combination of a specific analytical perspective, distinctive institutional arrangements and a restricted number of interacting (collective) actors. The analytical distinction between these three networks relates to the way in which mechanisms of and perspectives on institutionalization, transformation and reproduction are conceptualized. In reality, the actors and institutions in

[23] The definition of "network" completely differs in transportation systems, electronic sciences and sociology. For the nature of this study, here I focus only on the network analysis in social sciences.
[24] Although the triad-network was designed in analysis of industrial ecosystems, it will be discussed in a broad sense of social sciences in this thesis.

the three networks closely interact (Koppen and Mol, 2002).

Actors and institutions involved in policy networks should be understood and analyzed primarily from a political-administrative perspective. In analyzing policy network of renewable energy development, four dimensions should be clarified: the rules of the game, the resources used in the network, the strategies between private actors and governmental authorities, and the so-called appreciative system. The ‘rules of the game’ are the guidelines according to which different actors behave towards each other and allocate their resources. The ‘resources’ used in policy network include legal resources, economic and financial resources, and informational and knowledge resources. Different ‘strategies’ between governmental actors and private members can be distinguished in policy networks: insulation (to keep government as far away as possible), penetration (of the private actors in the government or vice versa), mutual adaptation, and inter-organizational concentration (cooperation through mutual understanding of each other’s positions and interests). The ‘appreciative system’ concerns the ideological identity or worldview dominant in the policy network, promoting and legitimating specific action strategies within the network.

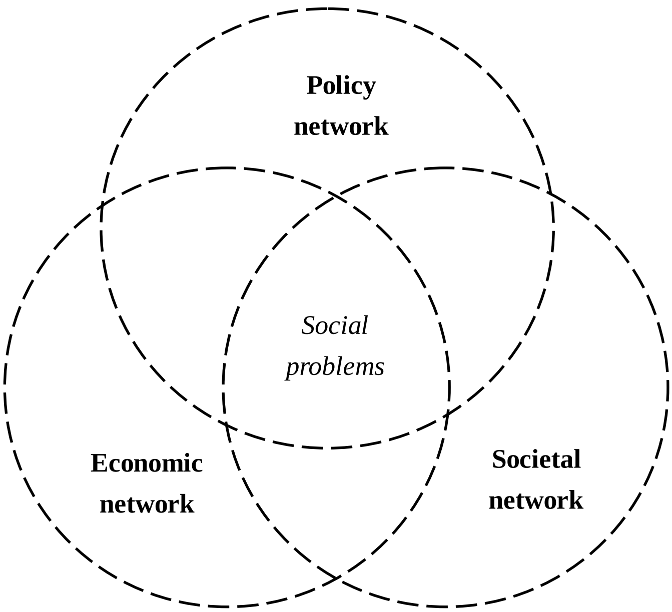

Figure 3.2 The triad-network model

Economic networks basically focus on understanding economic interactions via economic rules and transactions between primarily economic agents. In analyzing economic networks, the following relations should be studied: the relationships between economic agents in a product chain, from material providers till end users; the relationships between competitors in the same sector; the interactions between firms, other economic agents and research institutes; and relations and interactions in restricted geographical areas. It is especially economic and business theory that is helpful in further operationalizing economic network analysis.

Societal networks focus on local communities and social organizations in relation to problem complex. In analyzing societal networks, following aspects should be studied: the nature of the relations between these social organizations and other stakeholder; the impacts of the studied social issues on the process in which these relations are formed; the extent to which the existing relations in societal networks can improve or hinder development of the studied social issues.

3.3.2.3 "Value-pluralistic" and responsive evaluation

Values are understood as the beliefs and desires that individuals or agents hold, and based on which they judge what is good among alternative options and their proper behaviors (Lacey, 1999).

Traditionally, scientific research pursued an opinion of "value-free" investigation for centuries. To this end, "value-free" means: based on the assertion that values are shared by the whole society and that "objective facts" exist, *impartiality* on the one hand and *neutrality* on the other hand. *Impartiality* is a belief that certain theories and understandings are soundly accepted without needs of further investigation. *Neutrality* is the attitude that science itself is neither good nor bad, regardless of culture, race, or religion (Proctor, 1991; Lacey, 1999). The sharp demand for value-free sciences goes back to the days of, among others, Galileo Galilei and Francis Bacon (Drake, 1957; Bacon, 1960). Marx Weber had a controversial belief in "value-free" social science, in his distinction between the scientific-objective approach, which should be "value-free" and the political policy which can never be "value-free" (Ciaffa, 1998).

However, the idea of value-free science became increasingly challenged during the last decades. With respect to policy sciences Bahm (1971) argued that a researcher's "objective" willingness does not necessarily imply completely value-free research, and he tried to prove this by analyzing why values and obligations are inherent in scientific problems, scientific attitude and scientific methods. Krathwohl (1980) argued that evaluators make their own judgments, instead of automatically and deterministically following "scientific knowledge", as the only logic of evaluation. He also explored how to involve values into evaluation. Gray (1983) insisted that sociologists cannot analyze the consequences of social structure, forces, and change in a value-free context. Guba and Lincoln (1989) criticized value-free evaluations for being partial and vulnerable to specific interests of stakeholders, even if it uses "scientific" methodologies. They advocated the notion of value-pluralism and regarded it as an important part of a new generation of policy evaluation. Any policy evaluation is to some extent influenced by the social environment, personal and public interests, and the evaluator's values. This limitation of objectivity cannot be totally prevented but it can be understood. It is always helpful to recognize key stakeholders of a specific public policy and understand their opinions and values in order to judge pros and cons of the evaluated policies, rather than reaching judgments simply based on "true" or "right" criteria as was dominant in value-free assessments.

A representative approach that copes with the demand of value-pluralism in policy evaluation is the *responsive evaluation mode*. The term *responsive* evaluation was first proposed by Stake (1975). It refers to a focus in the evaluation on parameters and boundaries through an interactive, negotiated process that involves stakeholders. This interactive and negotiated process consumes a considerable portion of the time and resource available in policy evaluation. Responsive evaluation has three elements, viz. the *claims*, *concerns* and *issues* of the evaluated policy as identified by different stakeholders. A *claim* is any assertion that a stakeholder may introduce that is favorable to the evaluated policy. A *concern* is any assertion that a stakeholder may introduce that is unfavorable to the evaluated policy. An *issue* is any state of affairs about which reasonable persons may disagree. Different stakeholders hold different claims, concerns and issues.

Responsive evaluation has also consequences for the way a policy evaluation is implemented. Guba and Lincoln (1989) describe four steps of a responsive evaluation. First, stakeholders are identified and are solicited for those claims, concerns and issues that they may wish to introduce. Second, the claims, concerns and issues raised by each stakeholder are introduced to all other stakeholders for comments, refutation, agreement or any other reaction. Third, information is collected for those claims, concerns and issues that have not been resolved at the second step. Finally, negotiation among stakeholders, under the guidance of evaluators, is conducted to reach consensus on each disputed claim, concern and issue by using collected information. Of course, it is unnecessary and impossible to reach full consensus on each item among all stakeholders. The evaluator's judgment plays an important role in drawing conclusions on how to proceed on issues, claims and concerns that are not resolved through consensus in policy evaluation.

3.4 Policy as an Institutional Phenomenon

The third perspective on policy regards public policy as an institutional phenomenon. It does not focus on specific policy processes here and now, but on the policy field, i.e. the institutionalization of ideals, norms and opinions on the one hand, and practices and ways of going about things on the other hand. The contents and organization of policy are gradually fixed in specific patterns, common perceptions of the policy problem, in conceptions of the main mission and characteristics of the policy field, and in accepted views of who the principal players are, what the balance of power between these players is, and how they interact.

It is difficult to define or identify the institutional features of a policy field with theoretically constructed typologies. Policy scientists normally carry out an (international) comparison between two similar policy fields, a cross-sector comparison between two policy fields and/or a longitudinal comparison between a specific policy field a period ago and today to analyze and describe the characteristic institutionalization of a policy field.

Policy evaluation in this perspective then focuses on the institutional features of the policy field, and how it is stimulated and applied. It reveals structural causes of policy success or policy failure and seeks practical reasons for improving policy. The institutional dynamics of the policy field is another interest of the policy evaluation from an institutional perspective. It assesses how stable and lasting the institutional patterns are, how they are continually being reproduced and consolidated, and how resistant they are to change to tackle new policy problems[25].

In comparison with the perspectives of policy as a control loop and as a political interaction, the policy evaluation in an institutional view lacks a robust methodological basis. It is also less frequently tested in practice.

[25] For example, the environmental policy field is comparatively younger than others, and thus constantly challenged with new issues and developments, which in turn displays high institutional dynamics.

3.5 Evaluation Model for Renewable Energy Policy in China

The discussion above summarizes three different views of public policy. When renewable energy policy in China is considered, any of the three perspectives can be applied. Renewable energy policy in China can be assessed in the perspective of a control loop. The policy problem is then rather clear: to solve the energy shortage and to relieve the environmental contamination resulting from fossil fuel consumption. It should and does have quantified policy goals[26]. It has also concrete policy options which can be the target of policy evaluation and of further recommendations[27]. Renewable energy policy in China can also be assessed as a political interaction. We see intensive negotiation on policy problem definition[28] and policy option selection[29] in the process of renewable energy policy formulation in China. Renewable energy policy in China can also be analyzed as an institutional phenomenon. This field of policy making has become institutionalized and shares a joint view: there is no need to further explain why renewable energy has priority above fossil fuels in the future. It is institutionalized by the establishment of relevant governmental departments (at different levels) and the national law.

By the same token, it is impossible to fully understand China's renewable energy policy, its development and its successes and failures from just a single perspective. Renewable energy policy in China is to be understood at the intersection of these three perspectives. In addition, the development of an evaluation model should also be guided by the specific questions to be asked and answered. Hence in developing a policy evaluation model for the present study, I have flexibly combined elements from the three approaches with the basic research questions as formulated in chapter 1. The used model consists of three steps: the assessment of policy performance, the analysis of driving forces, and the formulation of policy recommendations (Figure 3.3).

[26] For example the total amount objective: 10% of the total energy consumption by 2010 and 15% by 2020.
[27] For example the priority grid access policy or the demonstration projects.
[28] For example the discussion on whether large hydro is renewable energy.
[29] For example the balance between bioenergy development and agricultural production

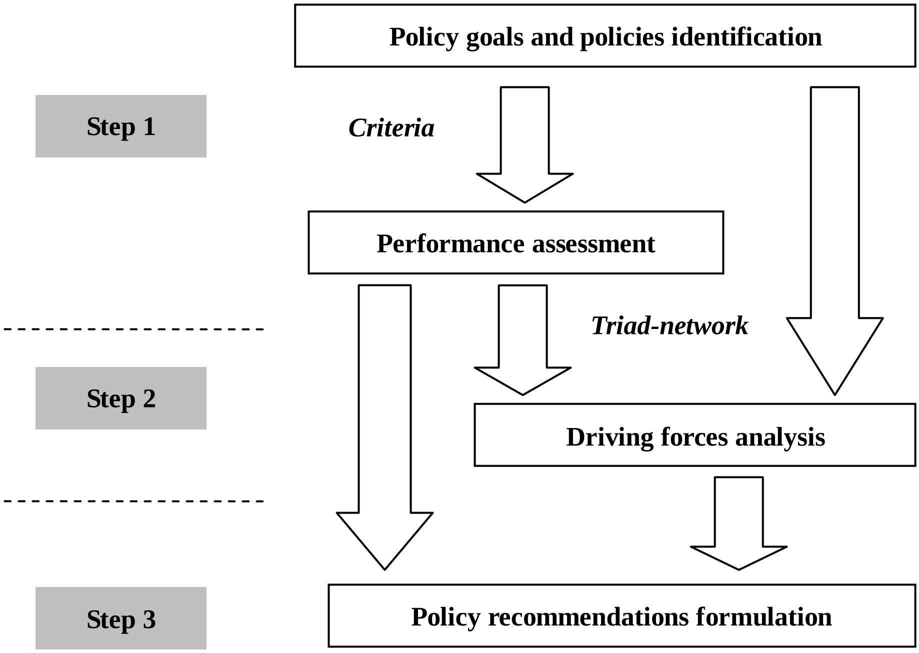

Figure 3.3 Evaluation model for renewable energy development in China

3.5.1 Policy goals, policies and performance

As most policy analyses the model in this study starts with identifying the policy goals formulated (in this study by the relevant Chinese authorities on renewable energy development), followed by the identification of the policy measures and activities implemented and the identification of governmental and non-governmental actors related to this policy field. This is mainly a descriptive element, as this study is less focused on understanding the processes of agenda-setting and policy formulation, but concentrates on policy performance evaluation.

Hence, the core of this policy evaluation model concentrates on performance assessment. This performance assessment consists of two parts: the analysis of effects and the evaluation of performance. The analysis of effects is carried out in a “goal-free” way, i.e. all the observed institutional, economic and societal transformations in relation to the studied renewable energy issue are concerned, no matter whether they are expected and planned results of the studied renewable energy policy, or unexpected and unwanted side effects by other influencing factors. At this step I also identify the absent effects that are regarded as necessary for a successful development of the renewable energy issue.

The observed effects are then evaluated by a set of performance criteria, viz. the *economic performance*, the *technological performance*, the *environmental impact* and the *social impact* (Table 3.1). These criteria are used for both the renewable energy projects in each case study (as described in Chapters 4, 5 and 6) and the renewable energy development in China in general (as applied in the concluding chapter).

Economic performance refers to profit of renewable energy projects and end users' saving money from adopting renewable energies. Although most renewable energy projects in China are receiving governmental subsidies or other funding, a proper level of profit is fundamental for sustaining these projects, especially now that China has also embraced a market economy model. Poor profit levels can also reduce the enthusiasm of investors. Economic benefit to local residents has impact on the public acceptance of renewable energy. Arguably, for most people in a transitional economy such as China economic viability is the most important reason to develop and use renewable energy, rather than perception of environmental protection or the desire of a modern lifestyle.

Table 3.1 Evaluation criteria for renewable energy development in China

Indicator	Sub-indicator	Definition
Economic performance	Developer	Economic benefits for project developers
	End user	Economic benefits for end users
Technological performance	Technology	Proper selection of technology
	Equipment	Efficient use of equipments
Environmental impact	Pollution abatement	Contribution to the alleviation of environmental pollution
	GHGs reduction	Contribution to the reduction of greenhouse gas emission
Social impact	Direct	Improvement of life quality in local areas
	Indirect	Improvement of other aspects in local areas

Technological performance refers to proper selection of renewable energy technologies, efficient use of equipments and good quality of renewable energy products. Development of renewable energy resources are largely restricted by local conditions. Using unsuitable technologies in an area with plenty renewable energy resources might cause failures of projects. Another important aspect of technology performance is the efficient use of equipments installed in renewable energy projects. It might be influenced by both the technology itself and by the daily management of projects.

Environmental impact refers to improvement of environmental quality and reduction of GHGs emission in areas where the renewable energy projects are carried out. Some side effects to local environment are also studied.

Social impact refers to improvement of life quality in local areas. It can include direct benefits such as saving time for collecting fuels or new employment opportunities, and indirect benefits such as improvement of local infrastructure. During the process of evaluation, these criteria are further elaborated in the context of different renewable energy resources.

3.5.2 Analyses of driving forces

As the previous step assesses the performance of the studied renewable energy issue, this step links the performance to various driving actors and forces; or negative drivers: inhibiting actors and factors. These (non-)drivers can be found in policy measures and policy actors, but might also be related to other drivers outside the policy arena, such as economic and market drivers, or those related to civil society. These driving forces are analyzed within the framework of a triad-network model as introduced above.

3.5.3 Policy recommendations

When the performance has been assessed and the corresponding driving forces have been identified, the final step of this policy evaluation model is formulating recommendations. Taking into account the driving forces that have influenced the performance, problem-oriented recommendations are put forward with respect to institutional arrangements, policy formulations, market reform and technology improvements over short, medium and long term periods.

3.6 Research Methodology

As discussed in Chapter 1, the main purposes of this study are to evaluate the performance of renewable energy development in China, to find out the driving forces of this performance, and to recommend on future development of renewable energy implementation. Given the nature of the research objectives, qualitative research is used as the major research approach to gather an in-depth understanding of the strengths and weaknesses of renewable energy development and implementation in China. Research findings from three information-rich cases are used to analyze the performance of contemporary renewable energy development in China, and to generate policy recommendations for furthering renewable energy.

3.6.1 General Research Design

In general, qualitative methodology is the main research approach in this study. Although it is criticized by some politicians and hard scientists for being unscientific, or only exploratory, or subjective, qualitative research has become an important mode of inquiry for social sciences that crosscut disciplines, fields, and subject matters (Huber, 1995; Marshall and Gossman, 1999; Denzin and Lincoln, 2005). Qualitative research aims to gather in-depth understandings of the complexity of social interactions and the ways participants attribute to these interactions.

Qualitative research traditions share four characteristics: They take place in the natural and existing world other than in a laboratory; they use multiple methods that are interactive; they are emergent and evolving rather than tightly prefigured and fixed in advance; and they are fundamentally interpretive. Qualitative researchers are also believed to have common characteristics: They view social phenomena as holistic or seamless, they systematically reflect on their own roles in research, they are sensitive to their personal biographies and how these shape the studies, and they rely on complex reasoning that is multifaceted and iterative (Rossman and Rallis, 1998).

Qualitative research does not have one distinct set of methods. It is a set of multiple interpretive practices. The most commonly used qualitative research approaches in sociology, political science and education evaluation include the semiotics approach as developed by, among others, Morris (1971) and Peirce (1934), the narrative approach as advocated by Mills (1959) and others, the discourse analysis as developed by Atkinson and

Heritage (1984), the ethnography approach as elaborated by Spradley and McCurdy (1972), the grounded theory as developed by Glaser and Strauss (1967), and the case study strategy as elaborated by, among others, Yin (1984; 1993) and Hamel et al. (1993). The preferred qualitative approach depends primarily on the type of research questions and objectives. Taking into account the nature of our research objectives, case study research is the most suitable approach to apply in this study.

Case study research is an appropriate research strategy to use when “how” and “why” questions are asked (Yin, 1984). In this study, questions include how China has developed its renewable energy resources, what are the reasons for successes/failures of renewable energy development in China, and how to improve its performance in further development. These questions are typical “how” and “why” questions. This is the reason for choosing case study research as the major research methodology in this study.

Although the major part of China’s renewable energy development has a short history, the entire picture is too large and complex at vertical (China’s complex administration levels), horizontal (China’s large-size and varied territory) and thematic (different renewable energy types in China) directions to be studied as a whole. Hence, specific case studies need to be selected.

3.6.2 Research Strategies

In comparing quantitative research with qualitative research, a major difference lies in the logics of sampling approaches. While the former typically depend on larger number of random samples, the latter focuses on smaller number of purposefully selected samples. The logic of purposeful sampling strategy is selecting information-rich cases to acquire in-depth understanding of the studied issues, from which the researchers can learn information of great importance to the research purposes (Patton, 2002).

In total 16 strategies for purposeful selecting information-rich cases were raised by Patton (2002). In this study the *maximum variation sampling*, which aims at “capturing and describing the central themes or principal outcomes that cut across a great deal of participant or program variation”, is chosen to be the sampling strategy. Due to the limited time and resources available and the need for intensive, in-depth study of each case, a large number of cases is not allowed in this study. Small samples always cause problem of high heterogeneity among individual cases and limited generalizability. The maximum variation sampling strategy can turn this obvious weakness into a strength: any commonness of the great varied samplings are of particular value in looking for experiences of the studies topic. This is the main reason why this study selects maximum variation sampling as the sampling strategy of cases.

Three criteria are used to ensure the variation of cases. Based on the maximum variation strategy and the above-mentioned criteria, three cases of renewable energy development in China are selected for in-depth studies (Table 3.2 & Figure 3.4).

The first criterion is *type of renewable energy technology*. China started its efforts to develop renewable energy utilization about 30 years ago. Due to such a short history, only several renewable energy technologies have been widely developed. In this study, three of the most commonly applied renewable energy technologies in China are selected for case studies: biomass gasification, grid-connected wind power and solar water heater. Each case stands for one renewable energy technology. This also means hydropower as the forth main renewable energy in China is not included in this study.

The second criterion is *administration level*. In China, tasks for renewable energy development differ among different administration levels. At higher administration level, renewable energy resources are developed in relatively long-term plans and on a more strategic level. Here financial resources are allocated from multiple sources. However, the structure of stakeholders' interactions is more complex, which causes specific patterns of during the processes of developing renewable energy resources. At lower administration level, renewable energy resources are normally developed in the form of small-scale demonstration projects on short term policy. Local communities may have important impacts on the implementation of such development strategies.

Table 3.2 Overview of cases for this study

Study area	Type of renewable energy technology	Administration level	Economic development level
Inner Mongolia	Wind power	Province	Poor
Shandong	Biogas gasification	Village	Moderate
Zhejiang	Household solar energy	City	Rich

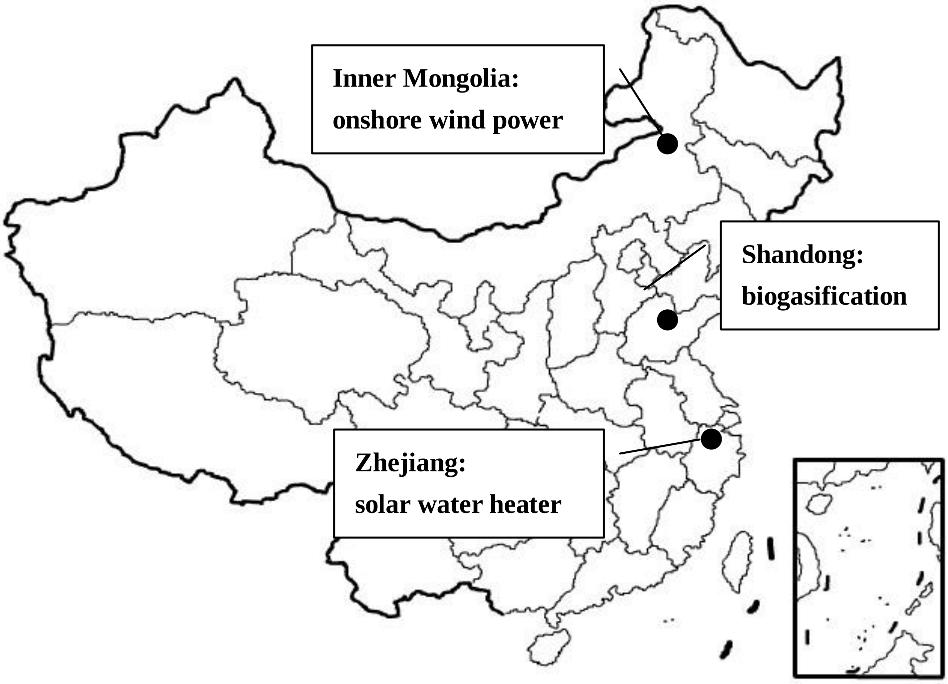

Figure 3.4 Map of China with highlighted case study sites

The third criterion is *economic development level*. Economic development might put tremendous influence on environmental and energy governance capacity. A region with high economic development level is expected to be more concerned about environmental quality, have larger environmental capacities among its bureaucracies and is more willing to accept and implement environment friendly policies (and thus renewable energy above fossil fuel projects). All these differences are expected to impose different impacts on local policies and practices of renewable energy development.

In the three case studies, the evaluation framework (developed in Seciton 3.5) is applied in a not too rigid way to each case, to allow for the case specific dynamics in policy development. Each case is put in a wider context so that we can understand the particularity of that case vis-a-vis other situations where the same renewable energy is implemented.

3.6.3 Data Collection Methods

Data for qualitative researches can be distinguished, according to how they are acquired, into primary and secondary data. In collecting primary data the researcher purposefully design the data collection processes and plays an important role in doing it. In collecting secundary data researchers put more energy into critically examining and analyzing data from other invetigations, organizations and government departments, who have collected data for their own purposes (Clark, 1999; Denzin and Lincoln, 2005).

A structured approach – *triangulation* – is applied to bring together the various data sources and data collection methods in this study. Triangulation is an effective tool widely used in social sciences. It is the usage of different methods, data, theories or investigators in studying the same complex social problem (Greene and McClintock, 1985; Chappel et al., 1999). I apply site oberservation (as a competent observor, cf. Clark, 1999: p. 79), face-to-face interviews, surveys, and interpretation of existing textual material, statistics and mass media reports to gain an case-specific and overall understanding of renewable energy development in China (Figure 3.5).

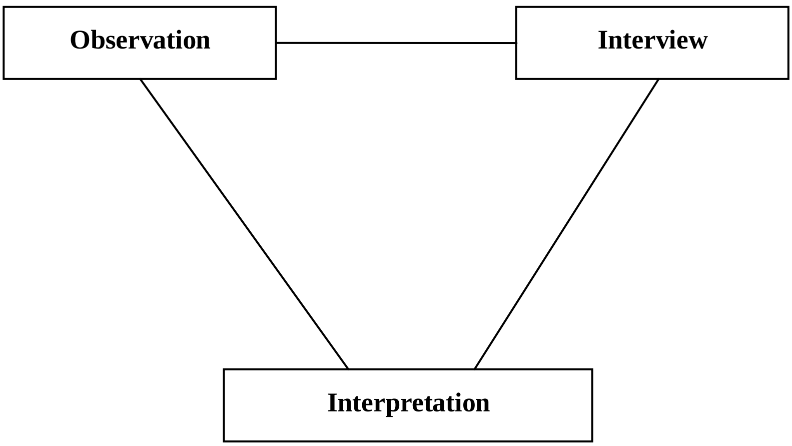

Figure 3.5 Triangulation method

Primary data used in this study are collected via site oberservations, face-to-face interviews and questionnaires. Site observations are carried out at 7 biomass gasification stations in Shandong in July 2006 (cf. Chapter 4), at 3 wind farms in Inner Mongolia from September to October in 2007 (cf. Chapter 5) and at 5 solar water heater manufacturers and 6 solar water heater retailers in Zhejiang from May to June in 2008 (cf. Chapter 6). Face-to-face interviews are carried out with officials, scientists, project developers, industries/manufacturers and community members in relation to renewable energy development in Beijing, Shandong, Inner Mongolia and Zhejiang (see Appendix 1). A uniform questionnaire with closed questions is used in evaluating performance of household solar water heater utilization in Zhejiang (see Appendix 2).

Besides the data collected through primary methods, secondary data are also used as information sources for this study. National and provincial statistical yearbooks are used to obtain historical data of socio-economic development and energy development. The information about bureaucratic structures and policy frameworks for renewable energy development is acquired from websites, documents and through interviews of both the central government and local governments. Data on renewable energy prices, installation capacities and market shares are collected from the reports written by governmental departments, NGOs and other third parties[30]. Academic journal articles are referred to mainly in order to obtain technological parameters of renewable energy utilization. And data from mass media with reliable information sources have been used to assess public perception[31].

[30] Such as the EU, the NDRC, the Green Peace, the National Renewable Energy Laboratory (NERL) and the Energy Research Center of the Netherlands (ECN)
[31] Such as the Xinhua Net and the Renewable Energy Policy Network for the 21st Century (REN21) website

Chapter 4 Small-Scale Bioenergy Projects in Rural China: Lessons to be learnt[32]

"Safety and certainty in oil lie in variety and variety alone."
- Winston Churchill (1913)

Abstract

Large amounts of small-scale bioenergy projects were carried out in China's rural areas in light of its national renewable energy policies. These projects applied pyrolysis gasification as the main technology, which turns biomass waste at low costs into biogas. This paper selects seven bioenergy projects in Shandong Province as a case and assesses these projects in terms of economy, technological performance and effectiveness. Results show that these projects have not achieved a satisfying performance after 10 years experience. Many projects have been discontinued. This failure is attributed to a complex of shortcomings in institutional structure, technical level, financial support and social factors. For a more successful future development of bioenergy in rural areas, China should reform its institutional structure, establish a renewable energy market, and enhance the technological level of bioenergy projects.

Keywords: pyrolysis gasification; Shandong; renewable energy

4.1 Introduction

Bioenergy is receiving significant attention recently, for various reasons. First, it is celebrated for its potential contribution in mitigating greenhouse gas emissions. Second, it can contribute to alleviating rural poverty by additional sources of income. Third, it is often believed to increase energy security by lowering oil import dependencies of countries and regions (Mol, 2007; Verdonk et al., 2007). While first generation large scale bioenergy production from food crops as maize, oil palm and sugarcane is increasingly meeting severe

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criticism for its detrimental effects on the environment (biodiversity, soil and water deterioration, NO_x emissions) and food access, small-scale and second generation (from biodegradable waste and plant left-over) are considered more favorably (Mol, 2007).

While China has recently become involved in large-scale biofuel (bioethanol and biodiesel) production, it has a much longer history of small-scale bioenergy production, especially in rural areas. Especially since the end of the 1980s, bioenergy has been identified as an important and promising contributor to renewable energy production and rural development. Renewable bioenergy technologies that were widely applied from the early 1990s onwards included anaerobic digestion, pyrolysis gasification, bio-fuel solidification, bio-ethanol generation and bio-diesel cogeneration (Johansson et al., 1993). Being still predominantly an agricultural country, China has plenty of biomass resources for bioenergy development. It is estimated that China produces 200 – 400 Mt sce of non-product biomass available for energy purposes every year (Li et al., 2001; Li and Hu, 2003), most of it in rural areas.

Due to low levels of economic development in China's rural areas, pyrolysis gasification has been among the more popular technologies, as it is a rather simple technology and cheap compared with other bioenergy technologies. Around the year 1997, China started several rural biogasification demonstration projects under its agreement with European Union (Bridgwater, 1999; MOA/DOE Project Expert Team`, 1999). In 1998, about 200 village-level biogas stations were established in China (Zhou, 2002), and seven years later more than 1000 village-level biogas stations have been constructed through national investment, mainly in the rural areas of eastern and south-eastern coastal provinces such as Liaoning, Shandong and Zhejiang (Leung et al., 2004; National Renewable Energy Laboratory`, 2006). These projects aim to provide village residents access to clean and cheap energy and to improve local air quality by reducing direct combustion of straws and stalks. Ten years have passed since China constructed its first small scale biogas station, but anecdotal evidence suggests that the amount of functioning biogas stations has declined strongly.

Against the above-mentioned background, this paper aims not just to assess the performance of these low-technology bioenergy projects, by especially to explain how and why the set targets for these projects were not met. These insights are used to put forward suggestions for decision makers to improve the performance of these technologies. In doing so, the paper focuses on coastal Shandong province, where biogasification projects have been introduced widely. The next section introduces Shandong province (its renewable energy demand, available biomass resources, and its institutional and policy frameworks) and the biogasification technology used. The third section reports on a performance analysis of seven biogas stations in Jinan City, Shandong Province. The fourth section analyzes the causes and barriers that resulted in the poor performance of biogasification in Shandong Province. Finally, recommendations for future development of rural bioenergy utilization in China are formulated.

4.2 Bioenergy in Shandong Province

4.2.1 Demand for renewable energy

Shandong is among the largest energy consuming provinces in China. In 2004, its total energy consumption climbed to 159 Mt sce, ranking the second in all China' provinces and for the first time exceeding its total energy production (Shandong Statistical Bureau`, 2005). In the national economic development objectives, China's average annual growth rate of energy demand is estimated to be 2.8% for the coming 50 years (Wang and Lu, 2002). In other words, total energy consumption in Shandong will reach 566 Mt sce in the year 2050, if the growth of energy demand in Shandong keeps up with the estimated national rate.

At the same time, energy production in Shandong will not significantly increase if the current energy industry structure remains unchanged. Statistical data even show that coal production in Shandong in 2004 was 1.3% lower than that in 2003 and the production is believed to shrink further in the coming years (Gao and Gao, 2005). Although oil production is relatively stable (with 37.5% of oil products exported to other provinces), Shandong produces 6% of the total national oil production every year but has only 2.2% of the total national reserve. Its oil resources will be finished within the next 20 years.

Like most provinces in China, Shandong has a "fossil-fueled" energy structure, where coal (76.0%) and oil (23.3%) account for 99.3% of total primary energy consumption (Shandong Statistical Bureau, 2005). This "fossil-fueled" energy structure has two negative effects. First, it releases large amounts of greenhouse gasses. In 2004 about 10% of China's waste gas emission occurred in Shandong, equaling the proportion of Shandong's energy consumption in national energy consumption. Second, it causes spilling of energy. In China, fossil fuels are mined, processed and consumed at lower efficiencies compared with renewable energy resources. Most fossil fuel producing areas are located in its northwest and northeast China, while the major industrial areas and cities lie in east and southeast China, resulting in fuel transports over long distances. According to statistical analyses, approximately one fourth of China's primary energy is wasted during mining, processing and transportation.

There is increasing recognition among Chinese scholars and state officials that future energy shortages in Shandong cannot be solved simply by enhancing oil and/or coal mining (and imports), but need to involve a change of energy structure by enhancing the share of clean and renewable energy. The growing strictness of national and local environmental protection needs and targets only reinforce this. Biomass has a large potential to become a major renewable energy source for Shandong.

4.2.2 Biomass resources in Shandong

Agricultural biomass and forestry biomass are two main resources for bioenergy production. Agricultural biomass refers to agricultural product residues and agro-food processing wastes. Crop straw, rice husk, cornstalk and corncob are often mentioned as useful biomass for energy generation. Forestry biomass is produced during forest growth, harvest and wood manufacturing.

The agricultural sector in Shandong provides considerable amount of biomass resources, although no detailed investigation has been conducted yet. According to Bridgwater (1999), production of crop residues is related to amounts of crop-products and rates of residues produced from crops (cf. Section 2.2.1). Thus, the total amount of biomass residue from crops in Shandong in 2004 is about 67.32 Mt (Table 4.1). With pyrolysis gasification technology, 2.5 kg biomass is enough for a normal family to cook meals for a whole day. In other words, one forth of the total crop residue production, i.e. 18.25 Mt, can provide the 20 million rural families with sufficient fuels for cooking. This to some extent competes with the use of crop residues as animal fodder, industrial materials and fertilizers in Shandong. But it is estimated that currently about 20% of crop residues are burnt directly in the field as waste, which could in stead be used as bioenergy without conflicts for other use functions.

Table 4.1 Estimation of crop residue production in Shandong, 2004

	Wheat	Corn	Cotton	Peanut	Soybean	Potato
Area (ha)	3,105,700	2,455,049	1,059,207	925,298	241,180	N/A[a]
Yield (kg/ha)	5,102	6,106	1,036	3,948	2,972	N/A
G (t)	15,845,638	14,991,484	1,097,709	3,653,002	716,674	4,909,964
r (kg/kg)	1	2	3	2	1.5	2
BR (t)	15,845,638	29,982,968	3,293,127	7,306,004	1,075,011	9,819,928

[a] N/A: data not available

According to studies conducted by the Food and Agricultural Organization (FAO) of the United Nations, only half of the forestry harvest is used for industrial products at mills and manufacturing facilities (UNECE/FAO, 2006). Thus 50% of forest biomass, in the form of branches, barks, chips and sawdust, is available for energy production. In 2004, about 1.29×10^6 m^3 of forestry products were harvested in Shandong (Shandong Statistical Bureau, 2005), offering 6.45×10^5 m^3 forestry biomass for energy production.

4.2.3 Institutions and policies for renewable energy development

In Shandong Province, four major departments under the People's Congress (PC) and provincial government share power on renewable energy development (Figure 4.1). The Environmental Protection Bureau (EPB) is responsible for enforcing national environmental laws and policies, specifying local pollution standards, investigating environmental accidents and mediating environmental disputes. The Natural Ecosystem Protection Section (NEPS) under EPB takes responsibilities of directing comprehensive utilization of straws and monitoring improper combustion. The Rural Development Section (RDS) under the Department of Science and Technology (DOST) funds and organizes advanced-technology demonstration projects in rural areas, including renewable energy promotion projects. The Energy and Communication Section (ECS) under the Development and Reform Commission (DRC) develops policy measures for improving energy efficiency and promoting new energy in the framework of provincial socio-economic development plans. The Eco-Agriculture Section (EAS) under the Department of Agriculture (DOA), which is also called the "Office of Rural Renewable Energy Development of Shandong", forms the most important governmental agency for renewable bioenergy development in Shandong. It takes full responsibility for organizing, planning and implementing renewable energy projects in rural areas.

Shandong government develops renewable energy policies at provincial level, as supplement to or specifying national renewable energy policies and standards. These provincial policies entail regulatory instruments, financial incentives and technical standards for renewable energy development. The most important policies are summarized in Table 4.2.

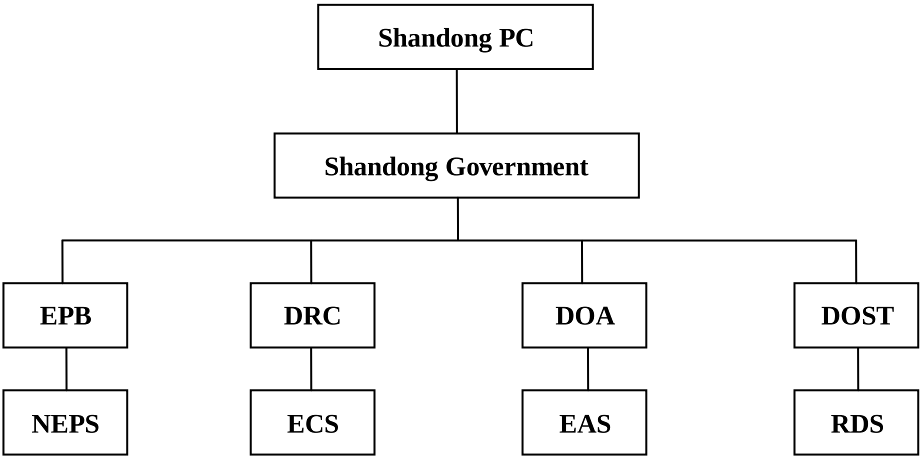

Figure 4.1 Institutions for renewable energy development in Shandong

Source: http://www.shandong.gov.cn/col/col5487/index.html

Table 4.2 Selected provincial renewable energy policies in Shandong

Policy	Promulgator	Statement
Regulation on Rural Energy Development and Management in Shandong Province	People's Government of Shandong Province (1997)	**Article 12:** Governmental departments of rural energy development should organize production and utilization of new and renewable energy in suitable areas.
Executive Order on Energy Conservation in Shandong Province	The Standing Committee of the PC of Shandong Province (2002)	**Article 29:** …Development of new and renewable energy, such as biogas, solar energy, hydropower and wind power, is encouraged.
Circular on Ensuring the Quality of Rural Energy Development Projects in Shandong Province	The Department of Agriculture of Shandong Province (2005)	…Select villages and households who have husbandry experience, good economic condition and willingness to use biogas, to carry out the "One Pool with Three Transforms" project.
Standards of "One Pool with Three Transforms" Rural Energy Project in Shandong Province	The Department of Agriculture of Shandong Province (2005)	…Households involved in the project should construct a biomass digester and reform the kitchen, toilet and pigsty.

4.2.4 Biogasification projects in Shandong

The urgent demand for renewable energy development, availability of biomass resources, and well-established institutional and policy framework enhanced the blossoming of bioenergy demonstration projects in Shandong. Around the year 1997, China started with bioenergy demonstration projects in rural areas and Shandong has been one of the key implementation provinces. By 2005 Shandong province had constructed over 400 village-level bioenergy projects. Pyrolysis gasification technology was widely applied in these stations, because it was the most mature one at the end of the 1990s, while the cost to construct a biogas station are relatively low. As such, it perfectly matched the need of developing renewable energy resources in rural areas, where financial constraints are large.

Pyrolysis gasification is suitable for treating various biomass materials, such as corn stalk, sawdust, wood chips and crop straw. The entire pyrolysis gasifier consists of four components: the feeding system, the gasifier, the steam generator and the gas storage facility (cf. Figure 4.2). The pyrolysis gasification process includes two stages (Sun et al., 1992; Li and Hu, 2003; Leung et al., 2004). At the first stage, workers put biomass into the feeding system. Then the feedstock is transferred into the gasifier and becomes fluid in it. The diameter of feedstock can range in size between 0.25 and 250 mm. Biomass undergoes partial combustion at a temperature above 800˚C in absence of oxygen, to produce volatiles (mainly carbon dioxide and water vapor) and charcoal. At the second stage, charcoal transforms the volatiles into CO, H_2 and CH_4. After three rounds of purification, a mixed fuel gas is obtained, consisting of CO, H_2 and CH_4. This mixed gas is stored in a gas storage facility and transported via underground pipes to individual families. The entire process operates in batches.

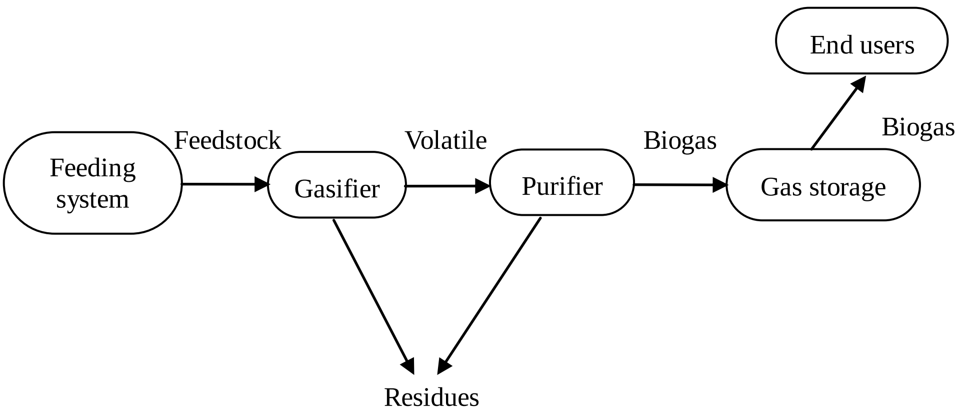

Figure 4.2 Process of biomass pyrolysis gasification

4.3 Methodology: Case studies and evaluation criteria

4.3.1 Case study methodology

In assessing and explaining the performance of these bioenergy projects, we apply a case study approach, mainly for four reasons. First, no evaluation has been carried out yet on these projects in China. This makes our research into the reasons for project success and failure rather explorative, for which in depth case study research is more suitable. Second, the nature of research questions demands a qualitative field research approach, rather than a quantitative survey. In investigating why some projects succeeded, while others failed, we need detailed information on causal relations, rather than statistical correlations. A case study method is especially relevant when “a ‘how’ and ‘why’ question is being asked about a contemporary set of events, over which the investigator has little or no control” (Yin, 1984). Third, performance of the bioenergy projects cannot be assessed in isolation, but is closely relation to their social, economic and natural environment. Case study methods are especially useful when we deal with unsharp boundaries between the event and the context and where we aim at “description and explanation of complex and entangled group attributes, patterns, structures or processes” (Verschuren, 2003). Fourth, quantitative surveys have to be based on large number of samples. However, information and data on bioenergy projects – and particularly the ones that have stopped – were very hard to obtain from governmental and other sources, making a large-scale quantitative survey impossible.

However, the nature of case study research brings limitations, especially with respect to the generalizability of the outcomes. By cautiously selecting our cases, we have tried to minimize this risk and maximize the value of the case study outcomes for a wider constituency of projects. A district in Jinan City, Shandong Province was carefully selected for the in-depth case study analysis. This district was selected based on following reasons. Firstly, this is a representative rural area in Shandong in terms of economic development, the importance of agriculture versus other economic sectors, demography and natural environment. Most residents are involved in agricultural production, making up 9.7% of local GDP in 2005. The average annual family income is just below 20,000 yuan (€ 2,000) (Shandong Statistical Bureau`, 2005), which is about the average for the province. Secondly, all the small-scale biogas stations in Shandong were constructed under the same project, which aimed to alleviate atmospheric pollution caused by direct burning of stalks in the side-fields along Jinan-Qingdao Highway and Jinan Airport Highway. In comparison with other areas, the selected district has the highest density of stations and the longest project history (seven stations were constructed during the period 1996 – 2005). This enabled us to evaluate longer running station and at the same time keep a number of variables constant. Thirdly, all the seven stations in this district used pyrolysis gasification technology, which is the most prevailing technology of biogas stations in China. This made the results relevant for other projects using similar technologies, while excluding technology as an explanatory variable. For these reasons, we can expect that the outcome of our case studies have relevance for other pyrolysis gasification cases in rural Shandong province.

Table 4.3 provides – as far as available – the basic data for each case study station, which is named after the village where it locates. Scales of these stations vary: the smallest station provides 110 families with biogas for cooking and heating, while the biggest one supports 1,000 families. Four out of the seven had been discontinued by the time of fieldwork (July 2006). SZY station was under reconstruction during our fieldwork, to become an electricity plant that uses biomass as fuel. SSC was the only station in good condition and XLJ was in operation for the longest time.

Table 4.3 Basic information of selected biogas stations

Biogas station	Construction time	Initial investment (10^6 yuan)	Capacity (families)	Status
Shasancun (SSC)	2002	3.0	1,000	In good condition
Xiaoliujia (XLJ)	1998	0.4	110	In use
Xiaozhangma (XZM)	2004	N/A[a]	N/A	discontinued in 2005
Nanguoer (NGE)	2000	N/A	330	discontinued in 2003
Chengxicun (CXC)	1997	0.98	260	discontinued in 2004
Shiziyuan (SZY)	2005	1.5	N/A	Under reconstruction
Yuanjiacun (YJC)	1996	0.96	300	discontinued in 1999

[a] N/A: data not available

Information was collected through interviews with officials in the governmental departments of Shandong Province and scientists in both Shandong Academy of Sciences and Shandong University, as well as the community leaders, station managers, workers and residents/consumers in each of the seven villages where biogas stations were constructed.

4.3.2 Evaluation criteria

Project performance was evaluated, paying attention to economic aspects, technological performance and especially effectiveness. Effectiveness points to the attainment of project objectives and intended impacts, and was further specified in four types: institutional effectiveness, target group effectiveness, impact effectiveness and societal effectiveness (European Environmental Agency, 2001; Gysen et al., 2002). Institutional effectiveness indicates the extent to which the output of the project meets the objectives. Target group effectiveness implies the relation between project objectives and the outcome, reflecting the extent to which the target group responded to project efforts. Impact effectiveness means the degree to which the project influences the state of environment (impact). And societal effectiveness refers to whether the final impact satisfied societal needs (and not just potentially ill-formulated project objectives).

4.4 Assessing the Performance of Bioenergy Projects

4.4.1 Economy of the bioenergy projects

In principle, all stations were funded by the provincial government, the village government and other organizations, as was agreed in contracts between the provincial government and village governments. Villages were carefully selected so that they could afford their part of the initial investment. Other organizations funding the projects include the national government, the municipal government, external corporations and research institutes. SSC is the only station who received funding from China’s Ministry of Agriculture. All stations received free experimental equipment from Shandong Academy of Sciences or Shandong University. Each household who applied (voluntary) for using biogas was charged 300 yuan (€ 30) for installation of pipes, a biogas stove and a meter registering biogas consumption.

The total investment of a single station relied heavily on its scale: the larger the scale is, the more expensive the investment is. In China, normally construction cost of a biogas station with capacity of 200 families ranges between 0.5 and 2 million yuan (€ 50,000 – 200,000) (Li et al., 1998; Bridgwater, 1999). Construction costs per capacity of 200 families of the case study stations were as follow: SSC 0.6 million yuan; XLJ 0.73 million yuan; CXC 0.75 million yuan; YJC 0.64 million yuan. This is all at the low end of the range of construction costs for China pointing at a cost-efficient way of construction.

During operation of the seven biogas stations, no financial support was received from higher level governments. It was the village government's full responsibility to run the station financially healthy. In most cases, the village government appointed one village official as station manager and hired two workers. The village government had authority to decide the price of biogas; higher-level governments gave no directions. Most villages set the price at a low level, comparable to the level of the neighboring village, to prevent complaints from villagers. The purchase of fuels, house rent, electricity, workers' salary and occasional repairs were all paid from the village government account. Every half year the station manager collected money from the villagers for the biogas they consumed, which formed the main income of the station and was put into the village government account. At the end of the year, the village government compensated any deficit. None of the seven stations could provide detail account records of its daily operation. Income and expenditures were recorded just as a single item on the community government's account, resulting in poor (financial) transparency. With the assistance of the station manager of XLJ station an estimation was made of expenditures and income of this biogas station in 2005 (see Table 4.4), suggesting a significant annual government subsidy.

4.4.2 Technological performance of the bioenergy projects

Major outputs of the bioenergy projects included the installation of equipments such as biomass gasifiers, pipes and biogas stoves. Of the seven stations, XZM, NGE, CXC and YJC were discontinued shortly after their construction (cf. Table 4.3). SZY is being rebuilt into an electricity plant that uses biomass as fuel. XLJ was still in use, although, the station has to be discontinued for several days every two to three months due to technical problems. SSC was the only station that was still functioning properly. Most stations only used about half of the designed capacity during operation.

Table 4.4 Expenditure and income of XLJ station in 2005 (yuan)

Expenditures		**Income**	
Item	**Amount**	**Item**	**Amount**
Purchasing fuels	**60,000**[a] (200yuan/t·300t)	Selling biogas	**60,000** (0.2yuan/m^3·300000m^3)
Electricity bill	**15,075** (0.67yuan/kWh·22,500kwh)	Apportionment of initial investment	**40,000**[b]
Workers' salary	**19,200** (9,600yuan/worker·2 workers)	Subsidy from village government	**36,275**
Repair cost	**2,000**		
Depreciation of equipments and buildings	**40,000**[b]		
Total	**136,275**		**136,275**

[a] Corn stalks bought from farmers as fuel;

[b] The initial investment of XLJ station was 0.4 million *Yuan*. It was designed to be used for 10 years

During operation, the gasification equipment faced various problems. Tar was the most serious problem. Equipment was regularly jammed by tar, which is very difficult to get rid of when it has coagulated on the inner surfaces of pipes and containers. In some villages workers had to open the equipment and clean them every week. This is time and money consuming. Another annoying problem with the gasification equipment consisted of biogas leakage from pipes. Biogas contains CO and CH_4, which are hazardous to human health. Therefore, leakage needs to be prevented or quickly mitigated. Because all pipes were placed underground, leakage resulted in high costs for repair and pipe replacements.

Average caloric value of biogas produced in these stations is only 5,316 KJ/m^3, much lower than other fuels (Figure 4.3). As a result, users have to consume more biogas than other fuels to cook the same meal. A consequence is that stations need large storage facilities. Normally workers in biogas stations run the equipment and fill the gas storage twice a day, which provides enough biogas for all users to cook meals for a day. If the caloric value of biogas could be doubled, the storage capacity could be halved or workers only needed to fill the storage once a day, saving costs.

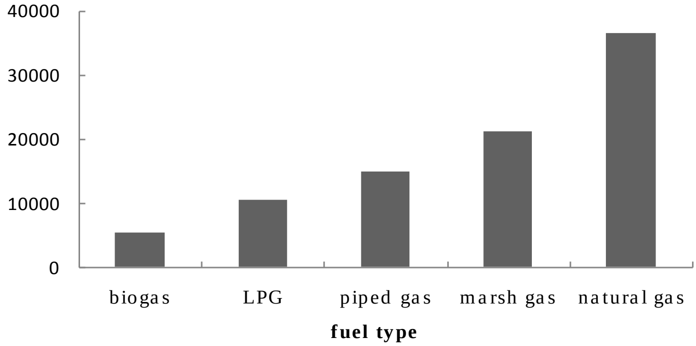

Figure 4.3 Caloric values of different fuels (KJ/m^3)

A final problem is that the gasification equipment cannot treat wet fuel, as it harms or even damages the steel equipment. Some rich villages such as SSC and SZY built extra buildings for storing fuels, while in others workers had to spend a lot of time drying wet fuels. During the raining seasons, these stations were often forced to stop producing biogas, due to a lack of dry fuels.

4.4.3 Effectiveness of the bioenergy projects

The available government documents often provide no concrete quantified objectives of bioenergy demonstration projects. Even the recently issued national policy, the *Medium and Long-Term Development Plan for Renewable Energy*, only provided six rather general objectives for bioenergy development in rural areas. Nevertheless, the motivation for bioenergy projects in Shandong province was clear: besides cheap energy production, the main goal was to alleviate air pollution caused by local farmers burning straw along highways. However, no quantified targets were set on both objectives, making them too vague for a quantified effectiveness evaluation. As a result, only qualitative judgments can be made.

4.4.3.1 Institutional effectiveness

Institutional effectiveness relates objectives to government outputs for bioenergy utilization, including the establishment of bioenergy projects and the managing of biogas stations. This study assessed government performance in relation to initial objectives of biogas project.

Approximately 365 million yuan (€ 36.5 million) was budgeted by both national and provincial governments for constructing biogas stations in Shandong. Village governments also supported Bioenergy projects. When Shandong government planned the project in Jinan city, more than 20 villages applied to be sites for bioenergy demonstration projects. After an evaluation – with criteria such as village scale, economic level, distance to highways and availability of biomass resources – seven villages were selected. Subsequently, opinions of villagers in these seven villages were collected regarding, among others, their willingness to install a biogas stove and the costs for biogas they could afford. Visits to neighboring villages with running biogas stations were organized for villagers. Their final opinions directed the design and capacity of the individual projects. All seven biogas stations have been delivered, be it sometimes with delay.

But significant ineffectiveness emerged during the running of the projects. During interviews staffs in EAS of Shandong DOA, who are supposed to take full responsibility for renewable bioenergy projects in rural areas, could not give clear answers to basic questions such as how many stations had been built or which institutes were doing research and development on bioenergy. Communications between Shandong authorities and village governments were poor. For instance, no Shandong department ‘in charge’ was informed two years after the NGE village government discontinued the biogas station and sold the equipment. In case of emergencies around biogas projects, it always took a long time to decide who had responsibility and where necessary financial and technical resources for repair could be obtained. In addition, no monitoring and evaluation mechanism was established to follow and investigate the status of the stations. It seemed that for Shandong province, bioenergy projects ended not when local people were provided stable biogas provision, but when it was reported that the construction of the station was finished and this good news was released to the media. Several stations had no other function than to ‘demonstrate’ the ability to construct a project.

4.4.3.2 Target group effectiveness

Most villages in Shandong showed a strong willingness to establish bioenergy projects. By the end of 2005, Shandong Province alone had constructed more than 400 biogas stations. Although several of our case study stations were shut down, all village leaders interviewed expressed strong interests in continuing the projects if financial conditions and technical support were improved. But citizens in these villages did not show the same enthusiasm. The average proportion of families that applied for using biogas was below 50% in all the seven villages. A large number of villagers expressed their reluctance to pay the 300 yuan for installation of pipes and stoves, which prevented many families from using biogas. Nevertheless, fewer families burned straw and stalks, even after bioenergy projects discontinued. This change in behavior relates to two mechanisms. Villagers found that the air quality improved during the period they used biogas and thus did not turn back to biomass burning in the field after discontinuation of bioenergy projects. And during the first years of the new millennium the government posed stronger enforcement and sanctions on burning biomass in the field. Currently, most biomass not used in bioenery projects is used as fertilizer or as feedstock for livestock, and a small amount is still used as fuel in traditional stoves. Much less burning in open air takes place nowadays.

4.4.3.3 Impact effectiveness

One important purpose of constructing biogas stations in Shandong was to improve local air quality. Crop stalk and firewood were once traditional energy resources for rural household in Shandong mainly for cooking and heating. In the 1990's, energy from crop stalk and firewood accounted for about 80% of rural energy consumption. With rapid development of economy, the rural energy consumption is increased while energy structure changed. The consumption of commercial energies such as electricity, coal, gas and oil increases rapidly, especially in the coast areas and vicinity of large cities. The consumption of energy from crop stalk and firewood decreases sharply. It is estimated that crop stalk consumption for rural residential in Shandong decreased from 33.5 million tons in 2000 to 28.8 million tons in 2004 (National Bureau of Statistic of China, 2006). As a result, a considerable amount of crop stalk is directly burnt in the harvest period by farms, leading to serious air pollution (Li et al., 1999).

After implementation – of course also of biogas stations outside our case study area – air quality in Jinan City was significantly improved, and that remained even after the discontinuation of several projects. Figure 4.4 shows the reduction of concentrations of three air pollutants (SO_2 for 65.3%, NO_2 for 70.7%, and PM_{10} for 69.5%) after the start of these biogas stations. Within the same period, average pollutant concentrations of in other areas without bioenergy project reduced much more slowly (SO_2 for 35.9%, NO_2 for 29.4%, and PM_{10} for 61.1%). Although we cannot exclude other factors, such as the change of industrial structure, enhancement of energy efficiency or the stringency and enforcement of environmental policies, that improved local air quality over the years 1997 till 2005, bioenergy projects did contribute to lower air pollutant concentrations in two ways. Firstly, they reduced burning of crop stalks in open air, which directly contributed to air quality improvement. This is clearly the most important reason, as it continued even after most projects ended. Secondly, the biogas stations reduced the consumption of fossil fuel. In comparison with fossil fuels, biogas production, transportation and consumption is more environmentally friendly. Biogas releases less harmful waste when being processed compared to coal and oil (although it has small amounts of byproducts of tar and ashes, which are usually dumped locally).

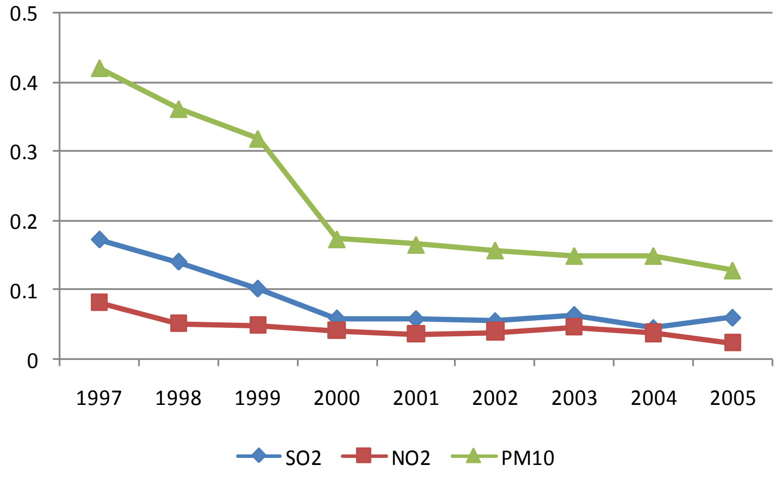

Figure 4.4 Concentration of air pollutants in Jinan, 1997 – 2005 (mg/m^3)
Source: Shandong Statistical Yearbook, 2006

4.4.3.4 Societal effectiveness

Normally societal needs are not stated directly in policy objectives. However, societal needs are fundamental driving forces for policies and projects. Therefore, societal effectiveness of these projects was also assessed, as the degree to which the projects contributed to societal needs.

Local farmers obtained economic benefits from the biogasification implementation. First, these projects provided them cheap energy resources. Every family only needed to pay 300 yuan for installation of pipes and a stove, and on average 0.20 yuan/m^3 for consumed biogas. According to rough estimations, a family could thus save 740 yuan annually on energy consumption. Second, these projects offered farmers new sources of income. In most villages with a biogas station, farmers could sell their straws and corncobs to the station at prices around 0.20 yuan/kg. For an individual farmer family this could mean annually several hundred yuan of extra income. Third, opportunities were created for new employment and business, including biogas station workers, equipment producers, station builders and contractors, and biofuel traders. Upgrading the technological level to generate electricity, as in the case of SZY, increases the need for more well-educated and skilled employees.

Bioenergy projects provided rural residents clean and safe biogas for cooking and heating. After the installation of a biogas station, straws were no longer piled all over in the villages, and sooty kitchens and chimneys disappeared. Villagers felt living a modern lifestyle, similar to urban residents using piped gas. This motivated them to improve other aspects of their daily life. Using biogas also reduced the chance children caught injured or burned through coal stoves.

With biogasification time used for cooking meals reduced significantly, freeing time for recreation and education. Traditionally, people in rural Shandong had to spend significant time on gathering straws, tree branches and waste wood for fuel. Even after coal was introduced for cooking in rural areas, buying and transporting coal from outside the village and heating the coal stoves remained time-consuming tasks, especially for women. Using biogas saved time. As local people indicated, after the introduction of bioenergy project, “only two persons are busy firing the gasifier when the whole village is cooking”.

4.5 Causes of Bioenergy Project Failure

Overall, our effectiveness evaluation shows at best mixed results. While stations have been established and environmental impacts seem to have improved, four out of the seven stations were out of use during our investigation. Extrapolating this proportionally, less than 200 stations would have survived in Shandong province. But our search for biogas projects indicates much smaller numbers. What are the main shortcomings that contributed to these project ambivalences? Our research, as well as experiences from other countries (Katinas and Markevicius, 2006; Nilsson et al., 2006; Prasertsana and Sajjakulnukit, 2006), found five causes that resulted in the failures of rural bioenergy projects.

4.5.1 Institutional shortcomings

Renewable energy development in China is co-managed by a number of agencies, both at the national level and at the local level. These governmental departments work under different national ministries and have different interests in developing renewable energy resources. No institutional arrangement has been constructed to encourage harmonious collaboration between these agencies, or to define clear hierarchies. As a result, coordination between different departments is heavily retarded, and responsibilities of each agency with respect to bioenergy development are unclear. All governmental departments are reluctant to monitor the status of biogas stations and to take responsibilities in ensuring project effectiveness. Stations encountering technical problems have no addressee for requesting financial and technical support. This lack of coordination and division of responsibilities is enhanced by unclear division of responsibilities between the central provincial departments and the local village authorities. These unclear institutional arrangements impose important negative impacts on bioenergy projects in China.

Poor management of biogas stations also reflects the institutional shortcoming.

4.5.2 Policy shortcomings

In 1986, the National Economic Committee issued the *Circular on Improving Rural Energy Development*. This was the first policy on renewable energy development that mentioned the importance of bioenergy. However, more than 20 years later no detailed plans have been formulated, no technical standards and guidelines for bioenergy been implemented to regulate the equipment market, and no quantified objectives have been set.

In rural areas, development of bioenergy lacks long-term planning and strategy. Many county and town governments constructed biogas stations not in the framework of a long-term energy policy, but following orders from higher-level governments. While most villages had strong enthusiasm for bioenergy demonstration projects, they lacked the authority and resources to formulate long-term energy policies that include these projects.

In recent years, emphasis of bioenergy development in Shandong has been shifted from pyrolysis gasification to marsh gas[33] as the national government does in its most rural areas. Pyrolysis gasification is no longer attracting the interest of government leaders. Infrastructure of marsh gas is cheaper to construct and easier to manage than that of pyrolysis gasification in rural areas (Hall et al., 1992; Lettinga and Haandel, 1993; Klass, 1998; Ma, 2005). However, marsh gas projects also encounter many problems. In northern China, the temperature is very low in winter, which easily freezes marsh gas pools. There is still no satisfying way to treat poisonous residues, which could cause heavy metal pollution to crops and vegetables. Marsh gas pools produce unpleasant smells. With current technologies, production and use of marsh gas is not safe enough. It was reported that a villager fell into the pool and died in Guangxi Province (Feb. 6, 2003), and that a marsh gas pool exploded in Fujian Province (Aug. 17, 2007).

Other policies also influenced the implementation of bioenergy projects in rural areas. To push the so-called “Building New Socialist Countryside” campaign, more and more farmland is occupied by new buildings and infrastructure. Farmers lost farmland, and areas of corn and rice plantation reduced. Shortage of biomass resources led to the closing of well-constructed and well-managed stations, such as CXC station. But at the same time government documents still see large-scale pyrolysis gasification projects as important contributions to “Building New Socialist Countryside” (China State Council, 2005).

4.5.3 Technical shortcomings

Pyrolysis gasification technology was designed and developed 20 years ago, for application in rural areas. Too much attention was paid to lowering costs, with equipment having a simple structure and labor-intensive operation. This had a number of consequences.

[33] It can also be called biogas or gas from anaerobic digestion. I used the term “marsh gas” in this research because it is the most widely used one in China.

Insufficient purification devices were designed, which resulted in tar jamming. The equipment could not treat wet fuels. The caloric value of produced biogas was too low. And during construction, no high-quality steel was used and storage facilities and pipes started to rust and leak biogas.

These technical problems prevented pyrolysis gasification from becoming a dominant renewable energy technology in China. Some advanced bioenergy technologies developed in Western countries remained too expensive for rural areas in China. Although domestic research institutes are making efforts to improve these technologies and experiment with electricity generation using biomass (e.g. SZY and other places), it will take some time before pyrolysis gasification technology can meet the technological requirements of today.

4.5.4 Financial shortcomings

Demonstration projects of pyrolysis gasification were developed mainly for rural areas, where social benefit is more important than economic benefit. Sufficient financial support, for example, through government subsidy, tax reduction and low-interest loans have been necessary for establishing these kinds of projects. External investment to the evaluated projects was for all stations sufficient to launch the biogas station.

Financial problems especially occurred during the running of stations. A biogas station has to pay for fuels, workers' salary, electricity bills, house rent and regular repairs. At the same time, no effective renewable energy market has been established, and biogas was sold at a low price (on average 0.20 yuan/m^3). The annual deficit of a biogas station evaluated in this study is estimated at more than 30,000 yuan (€ 3,000), which had to be compensated by the village government (see Table 4.4). Increasing the gas price would be a logical solution. In order to balance cost and benefit, the gas price should increase around 60%. Village officials – who are in charge of setting gas prices – are reluctant to set higher gas prices, as it is likely to raise strong opposition from villagers and a reduction in biogas consumption. But village budgets for necessary repairs, fuels, and salary are limited, also because only a part of the community profit from cheap biogas. SSC station is the only one that received continuous funding from China's Ministry of Agriculture during operation, which made it possible to carry out daily maintenance and further technical improvement. This seems to be a main reason why SSC station is the only station in good condition. Unfortunately, other stations can hardly survive without this kind of continuing financial support from (higher level) governments.

4.5.5 Lack of public support

Raising gas prices also is difficult as biogas stations did not receive full support from local residents. Changing cooking routines was one of the major obstacles, while advantages of biomass gasification have been insufficiently realized. In some villages, such as YJC, only one-third of the families chose to install and use pyrolysis gasification equipment. This increased infrastructure cost per consumer, while later connections to the biogas infrastructure were significantly more expensive. In addition, quite some villagers refused to pay for the installation of pipes and stove, as they claimed that government promotion of bioenergy in rural areas should come together with free infrastructure. Other villagers were even reluctant to pay for the biogas consumed. In SSC and NGE, many families opened the gas meters installed in their kitchens and destroyed the arithmometer, in order to use biogas "for free".

This low public support for biogasification had three interdependent reasons. First, villagers' access to information on bioenergy technology was insufficient, resulting in a lack of confidence on the economic and environmental benefits biogasification could bring. Second, on average the income level of rural villagers is low. The prime criterion to judge innovations is direct economic benefit. As sufficient fuels often were locally available for villagers, this resulted in a lack of urgency to use – and pay for – new energy sources. Finally, prices of Liquefied Petroleum Gas (LPG), coal and electricity were not high enough to economically motivate villagers to change to biogas.

4.6 Concluding Recommendations

According to its long-term plan on rural construction, China will further extend rural utilization of renewable bioenergy. As one of the relatively mature technologies, pyrolysis gasification is believed to play an important role in this. Around the turn of the millennium, biogasification was expected to provide 4 Mt sce of energy in rural areas by 2010 (Zhou, 2002). However, the various problems indicated and analyzed above seriously threaten this target; more than incidentally biogas stations have been discontinued shortly after establishment. In this respect, we can formulate three recommendations to overcome the various problems bioenergy projects now encounter, and to further bioenergy development in Shandong province and even throughout rural China.

First, it is essential to reform the institutional structure governing bioenergy projects. The spreading of bioenergy responsibilities over too many governmental institutions, with hardly any coordination, clearly frustrates effective development and implementation. Given the cross-departmental nature of bioenergy development, concentrating the responsibility for bioenergy development in one department seems not feasible. The establishment of interdepartmental working groups, both at national and provincial levels, consisting of representatives from the relevant departments and with clear mandates, could improve coordination and responsibility allocation. Such working groups should be in charge of distributing responsibilities regarding renewable energy, coordinating and harmonizing cooperation between governmental sectors and levels, formulating clear objectives and monitoring implementation, and distributing (financial) resources.

Second, an effective renewable energy market infrastructure should be established. Bioenergy technology is still a novelty that emerges in technological and market niches. It functions as a small addition to the existing energy system, and is far from competitive in a normal energy market. But at the same time, it needs to function in a market structure, with price competition, cost recovery and efficiencies, and not as a fully subsidized government program. Consequently, a special renewable energy market would be a logical space, until bioenergy technology matures and is capable to compete with conventional energy technologies. As such, bioenergy can compete with other renewables. In such a renewable energy market, price setting of energy is somewhat higher than in the conventional energy market. Financial policies, including government subsidy, low interest loan, and tax reduction, could take care of that. But full cost-recovery, competition between alternative technologies and arrangements, efficiencies and consumer satisfaction have to become integral parts of such a semi-protected market.

Finally, the technology and management structure of biogas stations need further development and improvement. The current low-technology, community-based bioenergy utilization is too inefficient. This requires of course large efforts in research and development on bioenergy, a tendency that can already be identified, and not only in China (cf. Mol, 2007). But it requires also a better assessment of the scale of bioenery production under various socio-economic and environmental conditions and context. Small-scale household-level gasifiers need less socio-material infrastructure, are less vulnerable, require simple management structures and can therefore be more efficient in certain contexts. In other situations, large scale high-technology industrial bioenergy plants might be prevalent.

Gasified biomass can be processed with advanced conversion technologies to produce electricity or co-generate electricity and heat, a well-know technology (Williams and Larson, 1993). And second-generation liquid biofuel technologies are currently being experimented in various countries. Standardized community-based, low-technology bioenergy production is not necessarily the best solution in all situations in rural China.

Acknowledgement

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Chapter 5 Onshore Wind Power Development in China: Challenges behind a successful story[34]

"Of all the forces of nature, I should think the wind contains the largest amount of motive power – that is, power to move things."
– Abraham Lincoln (1858)

Abstract

Wind energy utilization, especially onshore grid-connected wind power generation, has a history of 30 years in China. With the increasing attention to renewable energy development in recent years, wind energy has become the focus of academic research and policy-making. While the potential and advantages of wind energy are widely recognized, many questions regarding effectiveness of policies and performances of current practices remain unanswered. This paper takes Inner Mongolia, the province that has the most abundant wind energy resources in China, as a case to assess the performance of Chinese onshore wind power projects, focusing on the institutional setting, economic and technological performance, as well as environmental and social impacts. Results show that China is experiencing a rapid growth in wind power generation, which brings China great environmental, energy security and social benefits. However, for a full development of wind energy in China a number of barriers need to be removed: high generation cost, low on-grid price, and stagnating development of domestic manufacture. These findings lead to three policy recommendations.

Keywords: China; onshore wind power; project performance

5.1 Introduction

Wind energy is a pollution-free, infinite sustainable form of energy. Utilization of wind energy uses no natural resource and generates no greenhouse gas or toxic waste. Modern

[34] This chapter contains an article published as Han J., A.P.J. Mol, Y. Lu and L. Zhang. 2009. Onshore wind power development in China: Challenges behind a successful story. *Energy Policy*, Vol. 37, Issue 8: 2941-2951.

wind power technologies can convert the kinetic energy present in wind into a more useful form – electric power. Existing wind power technologies fall into three categories: grid-connected wind farms, distributed generation, and off-grid standalone system. All categories can be installed both onshore and offshore. The onshore grid-connected wind farm – subject of this paper – is the most mature and widely used technology in the world, and so is it in China.

With its large land mass and long coastline, China is rich in wind energy resources. Estimation by China Meteorological Administration showed that average wind power density in China is about 100 W/m^2, with 253 GW of exploitable onshore wind resource (measured at relatively low height of 10 m above ground) and 750 GW of exploitable offshore wind resource (Li et al., 2005). Another research, carried out by UNEP in cooperation with the US National Renewable Energy Laboratory (NREL), calculated 1,400 GW (at 50 m height) of exploitable onshore wind resource and 600 GW of exploitable offshore wind resource (Yang, 2004; Li et al., 2007).

China's efforts to develop wind power can be traced back to the early 1970s. Since then, especially in the past 20 years, the national government has initiated a set of nation-level projects to increase the production and consumption of wind electricity. As a result, total installed capacity in China increased from 25 MW at the end of 1996 to 5,906 MW at the end of 2007. About 160 wind farms at different scales have been established on the Qinghai-Tibet Plateau, Inner Mongolia, the North-West Region, and the South-East Coastal Region of China.

Grid-connected wind power is well developed in Inner Mongolia, especially after 2005. By the end of 2007, its wind power generation capacity exceeded 1,000 MW. Given its great potential for wind energy development, Inner Mongolia is considered a priority area to develop wind power by both national and local governments, therefore more wind farms will be built in this area in the future. The government aims to increase the total wind power capacity in Inner Mongolia to reach 4,000 MW by 2010. This makes Inner Mongolia a perfect case to examine wind energy development in China.

Against the above-mentioned background, this paper aims to investigate the constraints for development of wind energy production to suggest policy recommendations related to that. First, an overview of wind power development in Inner Mongolia is presented. Subsequently, wind power projects in Inner Mongolia are evaluated regarding their institutional setting, economic and technological performance, and environmental and social impacts. Finally, following this evaluation policy suggestions are formulated for improving wind power development in China.

5.2 Wind Power Development in Inner Mongolia

5.2.1 Rich wind energy resources

Inner Mongolia, China's northern border autonomous region, features a long, narrow strip of land sloping from northeast to southwest, neighboring Mongolia and Russia in the north (Figure 5.1). It stretches 2,400 km from west to east and 1,700 km from north to south. It is the third largest province in China, covering an area of 1.18 million km^2, or 12.3% of the country's territory. It is sparsely populated, with only 24.05 million inhabitants (data at the end of 2007). Inner Mongolia has plateau landforms, mostly more than 1,000 meters above sea level. Besides 86.67 million hectares of grassland, there are also hills, plains, deserts, rivers and lakes in Inner Mongolia. It is mainly characterized by temperate zone continental monsoon climate with yearly average temperatures of 0°C~8°C and yearly temperature differences of 35°C~36°C. Spring is warm and windy; summer is short and hot with many rainy days; autumn usually sees early frost and dropping temperatures; winter is long and bitter cold.

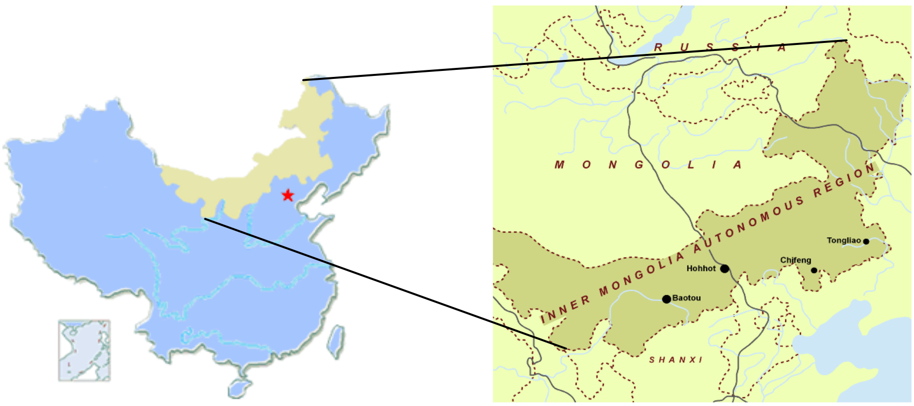

Figure 5.1 Map of China with hilighted Inner Mongolia

Inner Mongolia is abundant in wind energy resources due to its special geographic characteristics such as relative high altitude, open terrain, low vegetation, few buildings, speed increasing effect when north-south air flows through the raised landform, and small ground friction. According to estimations by China Meteorological Administration, Inner Mongolia has 101 GW of exploitable onshore wind energy resources, 40% of the nation's total amount. Furthermore, wind energy resource in Inner Mongolia is distributed evenly both at spatial and temporal scales. Four fifths of its vast territory is suitable for developing wind power, with minimally 4,400 and maximally 7,800 hours of effective wind speed (5~25 m/s) accumulation (Table 5.1). In one word, Inner Mongolia is a perfect place for developing wind energy.

Table 5.1 Wind energy resource in Inner Mongolia (adapted from Zang and Feng, 1998)

	Area (10^3 km^2)	**Wind power density (W/m^2)**	**Wind energy density (kWh/m^2)**	**Effective wind speed accumulation (h)**
Greatly abundant	83	240~400	1,500~3,600	6,100~7,800
Abundant	200	180~220	1,000~1,500	5,300~6,780
Exploitable	660	100~200	400~1,000	4,400~6,000

5.2.2 History of wind power development

Only in the 1970s, Inner Mongolia started to develop wind power by constructing off-grid standalone wind turbines for herdsmen. The first grid-connected wind farm in Inner Mongolia was built in December 1989. At that time, five 100 kW wind turbines (Model 56) produced by the American company Wind Power were installed in Zhurihe Wind Farm, in the north-central part of Inner Mongolia. Subsequently, four other wind farms were constructed in succession: Shangdu in 1994, Xilinhot in 1995, Huitengxile in 1996, and Dali in 1999. At this stage, scales of wind farms were very limited, with maximum individual turbine capacity of 600 kW and wind farm capacity of 5,400 kW (in Huitengxile). There existed no domestic wind turbine manufacturer. All equipments were imported from Spain, United States, Denmark and Germany.

Wind power developed steadily from 2000 to 2005 in Inner Mongolia, with an annual increase of 16% in installed turbines and 24% in installed capacity (Figure 5.2). At this stage, a market of domestically produced wind power equipment emerged, symbolized by the establishment and growth of domestic wind turbine manufacturers. Although the proportion of domestically manufactured installed capacity in total installed capacity reached only 15% in 2005, China became one of the countries capable of manufacturing wind turbines independently.

Installation of wind power in Inner Mongolia skyrocketed in 2006 and 2007, during which period most of the wind farms in Inner Mongolia were constructed. Installed wind power capacity tripled in both years and so did the number of installed wind turbines (Figure 5.2). At the end of 2006, Inner Mongolia exceeded Xinjiang to become the leading province in wind power capacity in China. By the end of 2007, Inner Mongolia had 33 wind farms (at 19 locations) with 1,856 wind turbines and 1,683.69 MW of installed capacity, which accounted for 26.5% of the total installed capacity in China (Table 5.2). At this stage, domestic manufacturing capability and capacity also increased rapidly. The proportion of domestically produced turbines in the total installed capacity increased to about 60% by the end of 2007. This proved to be vital for lowering the cost of wind turbines and of constructing wind farms.

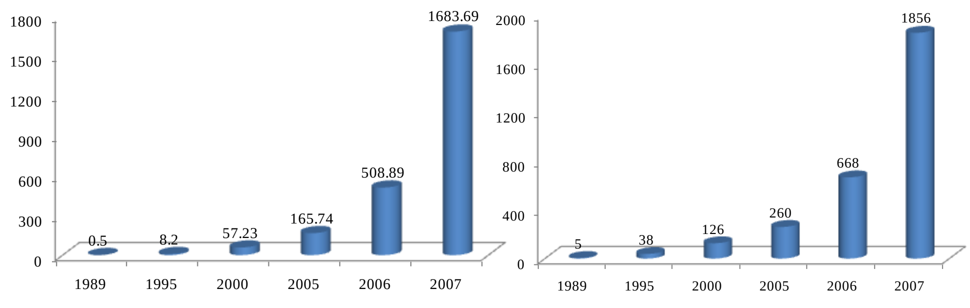

Figure 5.2 Installation of wind power in Inner Mongolia (MW)

left: wind power capacity; right: number of wind turbines

Table 5.2 Wind farms in Inner Mongolia (by the end of 2007. Source: Shi, 2008b, adapted and updated by the authors)

Location	Wind farm	Number of turbines	Total capacity (MW)
Sonid Youqi	Zhurihe	50	33.90
Shangdu	Dashanwan	12	3.60
Xilinhot	Baoligenshan	13	4.78
Qahar Youyi Zhongqi	Huitengxile	214	189.00
	Dadonggou	120	121.50
	Dayangpuzi	134	100.50
	Caoduozi	29	44.50
Hexigeten Qi	Dali (Maolin)	73	51.36
	Dali (Datang)	27	40.50
	Saihanba	195	165.75
	Daheishan	4	3.40
	Nandian	4	3.00
Duolun	Xishan	36	30.60
Ongniud Qi	Sunjiaying	134	100.50
	Wudaogou	66	49.50
	Bolike	4	8.00
Songshan Qu	Dongshan	120	102.00
Xin Barag Youqi	Altanemole	33	49.50
Zhuozhi	Bayinxile	34	44.00
Zhengxiangbai Qi	Baoligentaohai	2	3.00
Abag Qi	Huitengliang (Beifang)	33	49.50
	Huitengliang (Guohua)	73	99.50
	Huitengliang (Datang)	38	57.00
Bayan Kuangqu	Aorigehu	2	1.50
Damao Qi	Bailingmiao	28	35.00
Erehot	Xili	4	6.00
Hanggin Qi	Yihewusu	43	32.25
Urad Houqi	Narenbaoligen	10	7.50
Urad Zhongqi	Bayinhanggai	58	43.50
	Chuanjing	124	98.80
	Turiguge (Huiren)	66	49.50
	Turiguge (Zhongdiantou)	20	15.00
Taibus Qi	Gongbaolage	53	39.75
Total	**33**	**1,856**	**1,683.69**

5.2.3 Current policy objectives

From the Eighth Five-year Plan (1991-1995) until the Eleventh Five-year Plan (2006-2010), China gives the development of renewable energy resources, especially biomass, solar, small hydro and wind energies, strategic importance in every stage of its long-term national development plan[35]. *China's Renewable Energy Law*, which was activated in 2006, set developing renewable energy as priority in national energy strategy, aiming to establish capacity and infrastructure for rapid renewable energy development, and to create a sustainable market for renewable energy. Through the law, R&D and commercialization of renewable energy technologies were regarded as priority of modern technology and high-tech industry development at national level. The Chinese government has also set compulsory market shares of wind energy for different target years. The *Medium and Long-Term Development Plan for Renewable Energy* required installment of 5,000 MW of onshore wind power capacity and 200 MW of offshore wind power capacity by 2010, as well as 30,000 MW onshore and 1,000 MW offshore by 2020. The *11th Five-Year Renewable Energy Development Plan*, passed in March 2008, doubled the 2010 onshore objective to 10,000 MW. Besides these targets, in 2003 China also set targets for a mandatory proportion of domestically produced wind turbines used in newly constructed wind farms that every turbine must meet the 70% domestic cost content requirement, in order to further develop a national wind industry and to lower the costs of wind farm construction.

In Inner Mongolia, the government has set clear development targets for wind power in its official documents[36]: by the end of 2010, the total installed capacity of onshore grid-connected wind power has to reach 4,000 MW. It is an ambitious target, as the Inner Mongolia government aims to fulfill 80% of the 2010 national target of onshore wind power development. In order to achieve this target, in the same documents the Inner Mongolia government planned five GW-level wind farms – Huitengxile, Huitengliang, Bayinhanggai, Saihanba and Bayinxile – to construct another 2,316 MW installed capacity within three years. Notably, 1,174.8 MW of capacity was installed in 2007. In other words, most likely Inner Mongolia will easily reach its 2010 development targets within the

[35] In the *China Electric Power Act* (1995), the first Chinese law that discusses energy policy, it was declared that China government "encourages the development and utilization of new and renewable energy resources". This principle was reaffirmed in *China Energy Saving Law* (1998), *Medium and Long-Term Development Plan for Renewable Energy* (2007), and the *Eleventh Five-Year Plan for New and Renewable Energy* (2008).

[36] The *11th Five-year Plan of Energy Industry in Inner Mongolia* and the *11th Five-year Plan and 2020 Long-term Targets of Wind Power Development in Inner Mongolia*, both issued by Inner Mongolia Development and Reform Commission (IMDRC) in 2006.

remaining three years if it continues at the current speed of wind farm development. Some experts even expressed their concerns regarding a too rapid development of wind power, and advocated sticking to the predetermined schedule.

5.3 Evaluation Methods of Wind Power Projects Performance

After 15 years of development, wind power generation in Inner Mongolia has grown up. Nevertheless, increase in scale alone does not necessarily mean successful wind power development. Inner Mongolia still falls short in wind power production compared to a number of western countries. An integrated evaluation of the implementation performance of wind power projects in Inner Mongolia can assess the achievements in developing wind power in this autonomous region during the past years, and appraise what changes are necessary for the future.

In evaluating the performance of wind power development in Inner Mongolia, this paper focuses on a systematic analysis of wind farms in Inner Mongolia regarding four aspects: the institutional arrangements, economic performance of wind farms, technological performance of wind farms, as well as social and environmental impacts.

Data for performance evaluation were collected from three sources. First, documents from various sources were reviewed to get a clear idea what kind of policies have been formulated, what policy measures and objectives have been determined, and what outcomes have been claimed in Inner Mongolia. Different methods have been used at different stages of this study to collect official and unofficial policy documents, governmental reports and scientific publications. Second, face-to-face in-depth interviews were held with officials and experts in governmental departments (at national, provincial and local levels), wind power research institutes and companies. Semi-structured questionnaires were used for these interviews.[37] Third, representative case studies were carried out at Huitengxile, Zhurihe and Dashanwan wind farms in Inner Mongolia. These three wind farms are different at locations, scales and main turbine manufacturers, representing all wind farms in this Inner Mongolia. On-site observations, systematic closed interviews with staffs in wind farms, and discussions with local residents and neighbors were carried out at each wind farm.

[37] Interviews were held at: Center for Renewable Energy Development in Energy Research Institute NDRC; Department of Energy IMDRC; Department of Electricity of Wulanchabu City, Inner Mongolia; Inner Mongolia Association for Science and Technology; Government of Qahar Youyi Zhongqi, Wulanchabu City, Inner Mongolia; Chinese Wind Energy Association; Research Institute for Wind Power, Inner Mongolia; Inner Mongolia North Longyuan Wind Power Company Ltd.

5.4 Institutional Arrangements for Wind Power Projects

Issues concerning institutional arrangement for wind power projects in Inner Mongolia include project approval, wind farm management and pricing policy. There are two types of wind power projects in Inner Mongolia: government contract projects and concession projects. Government contract projects appeared in the early 1980s, while concession projects have a relatively shorter history, as the first project was carried out in 2003.

5.4.1 Government contract projects

Approval of government contract projects works as follow: wind power companies hand in project proposal to NDRC or Inner Mongolia Development and Reform Commission (IMDRC). For projects larger than 50 MW, the NDRC is responsible for decision-making; while the IMDRC, local counterpart of NDRC, can approve projects smaller than 50 MW without approval from NDRC.

Wind farms in operation are run by wind power companies that constructed the wind farms. While all wind power companies in Inner Mongolia are directly managed by IMDRC. Purchase of wind power is strictly controlled by the national government. Prices of wind electricity are decided in Power Purchasing Agreements (PPA) signed between NDRC (or IMDRC) and wind power companies by calculating generation cost and reasonable profit rate. The two power gird companies in China, the State Power Grid Corporation and the Southern Power Grid Corporation, are obliged to purchase all wind electricity, which is subsequently sold to ender users from these two grid companies. If the purchasing price of wind power is higher than the price of power generated from other sources, the price difference will be apportioned within the whole power grid (Figure 5.3).

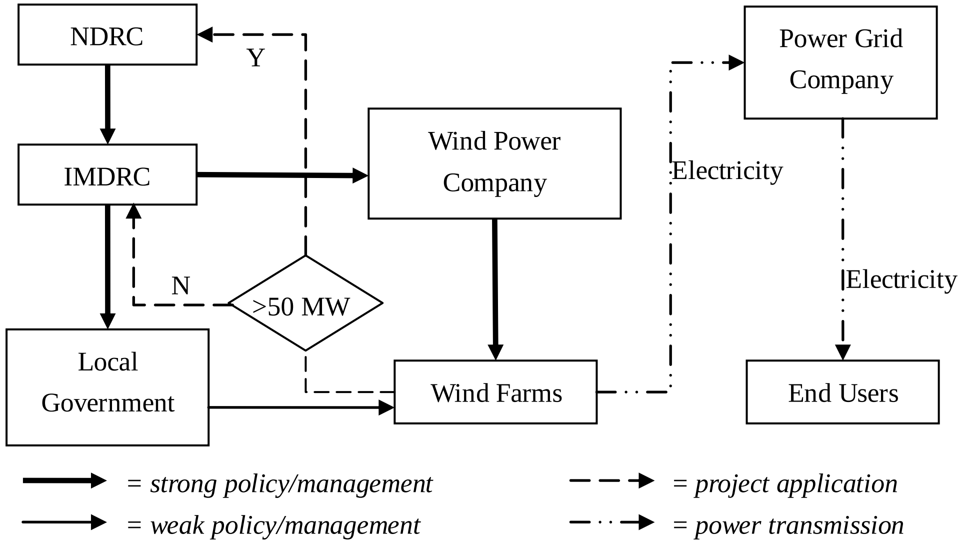

Figure 5.3 Institutional structure of wind farm management in Inner Mongolia

This project management mechanism has two advantages. First, there exist a legal separation between electricity generation and electricity transport & distribution. Wind power is generated by wind power companies, while it is transported and distributed by power grid companies. This separation to some extent can avoid monopolization of the wind power market. Some Chinese professionals foresee a separation of electricity transport and distribution in the near future, not unlike what we witness in several western countries. Second, the authority of IMDRC to decide on wind power projects smaller than 50 MW significantly increases efficiency of wind farm establishment. At the early stage of wind power development in China, every new project needed to be approved by NDRC, which made the application for wind power projects very complex and time consuming. This new project approval procedure gives impetus to the rapid development of wind farms in Inner Mongolia.

5.4.2 Concession projects

In addition to government contract projects, a new and special wind power project model, called the "concession model" (Figure 5.4), is increasingly used for wind power projects in China (Lema and Ruby, 2007). Before 2003, the development of a wind power project was granted to one consortium under a government contract. In 2003, the concession model was effectuated to stimulate competition in wind power development. Essentially, the concession model is a tender system. The China Meteorological Administration assesses wind resources throughout the country. NDRC offers several selected locations for concession projects to power companies who are interested in generating electricity from wind energy, and provides investment facilities like the establishment of access roads and power grid. Wind energy developers – usually power companies combined with a wind turbine manufacturer – are invited to bid for the development of a location. The one who offers the best price per kWh on the terms provided will win the concession and thus the right to produce electricity on the site[38]. In December 2007, the fifth concession bid was opened in Inner Mongolia.

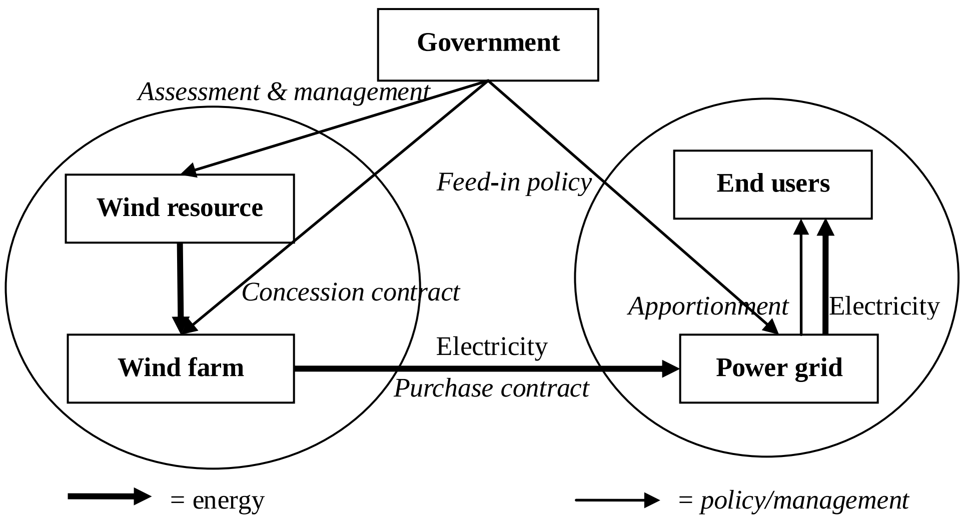

Figure 5.4 Concession model of wind power development

Source: adapted from Zhou and Han, 2005

[38] From the second bid, the so-called "equipment localization rate" was also brought into the decision of selecting the developer. This refers to the degree to which the developer uses domestically produced equipment and technology.

The pricing of wind electricity under concession projects works as follows: during the first 30,000 full load hours, wind farms sell wind electricity to the grids at the price pre-established in the original bid. After this initial period and until the end of the concession period, electricity is sold at a uniform on-grid price. The wind electricity is purchased in the same way as from government contract projects.

Advantages of this concession model include the combination of functions of government and power companies, the selection of suitable developers and lower wind power prices. All power companies are allowed to participate in wind power development by bidding for and putting financial resources into concession projects. By the end of 2007, 1,600 MW of wind power projects have been approved through the concession model in Inner Mongolia.

However, the concession model has also obvious disadvantages. First, some bidders intentionally underestimate operating costs to get a lower power price compared to other bidders. Once the bid is selected, it proves economically impossible to construct and operate the wind farm. In other words, insufficient financial resources are put into the development of the wind farm. Large power companies in China are required to build a certain amount of generation capacity from renewable energy resources[39]. This is an important reason for hiding costs of wind power in other investments to win the bid. Lacking competition of international developers or turbine manufacturers in the concession bids is another reason for this problem. This problem has been partly solved in the fifth phase of concession projects, which changed the bid and selection mechanism in the following way: the highest bid and lowest bid were excluded and then the bid most close to the average price of the remaining bids won the concession project.

Second, the concession model may reduce government's normal tax income. Under the concession model, wind power developing enterprises who win the concession bids enjoy preferential tax policy. There is a great chance that the enterprises include other economic activities into wind power projects so that they can gain more economic profits with low tax rates. Without effective monitoring, the government's revenue is possible to be hurt.

[39] In the *Medium and Long-Term Development Plan for Renewable Energy*, NDRC announced Renewable Portfolio Standard (RPS) mandates in power generation sector. For the whole sector, the share of electricity generated from non-hydro renewable energy resources should reach 1% of total electricity generation by 2010 and 3% by 2020. For any power producer with installed capacity greater than 5 GW, the mandatory share is raised to 3% by 2010 and 8% by 2020.

5.5 Economic Evaluation of Wind Power Projects

5.5.1 Funds for wind power project development

The most crucial task in wind power development is ensuring funding. Currently, the average construction cost of wind farms is about 10,000 yuan/kW. This means Inner Mongolia needs some 23.16 billion yuan over the year 2008-2010 to fulfill its development objectives. Funds for wind farm construction were initially raised mainly by the national government from Chinese banks and international cooperation projects. For instance, 50 million U.S. dollars of mixed credit[40] was provided by the Danish Government to construct the Huitengxile Wind Farm in 1996. A similar funding channel was used to develop the Zhurihe Wind Farm and the Dashanwan Wind Farm. With this mechanism, allocation and utilization of funds were strictly monitored by governmental departments, and financial security and transparency was ensured.

With the rapid development of wind power in Inner Mongolia (and in China), international financial resources could no longer meet the need of wind farms developers. In order to overcome this barrier, two additional mechanisms were introduced. First, the Clean Development Mechanism (CDM) provided a major channel for foreign funding (Gilau et al., 2007). In 2002, the first CDM contract between the Netherlands and China was signed. According to this contract, the Netherlands buys Carbon Emission Reduction credits (CERs) from China through the Huitengxile Wind Farm project at a price of 54 yuan per ton of CO_2 reduction. Within the 10 year contract period, 54,000 t CO_2 emission would be reduced, which provided Huitengxile 0.27 billion yuan of Dutch funding. Second, the wind power concession model has advantages in attracting investments from power companies. Inner Mongolia used the funds raised through the concession model to scale up its wind power development. The Huitengxile Wind Farm was extended (200 MW) by the second concession bid. The Huitengliang Wind Farm (300 MW×2) and Bayinxile Wind Farm (200 MW) were approved by the fourth concession bid (Li et al., 2007). The Niaolan Yiligeng Wind Farm (300 MW) and Tongliao Beiqinghe Wind Farm (300 MW) were approved by the fifth concession bid (Ni, 2008).

[40] Mixed credit is an interest free or low interest loan with 10 or 15 years maturity aimed at financing supplies of equipment and related services for development projects in relatively creditworthy developing countries.

5.5.2 Poor economic profits

To compete with conventional energy resources, it is important for wind farms to gain enough profit during operation. Unfortunately, wind farms in Inner Mongolia are not yet able to achieve satisfying profits, mainly due to both high generation costs and cheap prices of wind power.

Firstly, the cost of wind power is higher than that of fossil fuel electricity in Inner Mongolia. Average costs for wind electricity generation in Inner Mongolia range between 0.45~0.60 yuan/kWh. Meanwhile, the average cost of coal-fired electricity is only 0.30 yuan/kWh. The total costs of a wind power project consist of construction costs, maintenance costs, loan interests, salary costs and taxes. The most important "raw material", wind resource, is free. Although the construction costs of wind farms in Inner Mongolia experienced a steady decline over the past two decades (Li et al., 2005), the relatively high production costs of wind electricity – compared to fossil fueled electricity – is primarily caused by high construction cost of wind farms (Lew and Logan, 2001; Mathew, 2006). Currently, the average construction cost – consisting of equipment, infrastructure, the building process and land rents – is estimated to be around 10,000 yuan per kW installed capacity. The majority of the wind turbines installed in Inner Mongolia are imported from overseas. Key components of domestically made turbines are also imported. In comparison, imported turbines and components are 30% more expensive than domestic ones. As a result, depreciation of equipments accounts for a large proportion of generation cost of wind electricity, compared to coal electricity. To maintain equipment, a wind farm needs to pay about 0.15 yuan for every kWh of electricity it generates. The average rate of interest on loans for wind farms is about 9% of the total costs. Salary of employees is estimated to be about 0.07 yuan/kWh. Another 0.03 yuan/kWh relates to other issues in wind farm management. Taxes imposed on wind farms include value added tax[41] and income tax[42]. Import tariff and VAT on imported goods are refunded[43]. Approximately, on average wind farms pay 0.17 yuan taxes for every kWh of electricity.

High generation costs make wind electricity less competitive in comparison with fossil-fueled electricity. When there are still abundant fossil fuel resources available in the world, no power company is willing to afford less benefits – or even economic losses –

[41] Wind farms enjoy a preferential VAT rate of 8.5%, half of the rate normal enterprises are experiencing.
[42] Refunded completely in the first 2 years, refunded for 50% in the next three years (which means a tax rate of 16.5%), and experiencing the full rate (33%) afterward.
[43] Source: Ministry of Finance File No. 36[2008], "Policy on adjusting import tax of wind turbine components".

through the development of a large capacity of wind power. Currently, the incentive for power companies to develop wind power is mainly in anticipation of renewable portfolio policy and increasing fossil fuel prices in the future. If no further stimulation policy measures are taken and fuel prices remain fluctuating, power companies will quickly loose enthusiasm in wind power development.

Secondly, low profits are caused by cheap wind energy prices. Wind farms gain limited income by selling electricity to the power grids. In 2007, average wind electricity price in China was only 0.63 yuan/kWh. It is lower than wind electricity prices in 2004 in most western countries with a well-developed wind power sector (Figure 5.5). The only countries with wind electricity prices lower than China were Norway (0.32 yuan/kWh), Sweden (0.53 yuan/kWh) and the United States (0.55 yuan/kWh). However, in Norway up to 25% of the construction cost for wind farms is subsidized by the national government. Wind farms in Sweden receive an "ecological award" equaling 0.225 yuan/kWh, while wind farms in the United States get 0.126 yuan/kWh tax refund. Furthermore, wind resources in all three countries are better than in China, which lowers their costs of wind electricity generation.

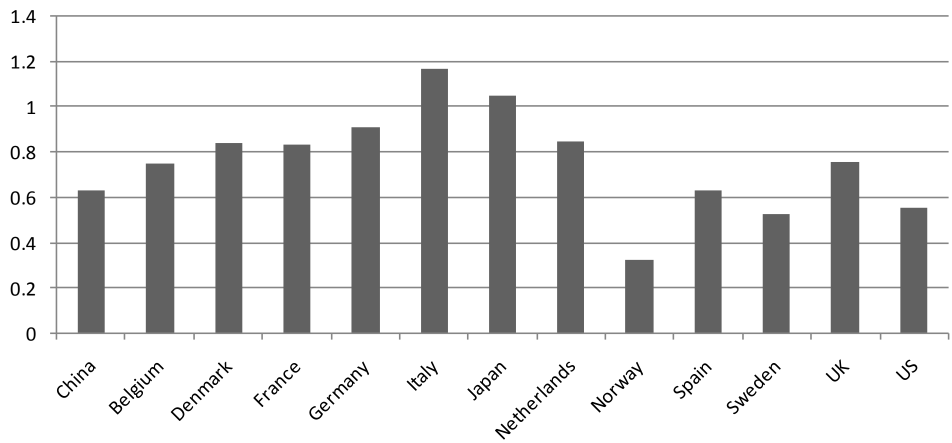

Figure 5.5 Comparison of wind power price in China (2007) with foreign countries (2004) (Sources: Li et al., 2005; author's calculation)

Low price of wind electricity in China has its institutional reasons. As mentioned above, the price of wind electricity is formed in two different ways. If the wind power project is directly – that is, not in competition – contracted by NDRC/IMDRC to the company, the electricity price is decided by NDRC/IMDRC when the project is approved. The price is then normally high enough to ensure wind farms an economic profit. Under the concession contract, the price is set differently. In order to win the concession bid, and partly due to an overestimation of the on-grid price in the future, wind power enterprises are inclined to take high risks and set a low price in their bids for the first 30,000 full load hours. As a result, the average wind electricity price of concession projects is much lower than the electricity price of government contract projects (see Table 5.3). The low purchasing price offered by winning concessions provides little incentives for further investments.

Table 5.3 On-grid price of wind electricity of major wind farms in China

Wind farm	Location	Price (yuan/kWh)	Pricing mechanism
Huitengxile	Inner Mongolia	0.382	Concession project
Bayinxile	Inner Mongolia	0.466	Concession project
Huitengliang	Inner Mongolia	0.420	Concession project
Rudong	Jiangsu	0.436	Concession project
Baoligenshan	Inner Mongolia	0.648	Government contract
Zhurihe	Inner Mongolia	0.609	Government contract
Dashanwan	Shangdu	0.609	Government contract
Dabancheng	Xinjiang	0.533	Government contract

High generation costs and low on-grid prices of wind electricity have a direct impact on current wind power development in China: many power companies wait with further investments until the wind power market proves mature and profitable. The Chinese wind power industry seems to be caught in a vicious circle of “high costs/low price – insufficient investment – high costs”.

The second phase of Huitengxile Wind Farm can be taken as an example for roughly assessing the economic profits of a wind farm in Inner Mongolia (Table 5.4). This project started in October 2005 and the turbines came into use at the end of 2006. Total investment for the second phase reached 516.5 million yuan, with 39.6 MW installed capacity and a designed operational lifetime of 20 years. The electricity price in the concession contract was 0.382 yuan/kWh (post-tax). Information on economic costs and benefits is listed in Table 4. During its operating lifetime, the wind farm generates 2,854.9 (142.97×20=2,854.9) million kWh of electricity. The construction cost per kWh electricity is 0.181 yuan and the total cost per kWh electricity is 0.450 yuan. However, during the first 30,000 full load hours (8.3 years) the electricity generated by this wind farm is sold to the grid at a price of 0.382 yuan/kWh, resulting in an annual deficit about 10 million yuan. This deficit can be compensated only if the generation cost of wind electricity is reduced significantly to 0.334 yuan/kWh or if the price of electricity after that is increased to 0.5 yuan/kWh.

Table 5.4 Cost and benefit information of Huitengxile Wind Farm (39.6 MW)

Cost		Benefit	
Construction costs (yuan/kW)	10,901	Electricity price (yuan/kWh)	0.382
Interests (yuan/kWh)	0.041	Electricity generation (10^6 kWh/y)	142.97
Salary costs (yuan/kWh)	0.068		
Maintenance costs (yuan/kWh)	0.156		
Other costs (yuan/kWh)	0.034		

5.6 Technological Performance of Wind Power Projects

The third performance indicator of wind power development is technological performance. We will especially pay attention to three sub-indicators: site selection, average scale of individual wind turbines, and the localization of wind power manufacturing.

5.6.1 Site selection

A suitable site for a wind farm influences its technological as well as economic performance. Richness of wind resources, transportation conditions and distance to the power grid are main criteria for selecting wind farm sites.

The amount of potential wind energy depends mainly on wind speed at site and to a lesser extent on the density of air, which is determined by air temperature, barometric pressure, and altitude. For any wind turbine, the power and energy output increases when the wind speed or air density increases (Abderrazzaq, 2004). Therefore, it is crucial for a wind farm to be located in areas with high and stable wind speed. Besides a favorable meteorological situation, convenient transportation and access to power grid are vital for lowering construction and operational costs of a wind farm. Close distance to railways or highways helps reducing transportation costs during the construction of wind farms. Convenient conditions to transmit electricity to the grid are necessary for large scale electricity generation by wind farms.

These three indicators – wind resources, transportation and access to power grid – were applied to assess technological performance of the three wind farms selected for case study (Table 5.5).

All three wind farms are located in rich wind resource areas, according to the National Standard for areas with rich wind resources. In comparison, Huitengxile wind farm is richer in wind resources than the other two. Although average wind speed in Huitengxile is the lowest among the three farms, the longer time of effective wind speed compensates this disadvantage. Transportation conditions are somewhat different among the three. Huitengxile Wind Farm does not have convenient access to railway, but it locates at a province-level expressway. Zhurihe and Dashanwan are very close to the railway system. Both wind farms constructed roads to railway stations nearby.

Table 5.5 Site situation of three wind farms in Inner Mongolia

Wind farm	Wind speed (m/s)*	Effective wind speed (h)**	Wind power density (W/m²)	Transportation condition	Distance to grid
Huitengxile	7.2	6,255	662	38 km from railway; highway across	50 km from 220 kV; 110 kV across
Zhurihe	8.1	5,808	554	9 km from railway	9 km from 110 kV
Dashanwan	7.8	5,628	447	0.5 km from railway	35 kV across
Standard***	>6	>5,000	>300	-	-

* At 10 m height; ** 5~25 m/s at 10 m height; *** National standard for area of rich

Connection to power grid has become a bottleneck for wind power development in Inner Mongolia. Within the three wind farms, Huitengxile is the only one who has a convenient connection to power grid. The electricity it generates is sent to a 110 kV grid across the wind farm. However, the grid can not satisfy further development of the wind farm. Zhurihe needed to build an additional transmission line to the grid 9 km away. The 35 kV power grid across Dashanwan was too small. An upgrade proved essential to improve electricity transportation efficiency.

Grid expansion is too costly for power companies. In China the average cost to construct 100 km of transmission line is 350 million yuan. Upgrading the power grid is even more expensive. Wind farms are normally built in remote areas. Power companies can hardly afford the construction cost of transmission line from the main power grid to their wind farms. Although it is stated in concession project policies that “the power grid company will construct transmission line to the wind farm”, there is no obligation regarding the time the construction should be finished or the standard of transmission line. Behind the booming wind farm construction, it is also notable that slow down in power grid construction can delay future development of wind power in China.

5.6.2 Average scale of individual wind turbine

At a given location, efficiency of wind power generation increases when average turbine scale increases. It is a worldwide trend that the scale of individual turbines is becoming larger and larger. Nowadays, 1,500 kW and 2,000 kW turbines are prevailing in the international wind turbine market (Shi, 2008).

The average scale of wind turbines installed in each year in Inner Mongolia shows a steady increase from 1989 to 2007, with an exception in 2000 (Figure 5.6). The minimum scale of individual turbines is 100 kW, which was installed in Zhurihe in 1989. The maximum reached 2,000 kW, which were turbines installed in Caoduozi, Bolike and Bayinxile in 2007. It is the largest scale of individual (onshore) turbines in China and comes close to the prevailing scale in the western world.

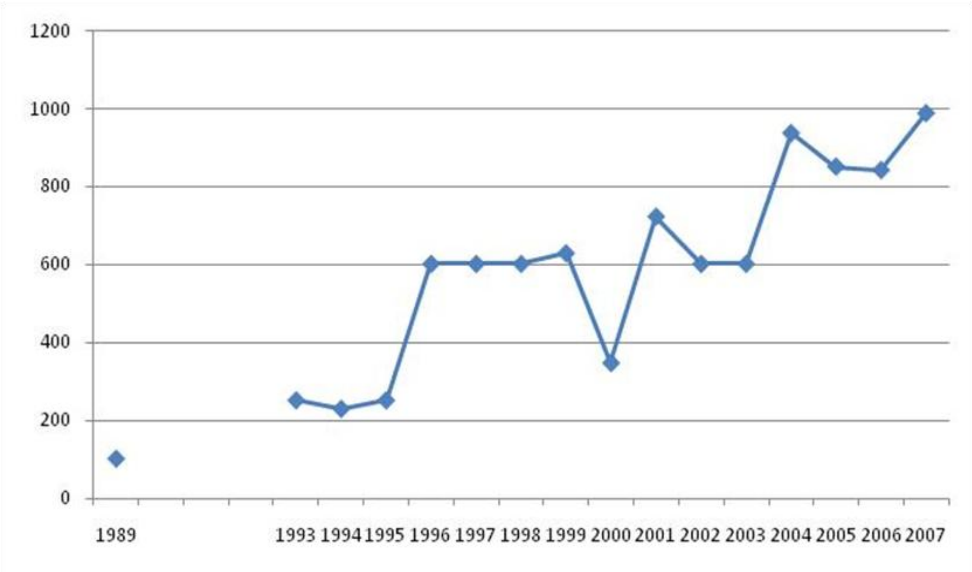

Figure 5.6 Average scale of turbine installed in Inner Mongolia

5.6.3 Localization of wind power system manufacture

According to the Global Wind Energy Council (2008), China is now the fastest growing wind power market in the world, while Inner Mongolia is the fastest growing wind power market in China. Increase in the use of domestically produced wind power systems can significantly reduce the construction costs of wind farms. Due to the reduction in purchasing price, transportation costs and custom tariffs, domestic wind turbines are about 30% cheaper than imported turbines[44]. Domestic turbines also have advantages in better adaptation to Chinese or Inner Mongolian circumstances, short delivery terms and convenient/cheaper after-service.

There are three types of wind turbine manufacturers in China: domestic-owned, joint ventures and foreign-owned. The market share of the former two types of enterprises is considered an indicator of the maturity of China's domestic wind turbine industry. Of all wind turbines produced in China up till now, there are more turbines manufactured by foreign-owned enterprises (53%) than those by domestic-owned (45%) and joint-venture enterprises (2%). This is partly caused by the short history of domestic wind turbine industry in China. A factor in the stagnating development of the domestic wind turbine industry was the high import tax of wind turbine components before 1997[45]. Domestic enterprises without wind turbine R&D capacity could not afford the cost of importing wind turbine components.

This situation did not change until it became mandatory that every turbine in concession projects meet the 70% domestic cost content requirement. Since then, the proportion of domestic turbines was included as one of the assessment indicators in evaluating bids of concession projects. The developer was also required to include a domestic manufacturer into the bidding team. All these policy measures provided opportunities for China's wind turbine companies to boom. Therefore, in 2007 in China the proportion of wind turbines manufactured by domestic-owned (56%) and joint-venture enterprises (2%) exceeded those by foreign enterprises (42%). The proportion of domestic wind turbines installed in Inner Mongolia also experienced rapid increase in the past decade. Before 2000, no domestically produced wind turbines were installed in Inner Mongolia,

[44] However, already 70% localization rate is required. The potential for additional cost reduction is somewhat limited in this respect.
[45] It is now totally refunded, according to State Council File No. 37[1997], "Circular on adjusting tax policy of imported facilities".

while in wind farms established in Inner Mongolia in 2006 and 2007 domestically manufactured wind turbines dominated with 55.7% and 58.9%, respectively.

Along with the market-oriented reform of wind power industry in China, a local wind turbine industry is evidently being developed in China. There are now over 20 domestic wind turbine manufacturers such as Goldwind, Huarui, Wandian, Huiteng, Longyuan, Zhonghang, and Yunda. Most of them have the technological capability to manufacture wind turbines with a generating capacity of 750 kW, and some are in the process of developing megawatt-scale turbines. Several demonstration projects have domestic 1.2 MW and 1.5 MW wind turbines (Shi, 2008).

However, there are obviously shortcomings of increasing localization of wind turbine manufacture in China. First, most local wind turbine companies still need to purchase core components, such as the rotor and gearbox, from overseas. They manufacture only supporting systems that account for a small proportion of the total costs of the entire wind turbine. Consequently, the construction costs of wind farms cannot be reduced significantly before these core components are manufactured domestically.

Second, cooperation with foreign companies results in the transfer of wind power equipment rather than technologies. This transfer of hardware (equipment) is helpful in meeting localization criteria in short term, while the transfer of software (knowledge and technology) is more important for the establishment of a successful domestic wind turbine industry in the long term.

Third, domestic wind turbine technology is still immature. Wind farms need to pay more time and money to maintain domestic turbines than imported ones. The immature domestic technology also results in wind turbines frequently breaking off. It is estimated that average full load hours of wind turbines in Inner Mongolia was 1,933 h in 2007 (Shi, 2008). It is higher than the national average (1,787 h), while much lower than that in western countries such as United Kingdom (2,628 h), Australia (2,500 h) and United States (2,300 h). In some (extreme) cases, a wind turbine with 2,000 designed full load hours can actually be in operation for only 300 hours a year[46]. Besides technical reasons, some researchers also ascribe the problem of low full load hours to the prevailing policy system that is more focused on installed capacity than actual utilization of wind resource. There are no statistics on real electricity produced by wind farms. MW, instead of kWh is the only criterion for assessing wind power development in China (Shi, 2008).

[46] As was the case for three Huarui wind turbines installed in Boligenshan Wind Farm in 2003.

5.7 Environmental and Social Impacts

5.7.1 Environmental impacts

Environmental impacts of wind power development in Inner Mongolia refer to the impacts of wind power development on local environmental quality.

The Chinese government has set the objective of 10% air pollutant reduction between 2006 and 2010 in its 11th national Five-Year Plan, and wind power will be an important contributor to reduce air emission pollution from energy generation. For every 1,000 kWh of wind electricity generated, 600 kg CO_2, 2.1 kg of soot, 4.76 kg of SO_2 and 31.5 kg of solid waste emissions are reduced. In addition, 2,520 kg of water and 290 kg of coal is saved (Huang, 1993; Li et al., 2005). In total 1,334 million kWh of wind electricity generation in Inner Mongolia in 2007, which resulted in a substantial prevention of emissions, as listed in Table 5.6.

Table 5.6 Pollutants reduction by wind power in Inner Mongolia (2007) (1,000 ton)

	Soot	**SO_2**	**Solid waste**
Reduction	2.8	6.4	42.0
Total emission	778.0	1,456.0	73,630.0
Proportion (%)	0.36	0.44	0.06

Wind power also has negative impacts on the local environment. Previous investigations showed that developing wind power could cause noise pollution, visual pollution, and threats to birds. It is notable that in Inner Mongolia these environmental problems are not as serious as initially thought. First, most local residents live at least 1,000 m away from wind turbines. The average noise levels of wind turbines in operation in Inner Mongolia is only 31 dB (A) at a distance of 1,000 m, equal to noise level in bedroom. Second, wind turbines in Inner Mongolia are constructed on wide-open grasslands, with little human activity. Therefore, wind power projects in this region hardly cause visual pollution. Third, all wind farms in Inner Mongolia had to pass an environmental impact assessment (EIA) before construction. An important part of an EIA concerns the impact of the planned wind farm on birds. Wind farms planned on migratory routes of birds are not allowed and need to be re-planned. Although data on actual bird mortality through wind farms are not available for Inner Mongolia, statistical analyses showed that there is only a very small chance for birds to be hid by wind turbines (Li et al., 2007).

5.7.2 Societal influence

Societal influence of wind power development in Inner Mongolia considers whether wind power projects satisfy societal needs.

Nationally, the growth of domestic wind turbine industry offers employment in R&D, manufacturing and selling of wind power products. At the local level, the construction and maintenance of wind farms create new job opportunities for local people in wind farms. Although wind farms are not labor-intensive, labor is needed for constructing wind farm, regularly monitoring wind turbines, guarding equipments, and maintaining turbines and other facilities.

Developing wind power increases total domestic energy production and thus energy security of the region. Inner Mongolia generated 1,334 million kWh of wind electricity, 1.5% of its total electricity consumption in 2007. Although this proportion can not be compared with that in Western countries, the steep increase promises contribution to Inner Mongolia's and China's future energy security.

There are also social benefits indirectly related to wind farms. Due to the establishment of wind farms, local transport and traffic conditions are often improved. Most wind farms in Inner Mongolia locate at remote and mountainous areas, where poor traffic conditions used to be a major limiting factor for economic development. After wind farm construction, improved road infrastructure facilitated transportation and mobility of persons and goods, and thus economic development. During our surveys in Inner Mongolia we found that more than two third of the hotels and restaurants around wind farms were established after the construction of the wind farm. All interviewed hotel and restaurant owners agreed that their business increasing due to the wind farms. Construction of wind farms also brings localities additional tourism resources. For example, the Huitengxile Wind Farm became an important attraction of Qahar Youyi Zhongqi, the city where this wind farm locates. Now about half of the local residents' daily income is gained from tourists.

However, developing wind power in Inner Mongolia also encounters societal problems. Wind power development in Inner Mongolia lacks communication between developers and local residents. The most important problem is that local governments do not have enough influence on the establishment of wind farms in their territory, nor do they have influence on the way wind farms are run. There is a potential conflict between local economic benefits and wind farm development in the future, since a large area of land will be used for a long time without sufficient compensation to local people. Besides, herdsmen's production is influenced by wind power projects. During the construction of wind farms (normally one to two years), grassland (about 1 ha. for each turbine) is not available for grazing. After construction is completed, the grassland needs to recover at least one year and that needs substantial human intervention such as leveling land, seeding and irrigation. Another problem relates to the security of wind farm facilities. Normally wind farms are very large and located on land open to the public. Wind farm managers complain that local residents steal components of wind turbines, especially at an early stage of wind farm completion. How to protect wind turbine components from being stolen bothers wind farm managers already for a long time.

5.8 Conclusion and Recommendations

Wind power in China is recently experiencing a rapid growth. Our research in Inner Mongolia illustrates the major environmental, energy security and social benefits that wind power development brought to this region. At the same time, this study also reveals several complications in wind power development: high generation cost, low on-grid price, as well as immature domestic manufacturing. These shortcomings need to be removed as they might complicate further wind power development in China towards levels that are now experienced in countries such as Denmark and Germany. To this end, three policy recommendations are put forward, to secure further development of wind power in Inner Mongolia and China.

5.8.1 Fossil fuel tax

In comparison with fossil-fueled (especially coal-fueled) electricity, wind electricity is still too expensive. Many experts have argued that the cost of fossil-fueled electricity is calculated improperly (Costanza, 1980; Durning, 1992; Kooten et al., 1999). Electricity generated from fossil fuels has major negative impacts to the local environment and human health, while conventional calculation methods do not include these costs (externalities) into fossil-fueled electricity costs and prices. To produce a level playing field for the various electricity producers, the actual costs of fossil-fueled electricity need to include environmental externalities, i.e. the cost of environmental pollution, human health and resource exhaustion. In the research project “ExternE” (European Commission`, 1995), it was estimated that if the externalities of fossil fuel are included, costs of coal electricity is anticipated to double. Based on this presumption, cost of coal electricity in China will then increase to 0.6 yuan/kWh, making wind electricity fully competitive with coal electricity.

An important policy measure that can realize the internalization of environmental externalities is fossil fuel tax. If the tax rate is properly designed, cost of fossil-fueled electricity will be increased to an equal level as that of wind electricity. Besides, part of the money raised from fossil fuel tax can be allocated to renewable energy (including wind energy) technology R&D. China has not yet started to use such taxes on fossil fueled power generation. However, this topic has been discussed for years and is expected to be implemented sooner rather than later (Hai, 1999; Wang, 2007)[47].

5.8.2 Reformed concession model

The concession model is a typically Chinese policy arrangement for stimulating wind power development. As analyzed in this paper the main problem of the concession model is the extremely low grid price offered by winning concessions, and the subsequent lack of further investment. Although through the concession model the Chinese government intended to select the most suitable wind farm developer, in practice the main (and sometimes only) selection criterion became the lowest on-grid price offered. Of all the winners of concession projects in China, only Longyuan Power Group & Hero Asia Company Limited succeeded in winning the Bayinxile Wind Farm project without bidding the lowest price (Meyer, 2006). The concession model for wind power development in China needs to be reformed on two points: fixed on-grid price and improved localization policy.

Firstly, a fixed feed-in tariff should be set for concession projects. Although China has

[47] On December 19, 2008, when this article was under review, China’s national government announced an increment of the fuel-oil consumption tax from 0.1 yuan a liter to 0.8 yuan a liter starting at the beginning of 2009. We expect that the same policy will be applied in the power generation sector in the near future.

set up feed-in policy for wind electricity generated under concession projects, the on-grid price of wind electricity is not fixed. Our survey among wind power companies revealed that these companies do not applaud the “two-step” pricing mechanism of China’s concession model (i.e. different prices before and after the first 30,000 hours full capacity generation), because it causes vicious competition in bidding for concession projects. Although NDRC modified the bidding rules by adding evaluation criteria of wind developing condition (site selection, technology selection, efficiency of project development, etc.) and the "mid-price" evaluation routine for the latest phases of concession projects to avoid vicious competition, this situation did not really change and the price setting procedure is obviously unreasonable.

If there is a fixed feed-in tariff for concession projects, wind power developers just need to concentrate on the creation of the best wind developing condition. Such feed-in tariff can be different among regions and project types, following an integrated consideration of wind resources, project characteristics, on-grid price of fossil-fueled electricity and purchasing power at site (Jobert et al., 2007). At the end of 2007, Guangdong province started to set feed-in price of wind electricity at 0.689 yuan/kWh, which is 0.25 yuan/kWh higher than the on-grid price of fossil-fueled electricity[48]. It is a helpful attempt towards setting fixed feed-in wind power prices, and at the same time bridging the economic gap between wind power and fossil-fueled electricity production.

Secondly, the localization policy of wind turbine should be improved. China is strongly promoting local manufacturing capacity and capability of wind turbines. The mandatory localization rate policy has shown its function in expanding domestic supply markets and reducing costs. However, two aspects of the localization policy can be improved. First, not only the quantity but also the quality of localized turbines should become an important policy objective. Quality criteria can relate to individual turbine scales, annual full load hours, lifetime of turbines, etc. Second, one turbine manufacturer should be allowed to sign contracts with more than one developer in bidding for the same concession projects[49]. In this way, turbine manufacturers with better resources will have more opportunities to develop and mature in a short term.

[48] Coincidentally, the NDRC document “Measures for Pricing and Cost Distribution of Renewable Energy Electricity” states that the on-grid price of electricity generated from bioenergy should be 0.25 yuan/kWh higher than that of fossil-fueled electricity.
[49] In the concession projects policy, business contracts between wind farm developer and turbine manufacturer are exclusive.

5.8.3 Enhanced international cooperation

China has a relatively short history of wind power development, with a comparable shortage of experience and infrastructure. International cooperation is of vital importance for the further development of wind resource utilization in China. Although China has made significant efforts in international communication and cooperation, this can be further enhanced.

In order to improve international communication of wind energy science and technology, it is meaningful to establish joint research institutes, which can be a combination of Chinese research institutes and their foreign counterparts, or new institutes consisting of Chinese and foreign experts. Joint research institutes can function in developing wind turbines that apply advanced technology from western countries while fitting China's unique environmental and social circumstance. These institutes are also helpful in properly understanding learning experiences from wind power promotion policies in western countries.

Another important content of improved international cooperation is capacity building. Due to the localization rate criterion of the concession model, domestic turbine manufacturers are more inclined to import hardware (components) than software (manufacturing knowledge/technology). However, the latter is much more important for the long-term development of the domestic industry. If the domestic wind industry is to mature, the government should further support both cross-boundary transfer and domestic innovation of wind power technology other than import of equipments.

It is also worth trying to involve overseas power companies into the bidding for concession projects. Currently developers of concession projects are all domestic power companies, sometimes linking with joint-venture turbine producers. However, both the financial resource and technology level of domestic companies are limited. In the process of improving international cooperation to spur technological development, it is worthwhile to try involving overseas power companies into the bidding for concession projects. Besides providing more financial resources and advanced wind power technology, overseas power companies are also expected to provide long-term maintenance and service.

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Chapter 6 Solar Water Heaters in China: a new day dawning[50]

"While China has only limited experience with solar power, it is already a global leader in taking advantage of solar hot water."
- Martinot and Li (2007)

Abstract

Solar thermal utilization, especially the application of solar water heater technology, has developed rapidly in China in recent decades. Manufacturing and marketing developments have been especially strong in provinces such as Zhejiang, Shandong and Jiangsu. This paper takes Zhejiang, a relatively affluent province, as a case study area to assess the performance of Solar Water Heater utilization in China. The study will focus on institutional setting, economic and technological performance, energy performance, and environmental and social impact. Results show that China has greatly increased Solar Water Heater utilization, which has brought China great economic, environmental and social benefits. However, China is confronted with malfeasant market competition, technical flaws in Solar Water Heater products and social conflict concerning Solar Water Heater installation. For further development of the Solar Water Heater, China should clarify the compulsory installation policy and include solar water heaters into the current "Home Appliances Going to the Countryside" project; most of the widely used vacuum tube products should be replaced by flat plate products, and the technology improvement should focus on anti-freezing and water saving; the resources of solar water heater market should be consolidated and most of the OEM manufacturers should evolve to ODM and OBM enterprises.

Keywords: China; Solar Water Heater; Performance assessment

[50] This chapter contains an accepted article for publication by *Energy Policy*, as Han J., A.P.J. Mol and Y. Lu. Solar Water Heaters in China: a new day dawning.

6.1 Introduction

In comparison with other countries, China has great potential for solar energy resources. The average annual solar radiation is 5,852 MJ/m^2, with a maximum of over 9,000 MJ/m^2 in, mostly, the western part of Tibet, the western part of Qinghai, the southeastern part of Xinjiang, the northern part of Gansu, and the northern part of Ningxia (Luo et al., 2005). Solar energy utilization, including solar water heater (SWH), solar energy heating and cooling systems (SEHC), and solar photovoltaic power generation (PV), is of great importance to China's renewable energy development strategy. Among these solar energy technologies, the SWH system is the most economical, mature and popular in contemporary China. SWH technology uses solar thermal energy to heat water for a wide variety of applications (e.g., domestic, office and industrial use). A SWH system is normally composed of a solar thermal collector and a fluid system to move the heated water from the collector to its point of use. The system uses pressure differences for pumping the water and has a reservoir or tank for hot water storage and subsequent use.

China has a great demand for hot water. According to a survey in 2004, only 10% of the water used by Chinese residents is hot water, while the amount in western countries reached 90%. More than 90% of the survey respondents indicated that they need more hot water in daily life[51]. In addition, along with the rapid industrialization and urbanization in China, large amounts of hot water are needed in factories, hotels and other public places. This provides ample opportunities for further SWH utilization in China.

China started SWH utilization in the 1970s. By the end of 2007, the country had installed 1.08×10^8 m^2 (collector area) of SWHs, which accounted for more than 60% of SWHs installed in the world (Luo, 2008). Recently, China set ambitious objectives for the mid to long-term development of the SWH system: 1.50×10^8 m^2 of installed collector areas by 2010 and 3.00×10^8 m^2 by 2020[52]. This would mean an annual growth rate of 13.6% for the 2010 objective and 9.0% for the 2020 objective. With an eye on this planned growth of SWH systems in China, the main objective of this paper is to assess and evaluate the past performance of SWH development in China. What have been the economic, technological and energy performance of SWHs in China, and are there serious social and environmental side effects related to SWH expansion?

[51] Source: http://health.sohu.com/2004/03/20/95/article219519544.shtml, retrieved on Jan. 07, 2009.
[52] Source: *China's Eleventh Five-Year Plan for New and Renewable Energy*.

The SWH industry and market in China has been especially strong in provinces like Shandong, Jiangsu and Zhejiang. This research takes Zhejiang Province as the case study area. It starts with an overview of SWH development in Zhejiang and the research methods applied. Subsequently, the performance of SWH utilization is evaluated in terms of legal and institutional framework and economic, technological and energy performance. After an assessment of environmental and social impacts, the analysis concludes with recommendations for advancing and improving SWH utilization in China.

6.2 Study Area and Methods

Zhejiang Province is situated on China's southeastern coast, directly south to Shanghai. It covers a total land area of 101,800 km^2, of which the mountainous and hilly regions make up 70.4%, the plains and basins make up 23.2% and the rest, 6.4%, is rivers and lakes. At the end of 2006, its population reached 46.3 million, with a high density (455 persons/km^2). Zhejiang has a sub-tropical monsoon climate, with a clear division of the four seasons. The average annual temperature is 15 – 18 °C and the average annual precipitation is 1,200 – 1,800 mm. Zhejiang is among the more developed provinces in China. With a 20,574 yuan annual per capita income for urban residents in 2007, Zhejiang ranked third of all provinces (following Shanghai and Beijing). In 2007, Zhejiang’s GDP was 1.864 trillion yuan, accounting for 7.6% of China’s national GDP. Pillar industries in Zhejiang include light industry, tourism and retail trade.

The Zhejiang Province was selected as the study area for the performance assessment of SWH development in China mainly for two reasons. First, the province has the highest installation rate of SWH systems in China[53], and second, Zhejiang is experiencing a boom in SWH manufacturing, with a 30% annual production increase over recent years. Although SWH systems are of particular importance in Zhejiang, we do not expect that SWH performance in this province will be radically different from that of other leading Chinese provinces[54].

In carrying out this research, documentary materials, interviews, site observations and questionnaires were used as the main research methods. Documentary materials provided

[53] It is estimated that SWHs had been installed at more than 30% of households in Zhejiang by the end of 2006; this is much higher than the national average (8%). Source: Zhejiang Solar Energy Industry Association website: http://zj.xn--fiqx11jxbb.cn/html/zixun/20081127/16143783.html; *Survey on SWH market characteristic in Zhejiang*: http://www.topo100.com/zonghebaogao/zhuanzhulingyu/nongcunshichang/2008-12-01/42860.html.

[54] SWH utilizations in different provinces in China were developed almost in the same period with the same “experiment – demonstration – marketaliztion” process.

information about status, formal goals, manufacturing capacity, markets and future planning of SWH development in Zhejiang. The documents reviewed in this research include laws, governmental policies, statistical materials, industrial and scientific studies and market reports. From May 2008 to June 2008, semi-structured face-to-face interviews were conducted with five governmental officials, two staff members of SWH sector associations and eight estate developers in Zhejiang to understand and assess the progress of SWH development. In June 2008, we visited five randomly selected SWH companies and six SWH retailers in Zhejiang to understand the status and problems of SWH manufacturing and marketing.

For analyzing household SWH use, a uniform questionnaire with closed questions was used, consisting of three parts. The first part focused on elementary family information, including number of family members, annual income, and average education level. The second part of the questionnaire collected SWH purchasing information, including time, place and purpose of purchase, product brand, price and size. The third part related to SWH utilization, including frequency, water temperature, annual maintenance costs, impacts on daily life, and expectation and experiences with performance. In total, 600 questionnaires were randomly distributed, with 300 distributed in 3 neighborhoods in Haining City (each 100) and 300 in 3 rural counties. Of the 300 questionnaires distributed in urban areas, 298 were completed correctly, while 281 out of the 300 distributed in rural areas were usable for further analysis.

6.3 Renewable Energy Development in Zhejiang

6.3.1 Energy shortage in Zhejiang

One of the main reasons for the diversification of energy sources in Zhejiang is its small energy production and fossil fuels availability. Zhejiang energy production in 2007 was only 11.69 Mt standard coal equivalent (SCE), which is 0.50% of the total energy production in China. Meanwhile, due to the rapidly growing energy consumption of both household and industry, Zhejiang energy consumption in 2007 reached 145.33 Mt SCE, which is 5.47% of the national consumption (National Bureau of Statistic of China, 2009). As a result, Zhejiang has suffered energy shortages for years. More than 90% of its energy demand has to be met by importing coal, oil and other energy sources from outside (mainly other provinces with little coming from overseas).

Energy shortage is becoming a major barrier for economic development in Zhejiang. In summer, when heat waves strike Zhejiang, the demand for electricity to run air conditioners increases sharply. Although Zhejiang has made significant efforts to enhance its electricity production – increasing from 62.5×10^9 kWh in 2000 to 203.7×10^9 kWh in 2007 – many factories are still regularly obliged to shut down production activities temporarily to save electricity for residents. This causes considerable economic loss for local industries.

Heavy dependence on imported energy also increases the cost of electricity generation. About 80% of the electricity generated in Zhejiang is thermal power. As Zhejiang has limited raw coal reserves, it has to import over 100 Mt coal from other provinces every year. When the coal is transported from its place of production, e.g., from Shanxi Province to Zhejiang, the price almost doubles[55]. Therefore, electricity generation costs in Zhejiang are higher than in most other Chinese provinces[56].

Besides energy shortage, environmental pollution presents a second reason to search for non-fossil fuel energy resource development in Zhejiang. Waste gas discharged from coal-fuelled combustion increased from 42.6 million m^3 in 2000 to 115.42 million m^3 in 2007. Soil and water environments in Zhejiang are also considerably polluted by fossil fuel residues.

6.3.2 Development of non-fossil fuel energy resources in Zhejiang

Zhejiang started its efforts to develop alternative energy resources as soon as the 1970s (Lian et al., 1991; Dong, 1999). For over 30 years, it has achieved notable growth in wind, hydro, nuclear and solar energy utilization.

Zhejiang has plenty of wind energy resources along its 6,486 km coastline. In 1972, China's first independently developed wind turbine was installed in Zhejiang, with a capacity of 18 kW. By the end of 2007, the total installed wind power generation capacity in Zhejiang reached 47.35 MW (Shi, 2008). However, most wind turbines in Zhejiang were installed along the seashore areas, which were more vulnerable to typhoons than the wind turbines installed in inland.

[55] Source: interview with officials in Zhejiang Development and Reform Commission on May 25, 2008.
[56] According to the NDRC document *Circular on Electricity Wholesale Prices and Electricity Transmission and Distribution Prices in Provincial Grids in 2007* (File No. 2920), the baseline of electricity wholesale prices in Zhejiang in 2007 was 0.573 Yuan/kWh, ranking the sixth highest within all provinces in China.

Zhejiang is also rich in hydro energy resources. Eight water systems crossing its territory provide Zhejiang with 6,613.2 MW of economically exploitable hydro energy. After the construction of the first large-scale hydropower plant on Xin'an River in 1957, more than 3,000 hydropower plants followed, resulting in about 4,000 MW of hydropower generation capacity and 14.0×10^9 kWh of annual hydropower production. Hydro energy resources in Zhejiang are mostly located in rural areas and thus are suitable for micro and small hydropower development. Although small-scale hydropower is more environment-friendly, its development is more expensive than large-scale hydropower.

Zhejiang is an important base for nuclear power generation in China. The first nuclear power plant in China's mainland, Qinshan Nuclear Power Plant, was constructed in Zhejiang Province in 1985. This 3,000 MW nuclear power plant provides China with an annual 22.6×10^9 kWh of electricity[57]. In 2008, construction of the first AP1000 reactor, Sanmen Nuclear Power Plant, began in Zhejiang. However, nuclear energy continues to have problems concerning residue disposal and safety.

6.3.3 Development of solar energy resources in Zhejiang

Zhejiang started its R&D on solar energy technologies in the mid-1970s. During the past 30 years, it has improved solar thermal and power generation technologies. Zhejiang was among the first group of provinces that started developing SWH technology, which is now the most important renewable energy technology in Zhejiang. In 1975 it sent a delegation to the First National Experience-Exchange Conference on Solar Energy Utilization Technology (in Anyang City, Henan Province) and developed a corrugated roof SWH (in Jiashan County) (Ding and Jiang, 1994). Zhejiang University was the first research institution engaged in the research of solar energy technology in China. It developed the "honeycomb flat plate" SWH in 1980 (Lu, 1999), which improved solar thermal efficiency considerably. In 1993, a glass vacuum tube SWH was developed in Zhejiang, with much lower costs than the flat plate SWH. More recently, SWH technology in Zhejiang further improved, by cooperation with research institutes outside the province (the University of Science and Technology of China, Tsinghua University and the Guangzhou Institute of Energy Conversion at the Chinese Academy of Sciences). The latest SWH technology in Zhejiang is the hybrid solar-heat pump water heaters. In recent years, Zhejiang University

[57] Data at the end of 2005. Source: China Atomic Energy Authority: http://www.caea.gov.cn/n602669/index.html

has also focused research on mono- and multi-silicon crystalline Solar PV modules and photovoltaic power generation system products. In addition, the Zhejiang Energy Research Institute (ZERI) carries out research projects on solar energy utilization, such as solar powered TV sets and clocks, household PV power generation systems, photoelectric transposers and silicon thin-film PV cells. It is also engaged in research on improving solar energy efficiency, such as improved Polyvinyl Fluoride (PVF) membranes, high-efficiency solar vacuum tubes and SWH systems. And the Zhejiang Center of Energy Efficiency in Buildings, affiliated with the Zhejiang Department of Science and Technology, focuses research on energy saving and, especially, solar energy utilization in buildings.

Parallel to – and sometimes directly linked with – these technological innovations, Zhejiang has experienced a remarkable growth in SWH equipment production, especially during the last decade. Jiashan Solar Energy Equipments Enterprise, the first SWH manufacturer in Zhejiang, was established in 1982. With the invention of the glass vacuum tube SWH in 1993, SWH manufacturers emerged in Haining, Wenling, Zhoushan, Ningbo and other cities. Zhejiang University also succeeded in transforming their research outcomes into commercial production and established Zhejiang University Sunny Energy Science and Technology Co., Ltd., which is under the support of senior experts and professors from Zhejiang University and has an annual PV production capacity of 20 MW. Currently, Zhejiang houses 1,000 SWH manufacturers (or 20% of the total number in China). In 2007, Zhejiang was China’s main centre for SWH production, with sales reaching 5.76 billion yuan (18% of the national market share).

At the turn of the millennium, the rapidly growing SWH production sector started to face problems with false advertisement, counterfeit products and malfeasant competition. Subsequently, in March 2003, the first solar energy sector association was established in Haining City, with 63 SWH enterprises as members[58]. Five years later, a provincial level solar energy sector association – the Zhejiang Solar Energy Industrial Association (ZSEIA) – was founded on November 8, 2008[59]. This not-for-profit organization consists of 67 solar energy enterprises in Zhejiang. The association serves as an information platform, represents sector interests, solves conflicts between members and bridges the gap between solar energy enterprises and the government.

[58] Source: interview with Mr. Guoguo Zhang, the director general of the Haining solar energy sector guild on May 23, 2008.
[59] Source: interview with staff in Zhejiang Solar Energy Industry Association on May 25, 2008.

6.4 Solar Energy Governance

The development of SWH in Zhejiang has been facilitated by a favorable institutional environment, where governmental agencies have created the conditions for market development and have worked closely with producers and technological institutes.

Various governmental departments at the provincial level influence solar energy developments in Zhejiang Province. The Zhejiang Development and Reform Commission (ZJDRC), like its counter partner at the national level, is in charge of developing renewable energy resources, including solar energy, in Zhejiang. It is responsible for drawing up and organizing the implementation of mid- and long-term strategies and annual plans for solar energy development in Zhejiang. The Department of Science and Technology (ZJDOST) protects the intellectual property rights of solar energy technologies and coordinates the international cooperation of solar energy technologies. The Environmental Protection Bureau (ZJEPB) examines and approves the Environmental Impact Assessment (EIA) of solar energy projects. Other governmental departments relevant to solar energy development in Zhejiang are the Department of Construction (ZJDOC), Department of Finance (ZJDOF), Local Taxation Bureau (ZJLTB), Quality and Technical Supervision Bureau (ZJQTSB) and the Administration of Industry and Commerce (ZJAIC).

In order to achieve the ambitious objectives of SWH development set in the *Eleventh Five-Year Plan for New and Renewable Energy*, the NDRC approved the *Implementation Plan on Promoting Solar Thermal Utilization in China* in April 2007. In this national policy, the installation of SWH systems is given priority for major hot water consumers, such as hospitals, schools, restaurants and swimming pools. Zhejiang has also drawn up regional policies on solar energy development, often functioning as an implementation of or a supplement to national policies. However, solar energy has not received the same policy support in Zhejiang as other renewable energy resources – especially wind and biomass[60]. More recently, though, the Zhejiang government has regarded the SWH system as an important and advanced technology. The SWH was recently listed as a key field for priority development in the *Guide to Key Fields of High-Tech Industries for Prior Development in Zhejiang*, issued by ZJDRC in 2007.

[60] There is one interesting and notable piece of evidence for this argument. The provincial government started to draft a policy titled *measures to promote utilization of solar energy and biogas technologies in Zhejiang* in 2004. However, when the final document came into force in 2005, the title was changed into *measures to promote development and utilization of biogas in Zhejiang*. The parts on solar energy were quite limited.

Nationally and provincially, the first governmental policies were very much focused on demonstration projects. In 1982, in the first SWH demonstration project in Zhejiang, the BTR-3A double-tube SWH was introduced to residents by the Zhoushan Office of New Energy in Chengguan Town, Zhoushan County. Within three years, up to 30% of local householders in Chengguan Town installed SWHs. Zhejiang Province now uses a variety of policies to promote and regulate SWH system development and installation in buildings. The *Management Measures on Building Energy Saving*, issued by the provincial government in October 2007, regulates that “installation of solar water heater systems is compulsory in new villas and terraced houses, strongly recommended in new apartment buildings not higher than 12 stories and encouraged in other buildings; application of PV and other solar energy utilization systems is also encouraged”. Economic subsidies on household SWH installation are used to promote household SWH utilization in Zhejiang. However, there is no uniform standard subsidy on SWH installation; the amount of subsidy differs between cities. In Haining City, one-third of household SWH installation costs are compensated by the government. In Yiwu County, every family who installs an SWH can get a 500-yuan subsidy. In Jiangshan County, the subsidy is 300 yuan, while in other counties there is no subsidy available. During the past 10 years, these policy efforts have contributed to an annual increase of 30% of SWH instalation in Zhejiang and currently 2.9×10^6 m^2 collector areas of SWHs have been installed.

Zhejiang Province also issues technical standards to control SWH quality and safety. The *Standard for Design, Installation, and Examination & Acceptance of Solar Water Heaters in Residential Buildings* stipulates the requirements for installing SWHs in buildings. This includes procedures for installing, adjusting and examining SWHs and the required materials for manufacturing SWHs. For example, it states that “light-weight filled walls are not suitable for supporting solar water heaters” (Article 4.3.3), “installation of solar water heater should not damage the building structure and function, the water-proofing or any other function of the building” (Article 5.1.6) and “materials for manufacturing water tanks of solar water heaters must be anti-rust, toxin-free, and capable to bearing the maximum water temperature in the tank” (Article 5.5.2). ZJDRC and other provincial departments mentioned above are responsible for the implementation of these regulations.

Recently, NGOs have become an important factor in further promoting solar energy technologies. Although China still has an underdeveloped NGO network (Mol, 2006) , there is an impressive promotion of diverse renewable energy activities by the two major Zhejiang environmental NGOs – "Green Zhejiang" and the "Zhejiang Environmental Volunteers Association". They have built a website for renewable energy information exchange, carried out annual summer camps for youths to increase their knowledge of renewable energy resources and organized dialogues between scientists, officials and businessmen to discuss mid- and long-term energy strategies in Zhejiang.

6.5 Economic and Market Performance of SWH

In assessing the economic and market performance of SWH systems, we concentrate on the cost benefit analyses of both SWH production and SWH utilization and on the market structure.

6.5.1 Cost-benefit analysis of SWH production

Profitability is vital for further growth of SWH manufacturing in Zhejiang. By comparing the economic costs and benefits of SWH manufacturing, the profit potential of this industry can be estimated. The costs of SWH manufacturing include material costs, labor costs and taxes, while the benefits are represented by the sale price. As the manufacture of SWH products in Zhejiang is divided over different component and assembly industries, we have only calculated the cost of the final assemblers. More than 90% of SWH units installed by households in Zhejiang are glass vacuum tube SWHs, and our cost benefit calculation is thus limited to this specific type of SWH, with the most common size having a 200 L water tank.

A glass vacuum tube SWH is composed of a supporting system, a water tank, a solar reflecting plate and glass vacuum tubes. The supporting system consists of a 1.8 – 2.0 m long frame made of stainless steel and costs about 180 yuan in Zhejiang. A stainless water tank (200 L) costs around 400 yuan, while the cost of the solar reflecting plate is 80 yuan. With the average cost of one vacuum tube at 16 yuan and 20 tubes normally included in one SWH, total costs for the tubes add to 320 yuan. Therefore, the total material costs of a 200 L glass vacuum tube SWH are 980 yuan. SWH labor costs are related to equipment assembly and product installation[61]. Although labor costs have increased sharply in Zhejiang over recent years, they do not account for a large proportion of the total SWH

[61] Cost of installation is normally included in sale price. Therefore SWH manufacturers provide end users with installation service.

manufacturing cost. For enterprises included in this study, the average labor cost per product unit is about 63 yuan. In Zhejiang, SWH manufacturing does not enjoy preferential tax policies, except for refunds of customs tariffs. With a VAT of 17% and an income tax of 25%, average taxes per unit of SWH are 128 yuan and 53 yuan, respectively. Therefore, total average costs per unit of 200 L whole glass vacuum tube SWHs in Zhejiang add up to 1,224 yuan.

Market prices of SWH products in Zhejiang depend on the brand, size and time and place of purchase. Collected market prices of 200 L glass vacuum tube SWH products in Zhejiang averaged 1,802 yuan in 2008. Therefore, the average profit from one SWH unit (200 L) is 578 yuan. As publicly perceived, and proven again in this research, SWH manufacturing is highly profitable in Zhejiang[62]. This profitability is arguably the most important factor driving the rapid development of the SWH sector.

6.5.2 Economic analysis of SWH utilization

In order to analyze the economic performance of SWH utilization, the costs of purchasing, operating and maintaining SWH products are compared with the economic benefit they bring to users. Because not all SWH products used in Zhejiang are produced in that province – but also in other Chinese provinces – data for calculating the purchasing price of SWHs were acquired via user questionnaires instead of the average market prices of Zhejiang producers. To estimate the annual economic performance, the purchasing cost of individual SWHs was apportioned within the designed life expectancy. Governmental subsidies were not considered, because they are provided only in some cities/counties (usually related to demonstration projects) and at different rates. The economic benefits of SWH utilization were realized mainly through saving fuel costs for heating water. Data for this were also obtained via user questionnaires.

Respondents in this research purchased their SWH products at an average price of 2,160 yuan. Most users also needed to buy pipes[63], at a price of 3 yuan/m. On average, users needed 30 m pipes, adding up to 90 yuan for pipes. Therefore, the average purchasing costs of SWHs in Zhejiang were 2250 yuan. This is much more expensive than the purchasing costs for an electric water heater (average 833 yuan) and a fuel gas water heater

[62] Note that in this research, interest on loans and other costs for running an enterprise have been excluded.
[63] Users who install an SWH after construction of the building need to install pipes from the roof to their kitchen and bathroom. Pipes are preinstalled in new buildings and the cost is included in the purchasing price of flats.

(average 560 yuan) in Zhejiang. The designed life expectancy of SWH products varies from 10 to 15 years. If we take the mean life expectancy (12.5 years), the apportioned purchasing costs are around 180 yuan/y. There are no operation costs, as users operate SWHs themselves without extra energy or materials. The costs for water can be excluded because SWH technology adds no additional water use or costs compared to alternative water heating systems. The maintenance costs for SWHs relate to cleaning and changing components and especially to frozen water pipes or tanks (which will be discussed below). From the questionnaire, the average maintenance costs of SWH users in Zhejiang proved to be 22 yuan/y. The total average costs households pay for SWH utilization in Zhejiang are thus around 202 yuan/y.

SWH technology saves fuel costs in comparison with other water heating systems. Heating 1,000 L of water from 5 °C to 55 °C consumes 210 MJ of thermal energy[64]. Taking the thermal efficiencies of electricity, LPG and natural gas water heaters as 98%, 84% and 84% respectively[65], it costs 18 (natural gas) to 41 yuan (electricity) to obtain the thermal energy by conventional energy resources. Meanwhile, no fuel costs are involved with SWHs (Figure 6.1).

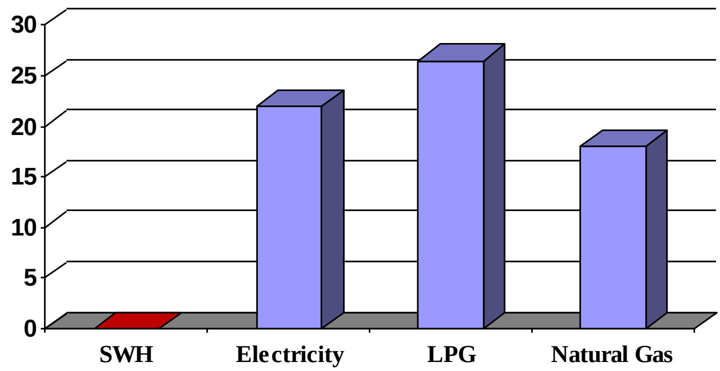

Figure 6.1 Fuel costs for heating water from 5 °C to 55 °C (yuan/1000 L)

[64] 4200J/(kg•°C)×1000kg×(55°C-5°C)=210×10^6J
[65] Source: efficiency data of LPG and natural gas fired water heater from *Minimum allowable values of energy efficiency and energy efficiency grades for domestic gas instantaneous water heater and gas fired heating and hot water combi-boilers.* Efficiency data of electrical water heater from Xu et al., 2006.

The average annual household water use for daily life in Zhejiang is 190.5 t (National Bureau of Statistic of China, 2009). If we take the proportion of hot water used in daily life from the 2004 survey, an average of 19 t of hot water is consumed by individual families every year. Meanwhile, results from the questionnaire revealed that an average of 81 t of hot water per year is consumed by individual families in the study area[66]. Therefore, by using an SWH, a household can save 342 to 3,321 yuan in fuel costs every year. Considering that the average installation and maintenance costs of household SWHs are 2,525 (2,250+22×12.5) yuan, the payback period is 8 months to 7.4 years.

6.5.3 SWH market structure

In Zhejiang, SWH manufacturing is concentrated in cities such as Haining, Huzhou and Ningbo as a result of preferential policies, demonstration projects and governmental subsidies. SWH utilization is very popular in cities with a mature manufacturing sector. Hence, a large part of SWH production in Zhejiang is consumed domestically. According to the user questionnaires, 94.3% of households in urban areas (n=298) and 65.8% in rural areas (n=281) in Haining had installed SWHs by the end of 2007. In other Zhejiang cities, installation of household SWHs also increased rapidly over the last few years, but not to such high rates. Besides domestic sales, SWH products produced in Zhejiang are sold to other provinces, such as Hebei, Henan and Yunnan, and are exported to Southeast Asian, American and European countries. SWH enterprises spend considerable resources on advertising and image building via websites, TV, newspapers and public places.

Of all SWH products, vacuum tube systems have the largest market share in Zhejiang, as in all of China (Figure 6.2). In 2007, 95.35% of SWHs in China were vacuum tube systems and only 4.65% were flat plate systems[67]. In the EU, 85.94% were flat plate systems and only 8.56% were vacuum tubes (Beurskens and Mozaffarian, 2008; Luo, 2008).

[66] There are two possible reasons for differences between the two data sources: first, average living in Zhejiang has been largely enhanced since 2004; second, families are supposed to increase everyday hot water consumption when there is no fuel cost.
[67] Because data of SWH market shares in Zhejiang are not available, data in China are used instead.

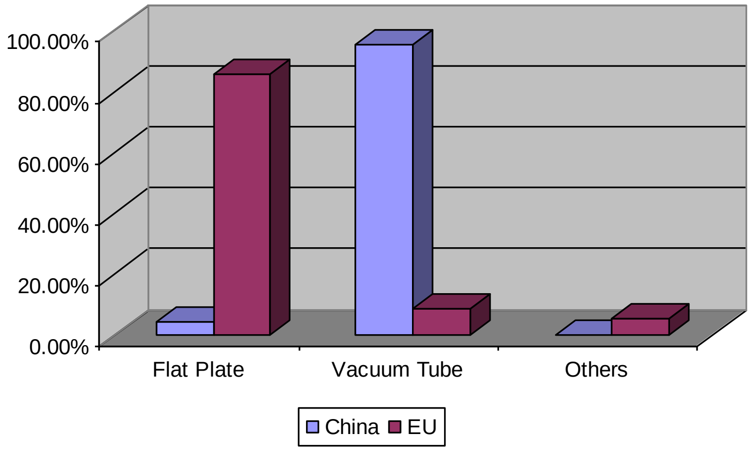

Figure 6.2 Market shares of SWH products in China and EU (2007)

As Zhejiang is not rich in mineral resources for manufacturing SWH products, most raw materials – such as polyurethane (PU) and steel – need to be imported from other provinces or from overseas. This makes the manufacturing of SWH products in Zhejiang vulnerable to external raw materials markets. In the past two years, prices of both PU and stainless steel have increased more than 20%, putting pressure on solar SWH manufacturers in Zhejiang.

Most of the 1,000 and more SWH manufacturers in Zhejiang have operated under the so-called Original Equipment Manufacturer (OEM) model[68]. Only one manufacturer owns the entire SWH product chain in Zhejiang. About two-thirds of the SWH enterprises in Zhejiang produce SWH components, such as supporting systems, heat pipes, vacuum tubes, solar reflecting plates and water pipes, while the other enterprises assemble these components into final SWH systems. The major problem the SWH market in Zhejiang has is the large number of enterprises with a limited scale. Of the 25 Chinese SWH manufacturers with an annual output value above 100 million yuan, only two are located in Zhejiang[69]. This results in malfeasant competition, especially concerning low prices, and bad-quality products and service. Although raw material and labor costs have increased in

[68] An original equipment manufacturer, or OEM, is typically a company that uses a component made by a second company in its own product, or that sells the product of the second company under its own brand.

[69] Besides the 2 manufacturers in Zhejiang, 8 are located in Jiangsu, 7 in Shandong, 4 in Beijing, 2 in Guangdong and 2 in Anhui. Source: Luo, 2008.

recent years, the average market price of SWHs decreased in Zhejiang. Hence, in order to keep profits, many manufacturers use low-quality material, resulting in unreliable products and poor quality. Under this circumstance, local users increasingly trust only famous brands. Our survey indicates that over 71% of the respondents (n=579) buy their household SWHs from one of the three brands that passed governmental product certification, even though the price of these brands is 17% above the average price of other brands. As a result, most of the cheaper SWH products are sold in external markets. In these markets, short life expectancy, unreliable quality and security problems during installation and utilization have reduced the reputation and, consequently, the market share of "made in Zhejiang" SWH products.

6.6 Technology Assessment of SWH Systems

6.6.1 Climate conditions

Solar energy utilization is highly dependent on the climate conditions at specific sites. The most important climate factors are the "sunshine hour" (SH) and "sunshine radiation" (SR). SH refers to the hours in which a specific region receives sunlight. SR refers to the total amount of sun radiation per unit area that a specific region receives during a period of time. SR presents the density of solar energy availability in this region. In China, provinces are divided among five groups, where the first group is the richest in sunshine and the fifth group is the poorest. Zhejiang Province is among the fourth group (Luo et al., 2005). It does not receive long hours of sunshine per year, with annual SH varying from 1,765 to 2,142 hours, depending on location[70]. It receives the most sunshine hours in July and August, when the average temperature is around 30 °C and there is little need for hot water in people's daily lives. In January and February, the coldest months, Zhejiang receives the lowest amount of SH (Figure 6.3). With an annual SR of 2,083 MJ/m^2, the amount of thermal energy from sunshine is also low in Zhejiang, when compared with the national average of 5852 MJ/m^2.

[70] Data from Zhejiang Meteorology Bureau.

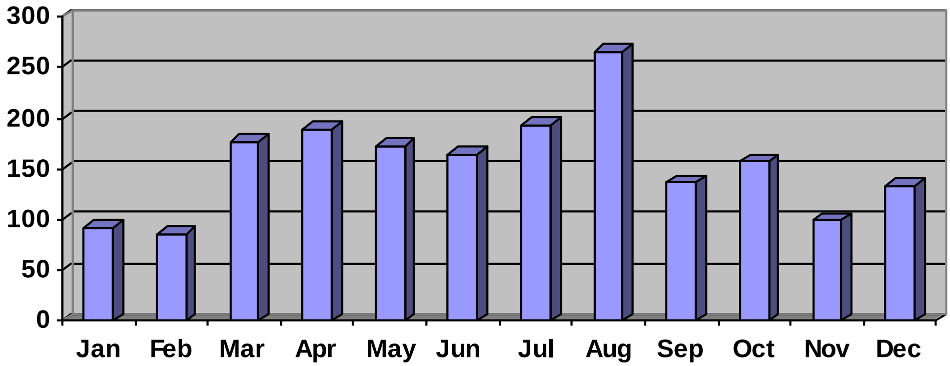

Figure 6.3 Average sunshine hours in different months in Zhejiang (1956-2005)

With unfavorable climate conditions for solar energy, Zhejiang is still the most developed province in terms of SWH utilization. There are three possible explanations for this phenomenon. First, the SWH system prevails in Zhejiang because it is a low-temperature solar energy utilization technology that is especially favorable for areas without plenty of solar radiation (Dickinson and Cheremisinoff, 1980). Second, Zhejiang is relatively rich among the provinces, where most households have enough purchasing power to afford SWH technology. It is also for this reason that Zhejiang is the home of many solar energy demonstration projects. Third, household SWH installation has boomed in parallel with the development of a well established SWH manufacturing industry in Zhejiang. The combination of high production profits, cheap products and low transportation costs has accelerated market development.

6.6.2 Technology performance

Several aspects should be considered in assessing the performance of glass vacuum tube SWH technology in Zhejiang and China: life expectancy, integration into buildings, water temperature performance, water wastage and performance under extreme conditions.

Although most SWH products are designed to be used for 10 to 15 years, this is not necessary true in practice. The questionnaire analysis results show that 48% of current SWH users in Zhejiang have installed an SWH before (n=579). The average life period of their previous SWH was only 6.5 years, much shorter than the designed life expectancy (10 to 15 years). New SWH systems were installed for mainly two reasons. First, users did not know or care about the designed life expectancy. An average 6.5-year life was already longer than the payback period. Second, many families replaced their first SWH not because it ceased to work, but because they wanted new products with a larger size and more advanced technology. The current SWH technology in use was installed, on average, 5.8 years ago, and 91% of these units are still in "excellent" or "good" condition[71]. The new SWH products are expected to have a longer life expectancy than the older ones.

Most SWH products in Zhejiang are used by households. Normally, the supporting system, the water tank and the solar collectors are installed on the roof. Cold water is pumped upward from the kitchen or bathroom to the roof and hot water is transported downward through the pipes. SWHs are better integrated into new buildings than existing buildings. After the provincial government issued the compulsory installation policy in 2007, SWH units became fully integrated into new apartment buildings during construction (Figure 6.4, left). When residents buy a new house or apartment, they automatically become owners of an SWH. In most other new buildings, space is automatically reserved for solar collectors on the roof and for pipes in the wall. However, current SWH technology does not integrate easily into most existing buildings. The solar collectors are eye-catching on the roof, and they cause visual pollution (Figure 6.4, right). The installation of water pipes in existing buildings causes another problem: if these are installed on top of the wall, it also causes visual pollution, while installation in the wall increases costs and causes damage to the wall.

The water temperature obtained in the water tank depends heavily on the heat absorption capacity of the tubes and the heat preservation qualifications of the water tank. The national *Technical Requirement for Environmental Labeling Products – Domestic solar water heating system* (HJ/T 363-2007)[72] requires that hot water temperatures from SWH systems not to be lower than 45 °C. Experiments by Xiao et al. (2004) showed that the outlet water temperature of SWH systems with vacuum tube technology varies from 40 to 80 °C under all possible weather conditions. Therefore, SWH systems can meet the temperature requirements except, perhaps, in extreme weather conditions. The latest SWH product technologies (with advanced heat pump and heat pipes) can produce water at a

[71] We defined an "excellent" SWH as a unit that had never been repaired; "good" is an SWH's technology functioning as it was designed after only minor repairs; "adequate" are SWH units functioning as designed after major repairs; "bad" are SWHs where minor functions have degenerated (e.g., leakage of valves); "very bad" are SWHs where major functions have degenerated (e.g., it can no longer heat water up to a satisfying temperature).
[72] Issued by the former State Environmental Protection Administration in 2007.

temperature above 60 °C under all weather conditions (Wang et al., 2000; Lu et al., 2002; Chyng et al., 2003).

Figure 6.4 SWH installed in apartment buildings (left: integrated in new buildings; right: added to existing buildings)

However, there remain two major technical concerns with SWH in China. First, the water tanks and pipes installed outside buildings can become frozen and crack during cold winters (with outside temperatures below -8 °C). Though it is not a problem in Zhejiang, this technical barrier does prevent the popularization of SWHs in northern China. The second problem relates to the waste of clean water, which is especially important in water-scarce regions. Because the water in pipes between the water tank and the place/tap of water use cannot be heated, users have to waste cold water before using hot water from the SWH. With the average internal diameter (12mm) and length of the pipe (15m), Zhejiang households waste 1.7 L of water every time hot water is used.

6.7 Environmental and Societal Impacts

In a final SWH assessment, environmental and social impacts of this technology should be included.

Except for the wasted cold water, SWH technology is applauded for its environmental benefits. Before the widespread SWH installation, people in Zhejiang used electricity (at private places) or coal (at public places) to boil water. By applying SWH systems, use of fossil fuels for heating water is reduced. It is estimated that installation of SWHs can reduce

120 kg SCE of fossil fuel consumption and 4.85 kg SO_2, 2.2 kg NO_2, 3.75 kg dust and 200 kg CO_2 emission per m^2 collector per year (Li and Hu, 2005). In Zhejiang, a 2.9×10^6 m^2 collector area of SWH systems had been installed by the end of 2007, saving 348,000 t SCE of fossil energy consumption every year. If this amount of fossil energy is used for electricity generation, it produces around 1 billion kWh of electricity, equal to the annual production of a mid-sized power plant in China. In addition, every year the 2.9×10^6 m^2 collector area prevents 14,065 t SO_2 emission (1.76% of Zhejiang's SO_2 emission in 2007); 6,380 t NO_2 emission (provincial emission data not available); 10,875 t dust emission (5.98% of Zhejiang's dust emission in 2007); and 580,000 t CO_2 emission (0.28% of Zhejiang's CO_2 emission in 2007). This contributes significantly to better air quality in Zhejiang.

The development of SWH utilization has several positive social impacts in Zhejiang. It brings local residents an economical, clean and safe way of heating water for daily life, and it saves fuels costs. Moreover, SWH systems reduce the risks of CO poisoning (as with gas water heaters) and electric shocks (as with electrical water heaters)[73]. In addition, the utilization of SWH systems provides people a way of expressing their concerns about environmental protection. In our survey 36% of the respondents (n=579) regarded "environmental protection" as the most important reason for installing an SWH. Utilization of SWHs can also improve public health conditions. A survey carried out by All-China Women's Federation (ACWF) in 2006 revealed that 86% of Chinese housewives have rheumatoid arthritis, and the use of cold water for laundry and dish washing is considered the main cause of this disease (Pienimaki, 2002). SWH introduction increases the availability and use of hot water and, thus, reduces the prevalence of rheumatoid arthritis.

But the development of household SWH systems also causes a number of social problems and conflicts. Though limited, there are some security risks related to installation, such as workers falling from high altitudes while installing SWHs on top of buildings[74] and utilization[75]. Conflicts with city administrations and estate management also present development problems. The city administration may interfere with SWH installation because, without careful planning, SWHs can cause visual pollution. The *Regulations on City Appearance and Sanitary Condition in Zhejiang Province* states that "Articles which

[73] It is estimated that hundreds of people die every year from these two risks in China (Source: China Consumer Council, http://news.xinhuanet.com/legal/2006-03/10/content_4285335.htm).

[74] On 1st July, 2008, an SWH installation worker fell from the top of a four-story building and died in Lishui City. Source: http://ajj.lishui.gov.cn/sgkb/sgxx/t20080702_428764.htm

[75] On 17th March, 2007, an SWH fell from the top of a five-story high building as the supporting system rusted. Nobody was injured. Source: http://ctjb.cnhubei.com/HTML/ctjb/20080318/ctjb288654.html

may impair city appearance or have security risks should not be installed on the top, porch, or out of windows” (Article 12). The *Regulations on City Appearance and Sanitary Condition in Hangzhou City* is even stricter: “It is not allowed to install any article on the top, porch, or out of windows of buildings close to main streets and key areas”. Although it is not clear if SWHs are an article “which may impair city appearance or have security risks”, the installation of SWHs on existing buildings is prohibited by city administrations in some cities in Zhejiang, in accordance with the above-mentioned policies.

Obstruction by the estate management is often more fierce and complex. Although most estate developers agree that SWH systems have environmental benefits and can be a selling point of new estates, the installation of SWHs is forcefully rejected by estate managements in many new apartment projects. In the Jiangsu and Henan Provinces, proprietors had to secretly install SWHs during the night, only to see them removed by the estate management shortly after[76]. There are three explanations behind these conflicts. First, there is a lack of space for SWH installation on top of new buildings higher than 12 stories. Second, some estate managers merely want additional income, and they allow SWH installation only under the condition that proprietors pay a 50 to 100 yuan “maintenance fee”. Finally, there is conflict over compulsory policies. The “strongly recommended” and “encouraged” legal provisions are vague. Installation, then, of SWH systems is only compulsory for new villas and terraced houses, which accounts for a small proportion of new buildings in China. There is no stipulation about how to deal with an SWH installation rejection, and solid local and provincial enforcement is lacking.

6.8 Conclusion and Recommendations

SWH technology has been developed for more than 30 years in China. Our evaluation reveals that using SWHs instead of conventional (gas and electric) water heaters has great economic benefits (saving fuel costs); environmental benefits (reducing fossil fuel consumption and pollutants emission); and social benefits (cheaper, cleaner and safer hot water for daily life). But SWH systems are meeting a number of bottlenecks in China. The following policy, technology and market recommendations address these shortcomings of SWH development in China.

[76] This kind of radical conflict has not happened in Zhejiang yet. However, about half of the interviewed estate management expressed their hostility towards SWH products in apartment communities.

6.8.1 Policy recommendations

Regardless of the economic benefits and the short payback period of SWHs, the current market price still makes them unaffordable for families in the poorer regions of China. Governmental subsidies can be effective in further promoting the use of SWHs in these areas. The current "Home Appliances Going to the Countryside" project is a nationwide government-funded project aiming to expand sales of household electric appliances in rural areas at prices 13% below those in cities. Including SWHs in the product list of this project would further disseminate SWHs in rural China[77]. Offering no-interest loans is another possible way to promote SWH utilization in rural areas, especially for families who cannot pay the purchasing price of an SWH all at once.

Current compulsory SWH installation policies are too vague; they need to be modified in two respects. First, the requirements for SWH installation on new buildings should be more stringent and clear: new buildings, for example, not higher than 12 stories must install SWHs simultaneously; new buildings must reserve enough space (on the roof) to install water pipes; and proprietors should be allowed to decide when to install SWHs. Second, there should be a penalty clause for estate managements that reject SWH installation or that charge money for installation.

6.8.2 Technology improvement

The widely spread glass vacuum tube technology has three disadvantages when compared to flat plate and heat pump SWH systems. First, the vacuum tube breaks down easily, while flat plate and heat pump systems are more robust, even under low temperatures. Second, the solar collectors of vacuum tube SWHs are larger and more difficult to adapt to buildings than flat plate and heat pump SWHs. Third, vacuum tube SWHs have a relatively low energy efficiency (45%) compared to flat plate (>50%) and heat pump (>80%) SWHs (Li et al., 2002; Lu and Luo, 2002). Hence, vacuum tube SWHs in China should be gradually replaced by flat plate and heat pump SWH technology. In order to achieve this replacement, three improvements of flat plate and heat pump SWH products are essential. First, the manufacturing costs should be reduced. Currently, the market price of flat plate and heat

[77] SWH was not included in the initial product list of "Home Appliances Going to the Countryside" project announced on March 10th, 2009, mainly because the technical standard of SWH is not accepted by all producers. However, it is believed that as soon as the standard is agreed upon, SWH will be included in the list.

pump SWHs are 30% to 50% higher than similarly sized vacuum tube SWHs. Second, several technical problems should be solved. For example, welding spots in water tanks may start leaking just a few years after installation. And it is impossible to take apart flat plates to clean their inner surface. Third, it is necessary to shift flat plate and heat pump R&D from focusing purely on laboratory efficiency improvements to field research on the adaptation of technology to market demand.

No matter which SWH technology is used, two technical problems must be solved: waste of water and freezing of pipes in winter. In China, several solutions to both problems have been suggested. Wang (1999) suggested that an electric heater be associated with automatic temperature control. Lu and Luo (2002) ummarized temperature control strategies in China, such as circulating water pipelines, electric heat tracing, and casing protected pipes. He (1999) invented an automatic water flow controlling device. Kang (2006) added 4-port solenoid operated valves and an F-drainpipe under the water tank. Zhao et al. (2007) provided four anti-freezing methods for SWH pipelines. However, all of these solutions increase the manufacturing cost of SWHs, and they need extra energy (normally electricity) input. Technologies satisfying both anti-freezing and resource conservation conditions are still lacking.

6.8.3 Market reform

Currently, there are more than 5,000 SWH manufacturers in China, most of which are limited in production capacity and product quality. In order to survive intensive competition, they sell their products at low prices, resulting in market disturbance. Therefore, SWH manufacturing resources should be consolidated by enabling larger companies to take over small enterprises. On average, large enterprises have the advantages of stricter quality control and better market reputation. In addition, market entry standards, in terms of process and product quality requirements, should be enhanced to ensure the quality of the industry. By enhancing market entry requirements, only enterprises with eligible production capacities and quality control mechanisms would be able to apply for production and distribution licenses.

Too many SWH enterprises in China operate under the Original Equipment Manufacturer (OEM) model. The OEM model is inevitable under socialized manufacturing, as it reduces investment risks and rationalizes resource distribution. But these OEM enterprises in China have become a barrier to the further development of the SWH industry.

A number of OEM enterprises need to evolve into what is called, in China, an Original Design Manufacturer (ODM). These should then evolve into an Original Brand Manufacturer (OBM). There are three major challenges to OEM enterprises transitioning to ODM and OBM enterprises. The first challenge is how to raise capital. Most OEM enterprises run on the capital they have accumulated by themselves over the past years, without bank loans or credits. Under ODMs and OBMs, more investment is needed, and these enterprises should use other possible funding resources to achieve further development. The second challenge is how to reform the product structure. Under an OEM model, SWH enterprises produce components but do not investigate market demand or develop new technologies or products. Under ODM and OBM models, SWH enterprises need to further invest in R&D, new products and market satisfaction. The third challenge is how to increase enterprise reputation. As part of the production chain of parent enterprises, OEM enterprises do not have to worry about their reputation. Under ODM and OBM models, constructing their own brand and reputation is essential. Product quality, media advertisement and branding are key components of reputation construction and maintenance.

In the international market, product quality standards are stricter than in the domestic market, and market prices are higher. SWH enterprises with large production capacities, advanced technologies and advanced quality control systems can expand into the international market. Chinese SWH enterprises have advantages in the international market because of the low material and labor costs and self-owned intellectual property rights. While to be more competitive in future international market, three strategies are essential for Chinese SWH enterprises. First, they need to find a good cut-in point. While in domestic markets, low prices are the main competitive advantage, in international markets, reliable quality and environmental performance are the main competitive advantage. Moreover, flat plate and heat pump SWH systems are mainstreams in international markets, and Chinese SWH enterprises should adjust their product structure accordingly. Second, Chinese companies should enhance international relations by cooperating with foreign partners, eventually establishing overseas branches to save on transport costs. Finally, they should employ qualified personnel for the development of various SWH technologies, foreign language competencies and international trade expertise.

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Chapter 7 Conclusions and Recommendations

"In the move to a low carbon economy, we believe that China will no longer be a developing country following where others have led, but a pioneer leading the way."

– Howard and Wu (2008)

7.1 Introduction

Renewable energy development is regarded as an important element solution to climate change, as it reduces carbon dioxide emissions. As such renewable energy has obtained global attention from both scientists and politicians. China started its efforts to develop renewable energy resources about 30 years ago. The Chinese government has issued various policies, allocated large amount of funding and carried out demonstration projects mainly on the implementation of biomass, wind power, solar energy and small hydropower. During the process of this study, the *Renewable Energy Law* was activated in 2006, which was a milestone of and forms a fundamental legal basis for the nationwide development of renewable energy resources in China. As a result, utilization of renewable energy resources increased rapidly over the past years since the start of the new Millennium. However, no systematic assessment has been carried out on the performance of renewable energy development policies in China. There is no clear answer to the question whether the policies and projects on renewable energy development were implemented in an effective way.

Against this background, the main objective of this study was to assess the performance of renewable energy policies and practices in China. Three main research questions were raised at the beginning of this study. First, has the implementation of renewable energy policies and practices in China achieved good performance? Second, what are the driving forces behind the successes/failures of renewable energy development in China? Third, what reforms can be recommended for further and future renewable energy policy and programs in China? These research questions were approached in the analytical framework of policy evaluation. With the help of three cases viz. rural biomass gasification, onshore wind power and SWH, performance of renewable energy development in China was assessed in terms of economic performance, technological performance, environmental impact and social impact. The driving forces behind the performance were also analyzed within the triad-network of renewable energy development in China.

This concluding chapter subsequently provides overall answers to the research questions. Considering the facts that all biogasification projects in China are implemented at community level in rural areas, Inner Mongolia is the province with most installed capacity of wind power, while Zhejiang has the highest installation rate of SWH, findings from the cases have some degree of generalization, i.e. the findings have relevance for other areas with similar renewable energy projects in China. But, of course, in generalizing findings one also needs to be careful on the case study specific characteristics. In Section 7.2 I conclude on the performance of renewable energy development in China. In Section 7.3 I analyze the policy network drivers, economic network drivers and societal network drivers to the performance of renewable energy development in China. In Section 7.4 I put forward recommendations for further implementation of renewable energy. This chapter ends with discussions on the implications for future research on public acceptance of renewable energy, evaluation of evaluation and post-Kyoto renewable energy development in China.

7.2 Performance of Renewable Energy Development in China

As discussed in Chapter 3 and carried out in each of the three empirical chapters, the performance of renewable energy development in China was assessed in terms of economic performance, technological performance, environmental impact and social impact. In this section, I try to bring together the evaluation results of the three cases to conclude on performance of renewable energy development in different conditions in China. Judgments on performance of individual cases in general are given in Table 7.1, followed by a detailed discussion on each performance criterion in the subsequent sections.

Table 7.1 General judgment on performance of cases

Indicator	Sub-indicator	Biomass gasification	Wind power	SWH
Economic performance	Project developer	--	--	+
	End user	N/A	-	++
Technological performance	Technology	--	+	-
	Equipment	--	-	N/A
Environmental impact	Pollution abatement	+	+	++
	GHGs reduction	+	+	++
Social impact	Direct	+	+	+
	Indirect	N/A	+	--

--: highly negative -: negative N/A: not applicable
+: positive ++: highly positive

7.2.1 Economic performance

Among the three cases of this study, only the SWH projects brought the project developers economic benefits (Section 6.5.1). SWH manufacturing is one of the most profitable industries in China. In comparison, the biogasification projects (Section 4.4.1) and wind power projects (Section 5.5.2) failed to achieve satisfying economic performance.

Application of SWH in households saved large amounts of fuel costs to heat water, which could recover the installation cost of SWH within a short period (Section 6.5.2). The biogasificaiton projects could also bring end users economic benefit by saving fuel cost. Considering the fact that most biogasification projects were established in rural areas, their economic benefits to end users were even more significant than the SWH projects. However, due to the large scale close down of biogas stations, this economic benefit was not realized in at least (but probably more than) half of the communities with biogasification projects (Section 4.4.3). Electricity generated by wind farms was purchased by grid companies, who sold the electricity to end users connected to the grid. If grid companies purchased wind electricity at a price higher than the price of power generated from other sources, the price difference was allocated within the whole power grid in the form of higher retail prices to the electricity end users (cf. Section 2.4.2). Therefore, economic performance of wind power projects to end users was negative[78].

7.2.2 Technological performance

There is still large room for China to improve the level of renewable energy technology it applies. The designers of biogasification technology were too much concerned with the reduction of costs. As a result the gasification systems suffered problems of tar, leakage and difficulties in treating wet feedstock (Section 4.4.2). China is the leader of SWH production in the world. However, the widely spread glass vacuum tube SWH technology applied in China is faced with several technical problems. There is no satisfying solution yet to adapt SWH systems to existing buildings. SWH systems in use caused waste of water. The water tank and pipes installed outside of the buildings were frozen during cold winters (Section 6.6.2). In comparison, the wind power technology used in China was carefully designed and applied at sites with sufficient wind energy resources. However, the average construction cost of wind power in China was too high, although it is expected to reduce by enhancing the proportion of domestically manufactured turbines installed in wind farms (Section 5.6.1 & Section 5.6.3).

China had more problems in managing the equipments of various renewable energy demonstration projects. Four out of the seven biogas stations I visited were closed down and one was working in worrying conditions, mainly due to management problems (Section 4.4.2). The average full load hours of wind turbines in China were much lower than those with the same technology in some western countries. In other words, they worked less efficiently than they were designed for (Section 5.6.3). Because the SWH systems were easy to operate, there was no information about management problems obtained during this study.

[78] Although most end users of wind power don't know this was negative

7.2.3 Environmental impact

Reducing air pollutants and GHGs emission reduction as well as preventing further exhaustion of non-renewable energy sources were the two incentives for China to start its efforts to develop renewable energy resources. The positive environmental performance of renewable energy projects analyzed in this study was achieved mainly via the reduction of fossil fuel consumption and thus a reduction of greenhouse gas emissions. In villages where biogasification projects were successfully carried out, local people used biogas instead of coal and straws for daily life fuels. As a result, emissions of air pollutants were reduced in villages with biogasification projects compared to villages without biogasification projects (Section 4.4.3). In 2008 the wind farms in China generated about 12 billion kWh of electricity, which reduced in total 0.0252 Mt soot, 0.0571 Mt SO_2, 0.378 Mt solid waste, and 7.2 Mt CO_2 emissions (Shi, 2009). China had installed 1.08×10^8 m^2 (collector area) of SWH by the end of 2007, which could theoretically reduce 0.524 Mt SO_2, 0.238 Mt NO_2, 0.405 Mt dust and 21.6 Mt CO_2 emissions every year.

7.2.4 Social impact

The development of renewable energy resources in China influenced the civil society and the local communities where the projects were carried out in both positive and negative ways. Villagers obtained economic benefits from the biogasification implementation by using cheaper fuel (than coal and LPG), selling straws to the biogas stations and obtaining new employment. With biogasification, they also had more time for recreation and education (Section 4.4.3). The construction and maintenance of wind farms offered new job opportunities to local people. In the areas where wind farms were constructed, the traffic conditions were always improved. The establishment of wind farms also brought additional tourism resources. However, herdsmen's production is negatively influenced by wind power projects (Section 5.7.2). Installation of SWH brought local residents an economic, clean and safe way of heating water for their daily lives. Through the utilization of SWH they had a new way to express their concerns on environmental protection. In addition, introduction of SWH increased the availability and use of hot water and thus reduced rheumatoid arthritis prevalence in local people. However, both the installation and utilization of SWH had limited security risks. The installation and maintenance of SWH caused several accidents to the public (Section 6.7).

Overall, from the case studies we can conclude that the development of renewable energy in China had poor economic and technology performances, highly positive environmental impacts and decent social impacts. Poor economic benefit had substantially negative impacts on implementation of renewable energy projects. A large percentage of biogas stations discontinued their production because of insufficient income. The low profit level, mainly due to the extremely cheap price of wind power, was making wind power less and less attractive for renewable energy developers in China. The stagnating technology evolution was another main bottleneck to renewable energy development in China. Without suitable technology and proper management of equipment, the renewable energy resources in China can not be utilized in sufficient ways. Environmental improvement, in the form of reduction of air pollutants, GHGs and fossil fuel consumption, is an important outcome of renewable energy development in China. The Chinese government aims to reduce 10% of its air pollutant emission during the 11th national Five-Year Plan. The implementation of renewable energy will be a contributor to this objective. The development of renewable energy resources in China also brought both benefit and conflict to local societies. How to obtain higher public acceptance and support is a challenge for renewable energy development in the near future.

When I selected cases for case studies, the administrative level was taken as a main criterion. Results showed that the projects at lower administrative level (biogasification) have more difficulties in communicating with and asking for supports from the top government than those at higher level (wind power). The economic condition was taken as another important criterion for selecting cases in this study. Results showed that the economic condition of study areas had substantial impacts on the performance of renewable energy projects. The initial investment became the main barrier for local people in poor areas to accept renewable energy technology, even if the technology had economic profit in long term (cf. Chapter 4). On the contrary, renewable energy technology was well accepted in rich areas in China (cf. Chapter 6).

7.3 Driving Forces of Renewable Energy Development in China

The emergence and performance of renewable energy development in China is not an "incidental or marginal phenomenon", but rather a result of systematic transformations in existing political, economic and societal institutions. In Chapter 3 I introduced a triad-network model for analyzing such transformations. In this section I use this model to generalize the driving forces of renewable energy development in each case. It is interesting to find out that each case is strongly influenced by two of the three networks, while the influence of the other network is very limited (Figure 7.1). To be more specific, the biogasification projects are mainly influenced by policy networks and societal networks; the wind power projects are mainly influenced by policy networks and economic networks; while SWH is mainly influenced by societal networks and economic networks. In this section I want to draw general conclusions as to (the absence of) these driving forces and what that might mean (in general terms) for recommendation to strengthen the renewable energy developments and improve performance.

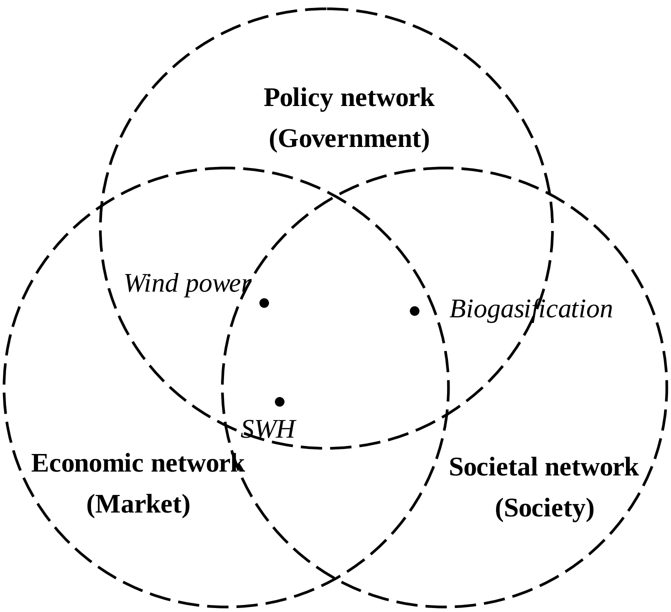

Figure 7.1 The triad-network of renewable energy development in China

7.3.1 Driving forces of the biogasification

The development of biogasification in China is strongly influenced by policy networks and societal networks. As was illustrated in the case, all biogasification projects were planned and established following a "top-down" governmental order. Two-third of the construction costs came from governmental investments. All the stations were constructed at community level and were run by the community governments. The acceptance and reactions from the local residents imposed great impacts on the operation, and even survival of the stations. In comparison, the biogasification lacked representation of strong economic actors and was not organized along economics of market rules and principles. The biogas produced by the stations was not sold to a grid, or to a fuel market. When the villagers purchased biogas, the gas price was not decided by market mechanism, but governmental order. There was no private investment in the construction and/or maintenance of the biogas systems.

The absence of economic network drivers has obvious negative impacts on the short and long term performance of biogasification projects in various aspects. It was the main reason for the poor economic performance of the biogas stations, as the biogas was sold at too low prices. Being isolated from the real market, the biogas stations had no access to external investments or new technologies. The management of the biogas stations was also very unprofessional [79] and completely neglected simple cost-benefit analyses. Hence, stronger influences of economic network drivers would improve the management and the economic performance of the biogas stations. In strengthening the economic network drivers, there are two important tasks. One is how to involve private economic agents into the development of biogasification projcets. The other one is how to run the biogas stations along market rules and principles.

7.3.2 Driving forces of the wind power

The development of wind power in China is strongly influenced by policy networks and economic networks. The government had and used the full authority to assess wind power resources, select project sites, decide on project scales and organize the bidding process around new wind parks. The production of wind power was heavily influenced by policy evolution. For example, after the introduction of 70% domestic equipment policy into

[79] Because they were not run by energy companies, but staffs from the community governments

concession projects, the wind power developers who once mainly used imported turbines had to look for domestic equipment providers in short time. Some of them lost the opportunity to apply for new project because they could not find a suitable provider of domestic equipment.. Meanwhile, the wind power developers could apply for concession projects under a completely competitive bidding mechanism that followed market rules. Domestic wind turbine manufacturers grew up quickly and took a considerable market share in China. The cooperation between domestic manufacturers and their foreign partners were also an important driver for furthering wind power developments. Setting wind power electricity prices involved both market and policy dynamics. However, there is little influence of the societal network on wind power development in China. NGOs in China had very limited voice in wind power projects and development, certainly when compared with those in western countries. Wind farms in China were normally constructed in remote areas, which resulted in little impact on the daily lives of local residents. Hence, the establishment of wind farms was seldom opposed by local people but local people had also no influence at all in design, siting and running of wind power parks. At best there was some kind of compensation, usually decided centrally by governmental authorities.

The strong influences of policy network and economic network drivers had crucial meaning to the rapid development of wind power in China. It provided favorable policy environment to wind power development. It helped find suitable wind resource and project developers, and it reduced transaction costs. And not in the least it is responsible for the extremely rapid growth of wind energy in China. However, it also induced the vicious competitions in the concession project bids. The absence of societal network drivers did not have fundamental influence on wind power development in China. If the influences of societal network are strengthened, side effects of wind power development will become more articulated by the society[80]. We can expect stronger Not-In-My-Backyard (NIMBY) kind of protests around wind power parks in China, when civil society networks are strengthened and more strongly involved in wind power developments. In strengthening the societal network drivers, there are also two important tasks. One is how to provide sufficient and up-to-date information of wind power development to the society. The other one is how to create a better platform for the public to express their opinions on wind power development.

[80] In fact the question here is not “whether” but “when” the societal network drivers are strengthened because the public perception of sustainable development is increasing rapidly.

7.3.3 Driving forces of the SWH

The development of SWH is strongly influenced and advanced by economic networks and societal networks. The production and retail of SWH products are completely marketalized in China. Both production and retailing of SWH is fully part of the economic network. Buying and installing SWH systems can be placed in-between the economic and societal network. All producers compete with each other on a 'free' market, with only limited policy structuring and involvement. Subsidy on SWH installation was still used in several cities in China, while the standard was not uniform. The installation of SWH system on existing buildings was obstructed by city administrations and real estate managers in many cities in China. However, certainly in comparison with the other two sectors of renewable energy, the development of SWH was much less influenced by policy network drivers. There was no other special policy measure implemented on SWH development.

The economic network drivers largely improved the development of SWH in China. SWH was the only renewable energy technology promoted through a real market, while other renewable energies were developed in "state-organized markets". The state-organized markets can ease development and implementation of renewable energy by providing greater ease of access to the grid, relevant (market) signals to encourage investment, and make available larger land areas (Shelk, 2008). However, the profit of a renewable energy project grows along with increasing market demand while the state-organized markets can not provide such 'real' market demands. Being in a 'real' market, producers of SWH in China achieved much economic benefit, which stimulated the rapid development and diffusion of SWH industry and technology in China. Meanwhile, the societal network drivers did not play a major role in the development of SWH except for the conflicts with other social sectors, as described above. The marginal influence of policy network drivers resulted in problematic SWH product market order, lack of technological innovation and poor energy performance. It further harmed the image of domestic SWH products in external markets. If the function of policy network is strengthened, development of SWH will receive stronger policy supports. The frequency of conflicts with other social sectors can be largely reduced. It is also possible to see an improved market with better qualities of SWH products and services. In strengthening the policy network drivers, there are also two important tasks. One is how to improve the communication between governmental authorities and the SWH companies. The other one is how to revise existing policies or formulate new policies to promote the development and technological innovation of SWH.

7.4 Recommendations for Further Implementation

The above discussion focuses upon the performance of renewable energy development in China and the driving forces to this performance. As another important research objective, corresponding recommendations (to strengthening the absent network drivers) for further implementation of renewable energy in China are put forward in this section. These recommendations include policy revision, market reform and technology innovation.

7.4.1 Institutional reform and policy revision

Although the institutional structure and policy framework for renewable energy development has been formulated by the Chinese government (Section 2.3 & 2.4), they need revision in the following aspects.

First, a full-authority Ministry of Energy should be established. It has full ministry level of authority so that it can negotiate with other ministries in making national development plans. It supervises the development of both conventional energies and renewable energy in China so that it can formulate and implement long-term renewable energy development strategy. It has monitoring system on the efficiency of renewable energy projects and watchdog department on the market order of renewable energy products.

Second, private energy companies should be allowed to purchase or contract the renewable energy projects that are run by the government. For further renewable energy projects, a completely competitive bidding mechanism should be used to select the project developers. The project developers are responsible for both the construction and operation of the renewable energy projects.

Third, the government should provide the social organizations and the public better accesses to construction and operation data of renewable energy projects, e.g. via periodical reports, websites and media information. There should also be better platforms, such as public hearings, opinion polls, and participation in public policy making, for the social organizations and public people to express their opinions in siting and mitigating local side-effects of renewable energy projects.

Fourth, feed-in tariff should be set on wind power. Currently feed-in tariff is applied on all renewable electricity generation except for wind power. The Chinese government has carried out five terms of concession projects, in order to select the best project developers under the bidding competition. But this caused the problem of extremely low grid prices offered by winning concessions and subsequently hampered the growth of wind power sector. Therefore, a fixed feed-in tariff should be set for concession projects. This feed-in tariff can be set at the market price of grid electricity so that the market can decide where to get electricity from. By setting the feed-in tariff, a reasonable profit of the developers can be ensured. The selection of developers for concession projects is then based on other criteria, such as technology level and management performance.

Fifth, renewable energy development should be involved in the "Building New Socialist Countryside" campaign. Developing renewable energy resources, especially biomass energy, in rural areas can provide local residents cheap and clean fuels. Its strategic meaning of environmental improvement and poverty alleviation are quite in line with the "Building New Socialist Countryside" campaign. Currently development of biogasification in rural China is threatened by the campaign as the latter caused reduction of biomass wastes harvest. If renewable energy development is involved as an important content of the campaign, it can attract more concerning from the higher government. The problem of biomass shortage can also be solved.

7.4.2 Market establishment

Renewable energy is still a novelty that emerges in technological and market niches in China. Before it is capable to compete with conventional energy technologies, a semi-protected renewable energy market should be established.

In such a semi-protected market, the government continues providing large amount of financial supports to renewable energy development. Foreign experiences have proved the importance of financial supports in promoting renewable energy successfully and effectively (Haas et al., 2004; Sawin and Prugh, 2004). Further financial supports are also vital for development of renewable energy development in China. The financial supports can be realized in three ways. The first way is governmental subsidy. Most of the governmental investment in renewable energy in China is spent on subsidizing project construction. In this way, the – sometimes extremely expensive – infrastructure can be constructed. The subsidy to end users is important for promoting renewable energy utilization in rural areas where the local people can not afford the cost of buying renewable energy facilities, such as SWH systems or PV panels. The second way is investment in scientific research. Although China has increased its investment on renewable energy development, only less than 20% of the investment is spent on human resource development and technology R&D. Human resource development and technology R&D are key elements of capacity building and therefore more investment on them is necessary for renewable energy development in China. The third way is tax incentive. Although the preferential tax on renewable energy development was stated in the *Renewable Energy Law* and trailed in wind power sector, there is no policy clarifying the standard of VAT, income tax and customs tariff of renewable energy in China.

In such a semi-protected market, the renewable energy products are sold more according to “real” market rules and conditions. For those whose costs can compete with conventional energies, the market competition can stimulate its scale of production. For those whose costs are still too high, they receive more governmental subsidies to level the platform of competition with conventional energies. When the technologies of those renewable energy products have improved and the costs have been low enough, they can participate in the market competition without governmental subsidy. The most important point is that the price of renewable energy products should be decided by market mechanism, not the government.

In such a semi-protected market, foreign investors can play an important role. The concession projects should be opened up to foreign investors. At the beginning, the foreign investors are required to have a Chinese partner; while later they can bid for concession projects independently. Before the year 2012 CDM projects should be a major platform for foreign investment. The government should help domestic renewable energy producers in calculating benchmarks and contacting CERs buyers. For those small-scale renewable energy projects in China, they can apply to be Programmatic CDM (PCDM) projects. PCDM can involve a group of small scale renewable energy projects with the same project idea. It therefore improve the possibility for rural renewable energy projects in China to apply for CDM projects and further exploit the potential of CDM projects in renewable energy industry.

7.4.3 Technology improvement

Besides the policy revision and market establishment, China should also improve the technologies it is using for renewable energy development.

In short term, some technological problems should be solved. As discussed in the previous chapters, development of renewable energy in China encountered several technological problems. For example, the biogasification equipments were jammed by tar, or the SWH equipments were frozen in extremely cold weather. These technological problems can be prevented in two ways. First, set more stringent standard on renewable products. It puts the pressure on the producers and subsequently stimulates their efforts in solving these technological problems. Second, leave these technological problems to the research institutes. Research institutes have advantages in accumulated basic research outcomes and information of sophisticated technologies. They may solve the technological problems that the renewable energy producers can not solve.

In medium term, technology improvement should focus on energy efficiency at the point of end users. Currently most of the renewable energy resources are utilized in low-efficiency ways, for example, thermal utilization of bioenergy and solar energy. By technology improvement, these renewable energy resources can be used in more efficient ways, for example, electric power. This will reduce costs for energy services and help meet other sustainable development objectives. In medium term, technology improvement should also focus on reduced technology imports and reduced dependency on foreign technologies. When the domestic technologies are improved, we should even consider the possibility for further technology or product exports to other countries.

In long term, technology improvement should focus on diversifying technology of renewable energy resources. Currently the increment of renewable energy consumption in China is mainly achieved by utilization of biomass, hydropower, wind power and solar thermal. In fact China has also large amount of other renewable energy resources[81]. These resources have not yet been largely developed partly because the cost is still too high and partly because they are located in remote areas. New technologies should aim at cost reduction and local utilization of these renewable energy resources. This is very important to achieve the long-term objectives of renewable energy development and energy security.

7.5 Implications for Future Research

This study has assessed the performance of renewable energy in China, analyzed the driving forces behind the performance and put forward recommendations to further development. Considering that renewable energy development is a nationwide, long-term strategy in China, this study touches only the tip of the iceberg. There are at least three

[81] As discussed in Chapter 2, the amount of geothermal and ocean energy are much larger than that of bioenergy and wind energy in China.

interesting topics for future researches in relation to renewable energy development in China.

7.5.1 Public participation and acceptance of renewable energy development

Public participation and acceptance of renewable energy is fundamental to further increasing the share of renewable energy in the overall energy consumption. In this study I have tried to analyze the influences of social actors on renewable energy development in China. The results reveal that economic benefit is an important precondition of public acceptance of renewable energy technologies in China. The biogasification projects were accepted by more villagers after their economic performance was proved (Section 4.4.3). Most household users (48%) installed SWH in consideration of saving money (Section 6.7).

It is interesting to strengthen this discussion in the following directions. The first direction is about the factors influencing public participation and acceptance of renewable energy in China. Similar studies have been carried out by Uperti and Horst (2004) who explored the causes and consequences of public opposition to a biomass electricity plant in UK, and Devine-Wright (2008) who classified the personal, psychological and contextual factors that shape public acceptance of renewable energy technologies. The second direction is about the public participation techniques in renewable energy development in China. Polatidis and Haralambopoulos (2004) support participatory multi-criteria decision aiding techniques to actively include all stakeholders of renewable energy development in Greece. Is this also possible and relevant in China? The third direction is about solutions to social barriers to renewable energy development in China, which can also be compared with previous studies. Agterbosch et al. (2007) analyzed the most crucial social barriers to realize wind power projects and concluded on different solutions of both the entrepreneurs and local civil servant to these barriers. Wolsink (2000; 2007) explained the limited public acceptance of renewable energy beyond the conventional NIMBY arguments and advocated ‘strong’ modernization in planning regimes and decision-making practices to enhance the implementation processes of renewable energy. Khattak et al. (2006) identified and ranked the barriers to renewable energy projects, within which social acceptance was considered as an important factor, in Pakistan and provided solutions in such a way that the barrier removal does not introduce another barrier.

Up till now no systematic studies have been carried on public acceptance and participation in renewable energy projects and developments in China. But considering the massive investments programs put forward by the Chinese government in renewable energy, and the poor record of Chinese research on participation and acceptance, research in strongly need in this field.

7.5.2 Evaluation of evaluation

This study evaluates the performance of renewable energy development in China. As Power (1999: 122-147) agued, performance evaluation is a complex, difficult and expensive approach, which raises a high risk that the evaluation itself will not provide a good performance. Now that China is slowly embarking on a more systematic trajectory of evaluation and auditing of major governmental policy, the question of the quality of such audits and evaluation moves to the fore. Hence, it would be interesting to start designing an evaluation of various policy and project evaluation studies and activities as carried out in China. Such an evaluation of evaluations can be focused on the one hand on the quality, completeness and feasibility of evaluation methodology and on the other hand on the quality of evaluation outcomes. Quality, completeness and feasibility of evaluation methodology refers to the extent to which the evaluation methodology can fulfill the evaluation plan, while the quality of evaluation outcomes refers to the extent to which evaluation outcomes are addressing the needs of evaluation stakeholders, both governmental and non-governmental.

7.5.3 Post-Kyoto Renewable Energy Development in China

The Kyoto Protocol, as the major result of the "Third Conference of the Parties" (COP) of UNFCCC in December of 1997, promoted financial and technical co-operation internationally to adopt climate policies and technologies, and set binding emission reduction targets and timetables for Annex I countries (developed nations plus economies in transition). It allowed developed countries to reach their targets under three “flexibility mechanisms”[82]. China ratified the Kyoto Protocol in 1998 as a non-Annex I country. As the largest developing country with fast industrial development in the world, China attracted large amount of investments and projects from western countries[83] and became the largest

[82] The developed countries are allowed to supplement domestic Policies And Measures (PAM) with projects abroad and with market instruments including International Emissions Trading (ET), Joint Implementation (JI) and Clean Development Mechanism (CDM).

[83] Mainly EU countries

receiver of CDM projects and as such contributed to the reduction of GHGs under the Protocol. It is notable that renewable energy is an important field for these foreign investments and projects.

We are approaching the final year of the Kyoto Protocol (2012). What are and should be the post-Kyoto strategies for China? And what will be the role of renewable energy among these strategies? Will China become a world leading in developing renewable energy?

First, considering the Chinese government's great determination on and the large amount of investment to exploit renewable energy resources, there is no reason to doubt the bright future of renewable energy development in China. As an important aspect of this bright future, China will promote domestic renewable energy R&D. As I have discussed in this study, China has developed rapidly in SWH technology innovation. There are also many institutes as well as researchers carrying out both laboratory and field researches on new renewable energy technologies. It is not interesting to study whether, but rather when and how China will take a global leading role in various renewable energy technologies.

Second, China can be expected to take a more active role under Bali Roadmap. The Bali Roadmap was issued on the second COP of Kyoto Protocol in December 2007. It put on paper a clear agenda and topics of future negotiation on a secure climate in post-Kyoto era. When China ratified the Kyoto Protocol in 1998, it was regarded as a developing country and thus non-Annex I country. Ten years passed and China has made great achievement in economic development in these years[84]. In future negotiations on international cooperation towards climate change problems, China may take a more active role under the "common but differentiated responsibility" principle. For example, China will contribute more to the projects in the Least Developed Countries, in forms of financial support and technology transfer.

[84] It is more and more regarded as a transition economy instead of a developing country.

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Appendixes

Appendix 1 List of Interviewees

The Case of Biogasification in Shandong Province

Name	Affiliation	Title
Mr. Zhong	Eco-Agriculture Section, Department of Agriculture	Director
Li Sun	Energy Research Institute of Shandong Academy of Sciences	Director
Min Xu	Energy Research Institute of Shandong Academy of Sciences	Professor
Yuping Dong	College of Mechanical Engineering, Shandong University	Professor
Zhiyong Wang	Baichuan Tongchuang Energy Sources Co., Ltd.	Manager
Chuanmin Ai	Aijia Village, Licheng District, Jinan City	Secretary
Laiming Zhang	Nanguoer Village, Licheng District, Jinan City	Deputy Secretary
Mr. Zhao	Shasan Village, Wangsheren Town, Jinan City	Secretary
Ronghe Li	Shiziyuan Village, Licheng District, Jinan City	Secretary
Chongguo Li	Shiziyuan Village, Licheng District, Jinan City	Mayor
Jinshan Wu	Sunyunzi Village, Shouguang City	Secretary
Mr. Liu	Xiaoliujia Village, Licheng District, Jinan City	Secretary
Mr. Zhang	Xiaozhangma Village, Wangsheren Town, Jinan City	Mayor
Bingfu Li	Biogas Station, Xiaozhangma Village	Manager
Fenghai Wang	Yuanjia Village, Dongjia Town, Jinan City	Secretary

The Case of Wind Power in Inner Mongolia

Name	Affiliation	Title
Zongming Li	Research Institute of Wind Power	Director
Guangli Zhang	China Renewable Energy Scale-up Program	Project Manager
Shupeng Zhuang	North Longyuan Wind Power Corporation	Deputy General Manager
Yijun Jia	North Longyuan Wind Power Corporation	Department Manager
Ms. Hu	North Longyuan Wind Power Corporation	Department Manager
Jian Zhang	Huitengxile Wind Farm	Manager
Jun Wang	Shangdu Wind Farm	Manager
Jianjun Zhang	Zhurihe Wind Farm	Manager

The Case of Solar Water Heater in Zhejiang Province

Name	Affiliation	Title
Zhisheng Xia	Zhejiang Solar Energy Industry Association	Chairman
Guoguo Zhang	Haining Solar Energy Sector Guild	Chairman
Xiaoping Zhang	Department of Agricultural Economy, Haining City	Director
Haitao Chen	Energy Section, Zhejiang Development and Reform Commission	Director
Xianyi Zhang	Agricultural Economy Section, Department of Science and Technology, Zhejiang Province	Director
Shixing Wang	Meteorological Information Center, Zhejiang Meteorology Bureau	Director
Zhifu Han	Ecological Section, Zhejiang Environmental Protection Bureau	Director
Funian Zhang	Zhejiang Wanma Real Estate Group	Manager
Weiliang Kong	Zhejiang Kaiyuan Real Estate Group	Manager
Hongyu Huang	Zhejiang Greentown Real Estate Group	Engineer
Shixiong Jin	Zhejiang Hongxiang Construction Group	Engineer
Jianhong Quan	Haining Interma Solar Electrical Co., Ltd	Manager
Dongwei Wang	Haining Onosi Solar Water Heater Co., Ltd	Manager

Appendix 2 Questionnaire for Solar Water Heater Users

Instruction

This questionnaire aims to understand the status, barriers and public opinions of purchasing and using solar water heater (SWH), and the economic, environmental and social benefits. This is an academic questionnaire purely for scientific researches. There is no “correct” answer to each question.

1. Personal information

1.1 Your family has ________ members.

A. 1; B. 2; C. 3; D4; E. 5 and above

1.2 Your family income in 2006 was _______.

A. <20,000; B. 20,000 ~ 40,000; C. 40,000 ~ 60,000; D. 60,000 ~ 80,000; E. >80,000

1.3 Your educational background is _______.

A. primary school; B. middle school; C. high school; D. bachelor; E. master and above

2. Purchasing SWH

2.1 The SWH installed in your home has been used for _____ years.

A. <1; B. 1; C. 2; D. 3; E. 4; F. 5 and above

2.2 Is this the first time your family has installed SWH? Yes ____ No ____. If not, the average life of the previous SWHs is _____ years.

2.3 You learn information about SWH from _______ (Multiple choices)

A. newspaper; B. magazine; C. TV; D. radio; E. internet; F. other __________

2.4 The price of the SWH you are using is _____ yuan. It is _____.

A. too expensive; B. expensive but acceptable; C. reasonable; D. cheap

2.5 You choose SWH because it is __________.

A. safe; B. environmental friendly; C. economical; D. from governmental order;
E. already installed when you purchased the house; F. other ___________

3. Using SWH

3.1 The capacity of the SWH is _____ L. Is it enough for your family? Yes____No____.

3.2 The annual maintenance fee of the SWH is ________ yuan.

A. 0; B. <20; C. 20～50; D. 50～100; D. >100

3.3 Before you installed water heater, you took baths _____ in winter.

A. in public bathrooms; B. at others' who had water heater; C. using hot water from water boiler; D. by cold water; E. other ________

3.4 After using SWH, the air quality at your home ________.

A. significantly improved; B. slightly improved; C. did not change

3.5 The SWH can be used in _____ days a year.

A. <100; B. about 150; C. about 200; D. about 250; E. about 300; F. 365

3.6 Averagely you take _____ baths a week.

A. <1; B. 1～2; C. 3～4; D. 5～6; E. 7 and above

3.7 SWH has advantages of _____ to other types of water heaters (Multiple choices).

A. cheap to install; B. cheap to use; C. safe; D. high water temperature; E. easy to use; F. environmental friendly; G. other ___________________

4. Prospect of SWH

4.1Will you continue using SWH? _______

A. Of cause. It is the best choice for my family; B. Yes. But I am expecting fro better products;

C. Yes, combined with other water heater; D. No. It is a big mistake to install SWH;

4.2 Do you believe it is promising to popularize SWH in this city? ___________

A. Highly possible. It has actually been popularized here already;

B. Maybe. But there need some additional conditions;

C. Difficult. Only if the government insists and invests a lot of resources;

D. Impossible. SWH has no future in this city.

4.3 What are the major barriers do you think to popularize SWH? _________ (Multiple choices)

A. The price is too high to afford; B. Poor market order;

C. It is largely restricted by weather condition; D. Too complicated to operate;

E. Low technological level; F. It is not safe;

G. Short life time; H. Other ___________________

4.4 The government should take measures including ________________ to popularize SWH (Multiple choices).

A. command-and-control measures; B. subsidies; C. better city planning; D. more technical supports to end users; E. better regulated market; F. more laws and regulations; G. public education of environmental protection; H. other ______________

4.5 Do you have more opinions and suggestions to the development of SWH?

____

____

4.6 Do you have more opinions and suggestions to this questionnaire?

____

____

That’s the end of this questionnaire. Thank you for your cooperation.

Summary

Energy demand in China has risen rapidly, driven by its massive economic growth. Meanwhile, the energy system in China heavily depends on fossil fuels, which causes serious problems of climate change and air pollution. China started to develop renewable energy about 30 years ago, aiming to alleviate the pressure of energy shortage and fossil fuel related environmental problems. The central government has shown great determination to promote the utilization of renewable energy resources and it set ambitious targets to increase the proportion of renewable energy in the country's total energy consumption to 10% by 2010 and 15% by 2020.

China has a large amount of renewable energy resources within its vast territory. Large potentials of producing bioenergy, solar energy, wind energy, hydro energy, geothermal and ocean energy have been identified in China. During the past three decades, the Chinese government made major efforts to develop these renewable energy resources. A series of policies have been formulated to promote renewable energy utilization. As the second largest investor on renewable energy in the world, China has invested considerable financial resources to renewable energy projects. As a result, the installed capacity of renewable energy in China has increased sharply, especially in the fields of wind power, solar thermal and hydro power. However, China lacks effective monitoring and evaluation systems to review the performance of renewable energy policies, programs and projects. It is not yet clear whether the objectives of China's renewable energy development policy will be reached in an efficient and effective way.

Under such circumstances, this study evaluates the performance of renewable energy policies and practices in China. The following three research questions are given a central place: What is the performance of the implementation of renewable energy policies and practices in China up till now? What are the driving forces behind the successes/failures of renewable energy development in China? What reforms can be recommended for future renewable energy policies and programs in China?

In order to answer these questions, this study uses various ideas and concepts of policy evaluation theories as sources of inspiration and information to build an analytical model for evaluating the performance of renewable energy developments in China. Within this analytical model, the performance of renewable energy development is evaluated by criteria of economic performance, technological performance, and environmental and social

impacts. The driving (f)actors behind the performance are subsequently analyzed using a triad-network model. Finally, recommendations for future development of renewable energy in China are formulated, based on these analyses.

This study takes primarily a qualitative research strategy, based on case study research. Three main cases form the central part of this study: one case of biogasification developments in Shandong Province, one case of onshore wind power developments in Inner Mongolia, and one case of solar water heater developments in Zhejiang Province. Data for each case study are collected through site observation, via in-depth interviews with key informants, via questionnaires and through secondary analysis of existing data, statistics and written sources. A structured approach – triangulation – is applied to combine the various data sources and data collection methods.

Results of the case study on biogasification prove that these projects do not bring developers and users economic benefit, due to the large-scale close down of biogas stations after a relatively short life time. The biogas stations also suffer from various technological problems such as tar jam, leakage of gas pipes and difficulties in treating wet feedstock. However, the establishment of biogasification projects improves the environmental quality of local area and the quality of life of local residents.

The analyses of wind power projects illustrate the poor economic performance of wind power projects due to the vicious competition for concession projects. Most of the wind farms are well designed and equipped with relatively new wind turbine technology, but many of them are used at low efficiency. The wind power projects reduce the consumption of fossil fuels for power generation and thus contribute to the reduction of air pollutant emission (among which greenhouse gasses). The construction of wind farms has marginal direct impacts on the life of local people and ecosystems. Nevertheless, these projects bring local areas some indirect benefits, such as improvements in the mobility infrastructure and accessibility and attractiveness to tourists (and thus economic income).

From the solar water heater case study it could be concluded that this technology brings both producers and end users major economic benefits. The use of solar water heater also reduces air pollutant emissions by reducing the consumption of fossil fuels. While overall this relatively simple technology functions well, the expansion of solar water heater utilization encounters some technological challenges. It proves difficult to adapt the solar water heaters onto existing buildings. Water tanks and pipes installed outside of the buildings are not resistant to extreme temperatures, as they freeze during extremely cold winters. The development and implementation of solar water heater has comes together with a number of social problems, especially in relation to obstructions by city administrations and real estate management in some cities.

The analyses of the driving forces behind these three renewable energy developments show some remarkable differences. The biogasification projects in China are strongly influenced and pushed by policy networks and societal networks, while economic networks play a marginal role in their development and implementation. Wind power projects in China are strongly influenced and advanced by policy networks and economic networks, while the influence of social networks is marginal. And the solar water heater projects in China are strongly guided and implemented by economic networks and societal networks, whereas policy network institutions and actors play less prominent roles. These driving networks, and the absence other networks, partly explain the performance of each of the renewable energy projects in China.

These findings also result in a number of recommendations for further developing renewable energy in China. In order to strengthen the poorly developed or absent network drivers in each case, improvements should be made with respect to institutional reform and policy revision, the further creation of market dynamics, and technology improvement. Some of the concrete recommendations formulated in this study are:

- The management of and investment in renewable energy projects should be improved by involving private companies into project development.
- Feed-in tariffs should be introduced in wind power projects.
- It is necessary to open up renewable energy development planning and siting to public participation and create a better platform for the public to express their opinion.
- A semi-protected market should be established to promote renewable energy development. In this semi-protected market, the developers continue to receive governmental subsidies, while the renewable energy products are sold increasingly according to “real” market rules and conditions, and foreign investments play a more important role than present.
- Technology improvements should aim to solve the technological problems in the short term, to improve efficiency of renewable energy utilization in the medium term, and to diversify the renewable energy technologies in the long term.

Finally this study formulates implications for future research. Research is recommended especially with respect to public participation and acceptance of renewable energy development as that hardly takes place at the moment; with respect to evaluation modes of performance evaluation itself; and with respect to China's post-Kyoto renewable energy development strategies.

Samenvatting

Door de enorme economische groei in China is de vraag naar energie er snel gestegen. Het Chinese energiesysteem is echter sterk afhankelijk van fossiele brandstoffen, wat ernstige klimaatveranderings- en luchtvervuilingsproblemen veroorzaakt. China begon ongeveer 30 jaar geleden met het ontwikkelen van hernieuwbare energie, met als doel de druk van energie tekorten en milieuproblemen door fossiele brandstoffen te verlichten. De centrale overheid toont sinds kort een grote vastberadenheid in het bevorderen van het gebruik van hernieuwbare energiebronnen en heeft ambitieuze doelen gesteld om het aandeel van hernieuwbare energie in de totale energieconsumptie van het land te verhogen tot 10% in 2010 en 15% in 2020.

Binnen het enorme grondgebied van China zijn vele bronnen van hernieuwbare energie beschikbaar. In China zijn goede mogelijkheden geïdentificeerd voor het produceren van bio-, zonne-, wind-, water-, geothermische en zee-energie. De Chinese overheid heeft de afgelopen drie decennia veel gedaan om deze hernieuwbare energiebronnen te ontwikkelen. Diverse beleidsmaatregelen zijn geformuleerd om het gebruik van hernieuwbare energie te bevorderen. Als op één na grootste investeerder in hernieuwbare energie ter wereld heeft China aanzienlijke financiële middelen geïnvesteerd in projecten op het gebied van hernieuwbare energie. Als gevolg daarvan is de geïmplementeerde capaciteit van hernieuwbare energie in China enorm toegenomen, vooral op het gebied van wind-, zonne- en waterenergie. Er is echter gebrek aan effectieve controle- en evaluatiesystemen om de resultaten van beleidsmaatregelen, programma's en projecten op het gebied van hernieuwbare energie te beoordelen. Het is daardoor nog niet duidelijk of de doelstellingen van het beleid voor de ontwikkeling van hernieuwbare energie in China op een efficiënte en effectieve wijze zullen worden gehaald.

Binnen deze context evalueert dit onderzoek de resultaten van de beleidsmaatregelen en de praktische toepassing van hernieuwbare energie in China. De volgende drie onderzoeksvragen staan hierbij centraal: Wat zijn de resultaten van de implementatie van beleidsmaatregelen voor, en praktische toepassingen van, hernieuwbare energie in China tot nu toe? Wat zijn de drijvende krachten achter de successen/mislukkingen bij het ontwikkelen van hernieuwbare energie in China? Welke hervormingen kunnen worden

aanbevolen voor toekomstige beleidsmaatregelen en programma's voor hernieuwbare energie in China?

Om deze vragen te beantwoorden maakt dit onderzoek, als bron voor inspiratie en informatie, gebruik van verschillende ideeën en concepten uit theorieën over beleidsevaluatie, om zo een analytisch model te ontwikkelen voor het evalueren van de resultaten van hernieuwbare energieontwikkeling in China. Met dit analytische model worden de resultaten van het ontwikkelen van hernieuwbare energie geëvalueerd met behulp van criteria voor economische resultaten, technologische resultaten en voor de gevolgen voor het milieu en de sociale context. De (f)actoren achter de resultaten worden vervolgens geanalyseerd met een Triad Network-model. Ten slotte worden op basis van deze analyses aanbevelingen geformuleerd voor de toekomstige ontwikkeling van hernieuwbare energie in China.

Dit onderzoek maakt gebruik van een kwalitatieve onderzoeksstrategie, gebaseerd op casestudyonderzoek. Centraal staan drie hoofdcases: een casus over ontwikkelingen op het gebied van biogasvorming in de provincie Shandong, een casus over windkrachtprojecten in Binnen-Mongolië, en een casus over de ontwikkeling van zonneboilers in de provincie Zhejiang. Gegevens voor elke casestudy zijn verkregen door observatie op locatie, via diepte-interviews met belangrijke betrokkenen, uit enquêtes en door secundaire analyse van bestaande gegevens, statistieken en schriftelijke bronnen. Een gestructureerde benadering - triangulatie - wordt toegepast om de verschillende gegevensbronnen en methodes voor gegevenscollectie te combineren.

De uitkomsten van de casestudy over biogasvorming tonen aan dat deze projecten geen economisch voordeel opleveren voor de ontwikkelaars en gebruikers, door de grootschalige sluiting van biogasstations na een relatief korte levensduur. De biogasstations lijden ook aan verschillende technologische problemen zoals verstopping door teer, lekkende gasleidingen en problemen met het behandelen van natte grondstoffen. Echter, het opzetten van biogasprojecten verbetert wel de lokale milieukwaliteit en de levenskwaliteit van de mensen ter plaatse.

De analyses van windkrachtprojecten illustreren de slechte economische resultaten hiervan als gevolg van de scherpe concurrentie om concessies. De meeste windparken zijn goed ontworpen en uitgerust met relatief nieuwe windturbinetechnologie, maar veel worden inefficiënt gebruikt. De windkrachtprojecten verminderen het verbruik van fossiele brandstoffen voor krachtopwekking en dragen zo bij aan een vermindering van de uitstoot

van luchtvervuiling (waaronder broeikasgassen). De directe effecten van windparken op het leven van lokale bewoners en ecosystemen zijn marginaal. Wel brengen deze projecten de lokale gebieden enkele indirecte voordelen, zoals verbeteringen in de verkeersinfrastructuur en grotere toegankelijkheid en aantrekkelijkheid voor toeristen (en daarmee inkomsten).
Uit de casus over zonneboilers kan worden geconcludeerd dat deze technologie grote economische voordelen brengt voor zowel voor producenten als eindgebruikers. Het gebruik van een zonneboiler vermindert ook de luchtvervuiling door het verbruik van fossiele brandstoffen te verminderen. Hoewel deze relatief simpele technologie over het algemeen goed functioneert, brengt de toename van het gebruik van zonneboilers enkele technologische uitdagingen met zich mee. Het aanpassen van de zonneboilers voor bestaande gebouwen blijkt moeilijk te zijn. Watertanks en leidingen die aan de buitenkant van gebouwen worden geïnstalleerd zijn niet bestand tegen extreme temperaturen, en bevriezen in extreem koude winters. Problemen met de ontwikkeling en implementatie van zonneboilers vallen samen met een aantal sociale problemen, vooral waar het gaat om gebrek aan medewerking door stedelijke overheden en vastgoedbeheerders in sommige steden.

De analyses van de drijvende krachten achter deze drie hernieuwbare-energieontwikkelingen geven enkele opmerkelijke verschillen weer. De biogasprojecten in China worden sterk beïnvloed en gestimuleerd door beleidsnetwerken en maatschappelijke netwerken, terwijl economische netwerken een marginale rol spelen in hun ontwikkeling en implementatie. Windkrachtprojecten in China worden sterk beïnvloed en bevorderd door beleidsnetwerken en economische netwerken, terwijl de invloed van maatschappelijke netwerken marginaal is. En de projecten met zonneboilers in China worden in hoge mate geleid en geïmplementeerd door economische en maatschappelijke netwerken, terwijl instellingen en actoren van beleidsnetwerken een minder prominente rol spelen. Deze sturende netwerken, en de afwezigheid van andere netwerken, verklaren voor een deel de resultaten van alle hernieuwbare-energieprojecten in China.

Deze bevindingen resulteren in een aantal aanbevelingen voor het verder ontwikkelen van hernieuwbare energie in China. Om de slecht ontwikkelde of afwezige netwerk-drivers in elke casus te versterken zijn verbeteringen nodig met betrekking tot institutionele hervormingen en beleidsherziening, het meer ruimte geven aan marktdynamiek en technologische verbeteringen. Enkele concrete aanbevelingen die in dit onderzoek zijn geformuleerd, omvatten:

- Het management van en het investeren in hernieuwbare energieprojecten moet worden verbeterd door particuliere bedrijven te betrekken bij de ontwikkeling van projecten.
- Er moeten feed-in tarieven worden geïntroduceerd bij windkrachtprojecten.
- Het is noodzakelijk de planning van het ontwikkelen van, en het kiezen van locaties voor, hernieuwbare energie te openen voor publieksparticipatie, zodat een beter platform kan ontstaan waar belanghebbenden hun mening kunnen uiten.
- Er moet een semi-beschermde markt worden opgezet om de ontwikkeling van hernieuwbare energie te bevorderen. Binnen deze semi-beschermde markt blijven ontwikkelaars overheidssubsidie ontvangen, terwijl de hernieuwbare energieproducten meer en meer verkocht worden volgens de regels en voorwaarden van de 'echte' markt. Buitenlandse investeringen moeten een belangrijkere rol gaan spelen.
- Verbeteringen van de technologie moeten als doel hebben de technologische problemen op korte termijn op te lossen om de efficiëntie van het gebruik hernieuwbare energie op de middellange termijn te verbeteren, en om op de lange termijn de hernieuwbare energietechnologieën te diversifiëren.

Ten slotte worden implicaties voor toekomstig onderzoek geformuleerd. In het bijzonder wordt onderzoek aangeraden naar publieksparticipatie en het accepteren van hernieuwbare energieontwikkeling, aangezien dit momenteel nauwelijks plaatsvindt, het evalueren van de resultatenevaluatie en China's post-Kyoto strategieën voor het ontwikkelen van hernieuwbare energie.

About the Author

Jingyi Han was born on July 18, 1980 in Haining City, Zhejiang Province, China. He obtained his Bachelor degree (Environmental Management and Planning) in Nankai University in July 2002 and his Master degree (Ecology) in Chinese Academy of Sciences in June 2005. His research interests and publications are related to environmental management and renewable energy development. In July 2005, he came to Wageningen University to pursue his doctorate.

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