Evaluation of Policies Designed to Promote the Commercialization of Wind Power Technology in China

By

The Ministry of Science and Technology
The State Development Planning Commission
The State Economic and Trade Commission

May 15, 2002

Preface

The development of human society is closely linked to the development of the exploitation and utilization of energy. A new type of energy can lead to enormous social and economic progress. Today, a prominent change in the energy structure is taking place worldwide: the mineral energy system is moving toward a sustainable energy system, which is based on renewable energy.

Mineral energy is gradually being exhausted. At the same time, the large-scale use of mineral energy brings about ecosystem damage and environmental pollution. Renewable energy development is a feasible solution to solving these global concerns. The development of renewable energy not only can solve the energy crisis problem, but also can help protect the environment.

Renewable energy includes solar, wind, biomass, geothermal, and ocean energy. Among them, wind energy power generation is developing most rapidly, and has entered the commercialization stage in some countries. The capacity of wind power generating sets worldwide have increased from 2 GW in 1990 to more than 17.5 GW in 2000. The average growth rate has reached 1.5 GW or 30 percent per year.

Although China's on-grid large-scale wind power technology lags behind that of some developed countries, wind power in China is growing rapidly. China has the ability to manufacture 600kW wind power generating sets, and is now organizing the R&D of wind power generating sets of over one Megawatt. At the end of 2000, the installed capacity of China's wind generating sets reached 344 MW, ranking China ninth in the world in wind capacity. From 1996 to 1998, China's wind power industry developed quickly, due to favorable government policies. However, recent reforms of the state managerial and power systems have hampered the development of wind power so that China's wind industry now lags behind those of many other countries, including some other developing countries. For example, the installed wind capacity in China is less than 6 percent of that in Germany and less than 30 percent of that in India. This is despite the fact that China's wind resources are 11.3 times more than those of Germany. In order for China's wind generation to catch up with the rest of the world, China urgently needs to establish incentive policies. Experience in other countries suggest that government support and incentive policies are key to the successful commercialization of the wind power industry.

In order to accelerate the development of China's wind power industry, the Ministry of Science & Technology of China, the State Development Planning Commission, and the State Economic and Trade Commission, with the support of the Energy Foundation—a U.S. non profit—investigated and analyzed incentive policies for wind power generation development in China. The results of this research are documented in this book, including discussion about (1) the necessity of developing the wind power industry, (2) the development of wind power technology in both China and other countries, (3) the barriers and problems concerning the commercialization of the wind power industry, (4) the importance of incentive policies, (5) the identification of possible incentive policies, (6) cost and benefit analyses of relevant policies for government reference, and (7) concrete implementation plans and recommendations regarding preferential cost policies.

This book recommends ways to accelerate the wind energy industry in China, particularly through incentive policies. I believe this book will not only promote the development of China's wind energy industry and its commercialization, but also play a positive role in the sustainable development of energy and environmental protection. It will bring benefit to future generations.

Hereby, let me express my heartfelt thanks to the Energy Foundation for their great support of China's wind power industry and environmental protection. I also extend my thanks to both the Chinese wind power experts for their contributions to this book and the relative departments for their comments and support.

Shi Dinghuan
Secretary General,
Ministry of Science and Technology,
People's Republic of China

TABLE OF CONTENTS

Evaluation of Policies Designed to Promote the Commercialization of Wind Power Technology in China

1. The Importance of Developing Wind Power Technology

1.1. Wind power is the key to adjusting China's energy structure

Fossil fuels were among the first energy resources to be exploited by humans. Since the beginning of the British industrial revolution in the 18th century, fossil fuels (coal first, then oil and natural gas) have been gradually replacing wood as a key energy source for human society, facilitating increased social productivity. Oil, natural gas, and coal are still the three main pillars that support the world economy, and there can be no doubt that these fossil fuels have made invaluable contributions to human progress and to the production of material wealth. However all these fossil fuels share certain limitations. First, reserves of all three are finite; second, the consumption of fossil fuels damages the environment. As a result, fossil fuels pose a growing threat to the security and development of human society, which is encouraging people to seek new, renewable, and environmentally friendly energy resources. Renewable energies such as wind energy are among the potential alternatives.

Since the 1970s, a considerable number of academics and energy experts have studied the amount of time fossil fuel reserves are likely to last, and almost all of them have come to the conclusion that the exhaustion of fossil fuel reserves is inevitable[1]. Although coal reserves could potentially last more than 200 years, exploitation will probably become economically unviable long before then, due to high exploitation costs and serious environment problems. Many developed countries, worried about energy resource security, have begun to restrict their consumption of fossil fuels, and in particular have limited the exploitation of domestic fossil fuel reserves. As well as importing large amounts of fossil fuels to satisfy the demands of the domestic energy market, governments have also started to emphasize the importance of renewable energy resources such as wind energy, solar power, and biomass energy. Most countries have implemented at least a few policy measures to promote the exploitation of these resources.

[1] Calculations based on current usage levels and exploitation capacity predict that oil reserves will last about 40 years and natural gas reserves about 60 years.

China is relatively rich in fossil fuel reserves, but calculated on a per capita basis reserves of conventional energy resources are less than half the average level across the world, and oil makes up only 1/10 of China's fossil fuel reserves. At present, this is not a serious problem as China's per capita consumption of energy resources is only half the world's average, but the rapid pace of economic development in China, and rising living standards, means that China's per capita energy resource consumption is likely to increase annually. By 2050, it will probably exceed two tons of standard coal, equal to the current world average, but still far below the current level of consumption in developed countries. However, even if China manages to stick to this minimum target, the government would not be able to rely entirely on conventional fossil energy resources to fulfill the nation's energy requirements. The comparative shortage of conventional energy resources in China, and their constant depletion if the current rate of consumption continues, will limit the sustainable development of the Chinese economy and society. Thus, a judicious adjustment of the national energy resource structure and an exploration of the possibilities offered by new and renewable energies should be national priorities.

Among the renewable technologies that appear to offer the most development potential, wind power is one of the most practical choices. China has wind energy resources that could be exploited on a large scale. According to statistics, inland wind energy resources offer the potential for supporting 253 GW of wind generation, while inshore (costal sea areas with water depth of up to15m) wind energy resources offer the potential for the generation of over 1,000 GW. If wind turbines were installed to exploit all these resources, the current national installed power generation capacity could be more than doubled. China's installed electricity capacity already exceeds 300 GW, but thermal power generation accounts for too high a percentage of this energy; approximately 75 percent of the total power generating capacity comes from coal fired power generators. This power generation structure, which relies so heavily on coal-fired plants, exerts double pressure on the national economy by simultaneously consuming large quantities of valuable energy resources and emitting vast quantities of pollution. The problem is particularly severe in those regions that have rich coal supplies but limited water reserves (e.g. Beijing, Tianjin, North China, Inner Mongolia, Jiangsu, Shandong, Henan, Shanxi, and Ningxia). Most of these regions have relatively rich wind energy resources, with good conditions for their exploitation and utilization. So if it were possible to expand the exploitation of wind energy resources in these areas, not only could the national energy supply be increased, but also the balance of components in the power generation structure could be improved.

1.2. Development of wind power capacity is vital to improve the security of the national supply of energy resources and to promote sustainable economic development.

Energy resource security is a pressing concern for the Chinese government in the 21st century. In the past, the amount of domestically exploited energy resources was basically enough to meet production demands, but since 1993, China became a net importer of energy resources. Since then, China's degree of dependence on imported petroleum has been rising rapidly; in 1999, more than 30 percent of China's energy resources were imported, and this is expected to climb above 40 percent by 2010. Given the volatile nature of international politics, it is unwise for a country to be too dependent on imports, and yet it is vital to a country's security that it can guarantee a reliable energy supply. Wind power technology has been sufficiently developed in other countries to offer a practical, if somewhat long term, solution to this problem. The replacement of at least some petroleum and natural gas imports with domestically available wind energy reserves would be a positive step towards enhancing the variety and security of China's energy supply.

China is currently in the process of opening up and developing the western regions of the country. Because of the sparse population and vast land area in these regions, it is impractical (and probably impossible) to rely on the traditional approach of installing large generating sets and a large, high voltage electricity grid to deal with the shortfalls in the power supply. Instead the government should develop more dispersed power generation and supply systems such as wind farms, in order to fully satisfy rising energy demands resulting from the regional development program. In addition, if China becomes involved in a war, large centralized energy generating systems that consume large quantities of raw materials will be far more vulnerable than dispersed systems relying on renewable natural resources like wind. The diversification of China's energy supply will alleviate national security concerns and is therefore a crucial strategic move.

1.3. Developing wind power capacity is a measure that will both help reduce pollution and prevent global warming.

Wind is an inexhaustible natural resource, so wind power generation does not involve any of the resource exhaustion problems associated with conventional power generation methods. As the process of converting wind energy to electric power does not usually involve consumption of any fossil fuels, it poses less of a threat to the environment. Although during the life cycle of a wind power system a certain amount of fossil energy is consumed, producing pollutants (for example in the production, manufacturing, and installation of the wind power facilities), the volume of emissions is still negligible compared the emissions of conventional combustion-based systems. According to research on this subject, the energy input-output ratio in the whole wind power process reaches 300 percent and the emissions intensity of greenhouse gases (CO_2) is only 4-20 gC/kWh (see Table 1-1 for further details). Table 1-2 presents the results of a study on the life cycle of various power generation methods based on the levels of carbon emissions. The results demonstrate that wind power technology is among the cleanest energy generation technologies in existence.

Table 1-1 Life cycle analysis of China's wind power generation units

	Total Consumption of Energy Resources (kWh/kW)	Percentage	Carbon Emission Volume (g-C/kWh)
Manufacturing and Installation Processes for Wind Power Facilities	83.7	11.0	—
Transportation of Wind Power Facilities	27.2	3.6	—
Preparation of Raw Materials needed for Wind Power Facilities	647.0	85.4	—
Total	757.9	100	4.0

Table 1-2 Analysis of total carbon emissions over the life cycle of various power generation methods

Power Generation Mode	Volume of Carbon Emissions (gC/kWh)
Coal-Fired Power	275.0
Oil Power	204.0
Natural Gas Power	181.0
Solar Thermal Power	92.0
Photovoltaic power	55.0
Wave Power	41.0
Ocean thermal Power	36.0
Tide Power	35.0
Wind Power	20.0
Geothermal Power	11.0
Nuclear Energy Power	8.0
Hydraulic Power	6.0

Source: Japan Energy, No.11, 1993.

2. The Development of Wind Power Technology Worldwide and an Assessment of Approaches in Different Countries

2.1. The development of wind power technology in an international context

The rapid developments in wind power technology and in the wind power industry during the past few years are detailed below.

1) Total installed capacity increased, and the scale of wind power projects grew

Total installed wind power capacity increased from 2 GW in 1990 (New Renewable Energy, 1998) to over 17.5 GW in 2000 (Table 2-1), with an average annual increase of 1.55 GW. The development of wind power in Europe in particular was far more rapid than expected. In 1991, the European Wind Energy Association (EWEA) drew up a development plan with a target of installing 4 GW of installed capacity in Europe by the end of 2000. By 1997, Europe had already achieved this goal so EWEA revised its target to 8 GW, but once again development was more rapid than expected. By the end of 1999, the installed capacity in Germany, Spain, Denmark, and the U.S. had reached 8.7 GW. According to the latest plans, the total installed wind power capacity in Europe alone should reach 40 GW by the end of 2010, and 100 GW by the end of 2020.

Table 2-1 Installed on-grid wind power capacity worldwide

No	Country	By year's end 2000 (MW)	By year's end 1999 (MW)	By year's end 1998 (MW)	By year's end 1997 (MW)	Capacity Installed in 2000 (MW)	Annual Rate of Increase 1999–2000 ((%)
1	Germany	6,113	4,443	2,875	2,081	1,670	37.6
2	U.S.A.	2,495	2,465	1,820	1,673	30	1.2
3	Spain	2,481	1,542	834	427	939	60.9
4	Denmark	2,301	1,771	1,383	1,066	530	29.9
5	India	1,109	1,062	968	940	47	4.4
6	Netherlands	449	411	361	319	38	9.2
7	Italy	427	283	178	103	144	50.9
8	Great Britain	406	344	333	319	62	18.0
9	China	344	268	214	166	76	28.4
10	Sweden	241	215	174	122	26	12.1
11	Greece	205	82	39	29	123	150.0

No	Country	By year's end 2000 (MW)	By year's end 1999 (MW)	By year's end 1998 (MW)	By year's end 1997 (MW)	Capacity Installed in 2000 (MW)	Annual Rate of Increase 1999–2000 ((%)
12	Canada	137	125	82	25	12	9.6
13	Japan	120	68	40	18	52	76.5
14	Ireland	93	73	73	53	20	27.4
15	Portugal	90	60	60	38	30	50.0
16	Austria	79	42	30	20	37	88.1
17	Egypt	68	35	5	5	33	94.3
18	France	60	22	19	10	38	172.7
19	Morocco	54	0	0	0	54	
20	Costa Rica	51	46	26	20	5	10.9
21	Finland	38	38	17	12	0	0.0
22	New Zealand	35	35	5	4	0	0.0
23	Australia	21	10	9	4	11	110.0
24	Brazil	20	20	17	3	0	0.0
25	Turkey	19	9	9	0	10	111.1
26	Luxembourg	15	10	9	2	5	50.0
27	Argentina	14	13	12	9	1	7.7
28	Belgium	13	9	6	4	4	44.4
29	Norway	13	13	9	4	0	0.0
30	Iran	11	11	11	11	0	0.0
31	Tunisia	11	0	0	0	11	
32	South Korea	8	7	2	2	1	14.3
33	Israel	8	8	6	6	0	0.0
34	Poland	5	5	5	2	0	0.0
35	Russia	5	5	5	5	0	0.0
36	Ukraine	5	5	5	5	0	0.0
37	Czech Republic	4	4	4	4	0	0.0
	Total	17,568	13,559	9,645	7,511	4,009	

Source: Wind Turbine Department, Chinese Agricultural Machinery Association. 2001

German wind power has developed more rapidly than in any other country in the world. Between 1998 and 2000, Germany installed 3.23 GW of wind power capacity, making the total installed capacity 6.11 GW by the end of 2000, and surpassing the USA in installed wind power capacity. Wind power generation accounts for 2.5 percent of all power generation in Germany, and the government plans to increase this figure to 10 percent by 2010 and 50 percent by 2050. (Another Suggestion to Accelerate the Development of Wind Power, 2001)

One of the main reasons for the speed of the development of the wind power industry in Germany is that the German Government developed a series of effective policies to promote the use of wind power. Environmental protection and a growth in the use of clean energy are among the government's main priorities. They injected two billion USD into researching wind power technologies, demonstration programs, the construction of wind farms, and subsidies on wind power prices. (Government support is a powerful force, 1997.) In Germany, the government has both subsidized almost every wind turbine in some way and drawn up a variety of regulations that have promoted the development of wind power. For example, Germany's *National Electricity Law* stipulates that electricity companies must purchase the electricity produced by wind farms, and at a price not below 90 percent of the average electricity purchase price.

The USA, India, some countries in South America, and many countries in Europe are enthusiastically increasing their installed wind power capacity. An important trend at the moment is the commercial development of large-scale wind farms; for example in 2001 two wind farms with an installed capacity of more than 200 MW were built in the United States.

According to the *EU White Book for Strategies and Implementation Plans*, EU member states produced approximately 90 percent of the wind turbines currently in use around the world. Total production capacity in the EU was 250 MW/year in 1990, and 1 GW/year by 2000. Wind capacity is expected to climb to 2 GW by 2010.

Worldwide, the wind industry provides more than 70,000 jobs, and in 2001 alone $5 billion USD was spent on wind power project installation. Wind power is becoming an increasingly important component of the energy industry and, according to International Energy Agency forecasts electricity consumption will double by 2020 if steady international development continues. By that time, installed wind power capacity will reach 1.2 billion kW, and wind power generators will produce 2.5~3 billion MWh, or 10 percent of total world electricity consumption.

2) Wind power technology is constantly improving, and turbine performance is being enhanced

After a long period of research and improvements, the technology for 500, 600, 750, and even 1500 kW wind turbines—now the main types of wind turbines used worldwide—have now been developed to a level appropriate for large-scale commercial production. Experts have developed wind turbines with even greater capacity levels, which they are now operating and testing on a small scale. For example, some recently established wind farms in Denmark installed wind turbines with an individual capacity of 2 MW, and in North Tolice, Morocco the capacity of an individual wind turbine reached 2.1 MW. Germany plans to build an inshore wind farm in the North Sea with an installed capacity of 1 GW. It will use wind turbines with 5 MW capacity and go into production in 2004 (Another Suggestion, 2001). At the same time, blade design and manufacture have incorporated new technologies and materials. Most modern horizontal-axis wind turbines have three blades, and their relatively high weight results in higher production costs. In order to reduce the weight, some producers are working to reduce the three blades to two. The Swedish company Nordic Wind power, AB has completed designs for two lightweight two blade wind turbines with 500 kW and 1 MW capacities.

For wind farm control and safety systems, electronic and computer technology is widely used. The technology not only plays an important role in improving the performance of these systems, but also enhances design standards and capacity at wind power facilities.

3) The steady decline in the cost of wind power generation

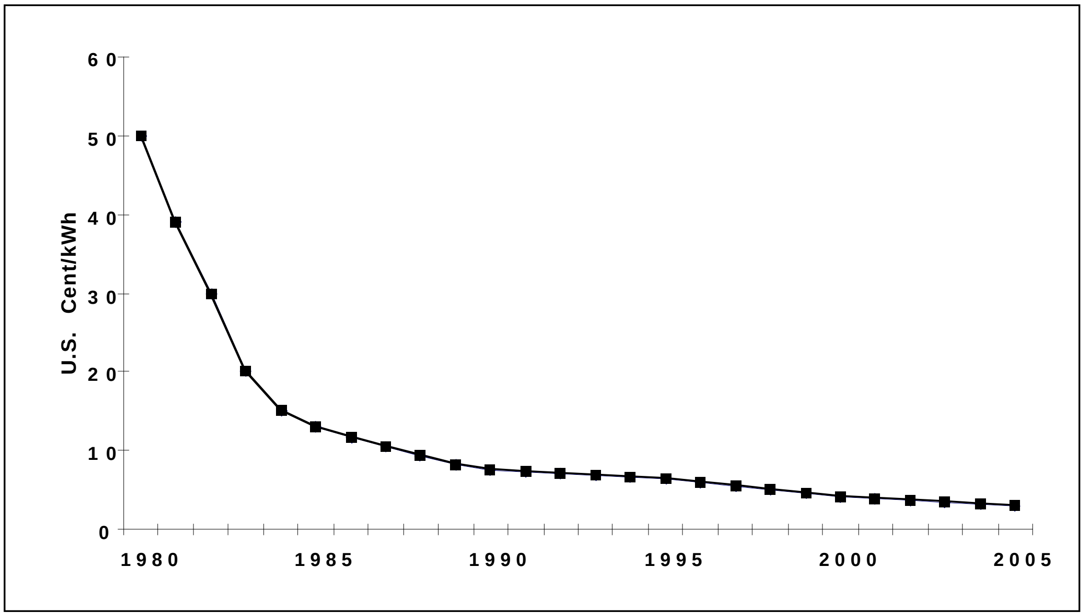
In recent years, the cost of wind power generation has steadily declined due to larger scale production, the application of new technologies, and the use of larger wind turbines. Between 1990 and 2000 the cost of wind turbines in the United States fell from 1333 USD/kW to as low as 790 USD/kW and, as a result, the cost of wind power generation was halved, falling from 8 ¢/kWh to 4 ¢/kWh over the same period (see Table 2-2 and Figure 2.1). Wind generated power in the U.S. can now compete with electricity generated using conventional combustion methods in some applications even though the generation cost of the first wind farm in the USA, at the beginning of the 1980s, was as much as 30 ¢/kWh.

Table 2-2 Changes in the cost of wind turbines in the U.S.

Year	1981	1985	1990	1996	1999	2000
Diameter of Rotor (m)	10	17	27	40	50	71
Capacity (kW)	25	100	225	550	750	1650
Production Cost ($1,000)	65	165	300	580	730	1300
Cost per kW ($/kW)	2600	1650	1333	1050	950	790

Source: American Wind Energy Association

Figure 2.1 Changes in the cost of wind power generation in the U.S.

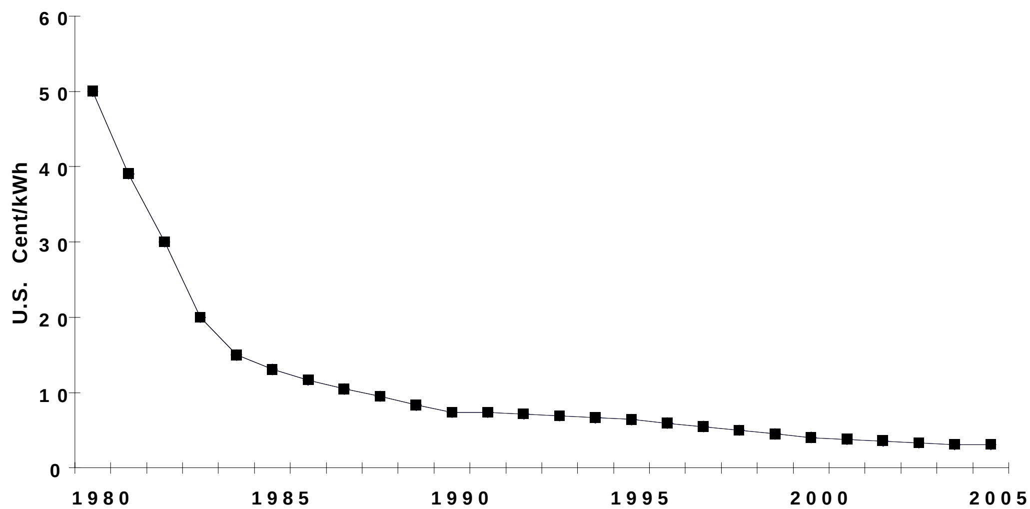


The United States Government currently provides a Production Tax Credit (PTC, adjusted according to inflation levels) worth 1.5 ¢/kWh to newly established wind farms for the first ten years of their operation. Because of the PTC, the contract price of electricity from some newly established wind farms is lower than 3 ¢/kWh.

BTM Consultants calculated that the cost of wind power generation in Denmark is becoming increasingly competitive (see Fig.2.2). Recently the cost of wind power generation has fallen to€ 0.04 /kWh and over the next 5 years, the cost should fall by a further 20 percent as a result of technological progress and cost optimization. At that point, the generation cost of wind power (including investment costs) will be similar to the generation cost of electricity from conventional combustion based plants. At present, the price at which wind power in Denmark is sold is € 0.06 /kWh.

The decrease in the cost of wind power generation is primarily due to both policy support and effective competition mechanisms. With targeted support from government policies, there will be a steady growth in the wind power market that will drive the further development of wind power capacity. At the same time, an appropriate policy framework will encourage a robust investment climate and encourage different participants—including equipment manufacturers, those responsible for constructing wind farms, and operation and management organizations—to reduce the cost of their products or services, and thus ultimately further reduce the cost of wind power.

Figure 2.2 Changes in the cost of wind power in Denmark



Calculations are based on the following conditions; 20 years depreciation; Interest rate on loan of 6 percent; Operation and maintenance costs of 0.007 Euros/kWh; air density of 1.23 kg/m^3; Average wind speed of 5.4 m/s at a height of 10 meters, 6.7 m/s at a height of 45 m

2.2. The Development of Wind Power In China

In comparison with the rest of the world, the Chinese wind power industry is relatively underdeveloped, but the industry has still achieved significant progress, as described below.

1) The scale of development reached a new level

In China, research into micro and mini wind turbines began in the 1950s and was applied on a large scale from the 1970s onwards. Today, China has installed about 150,000 turbines, the largest number of micro wind turbines in the world, but there has been very little development in the area of on-grid wind farms. However, China entered a new stage in the development of its wind power industry after the boom between 1996-1998 (see Figure 2.3). Statistics from the State Environmental Protection Commission show that by the end of 2000 there were 26 wind farms nationwide, with a total installed capacity of 344 MW, and China now ranks ninth in the world in terms of installed wind power capacity.

Figure 2.3 The annual installed capacity of China's wind farms

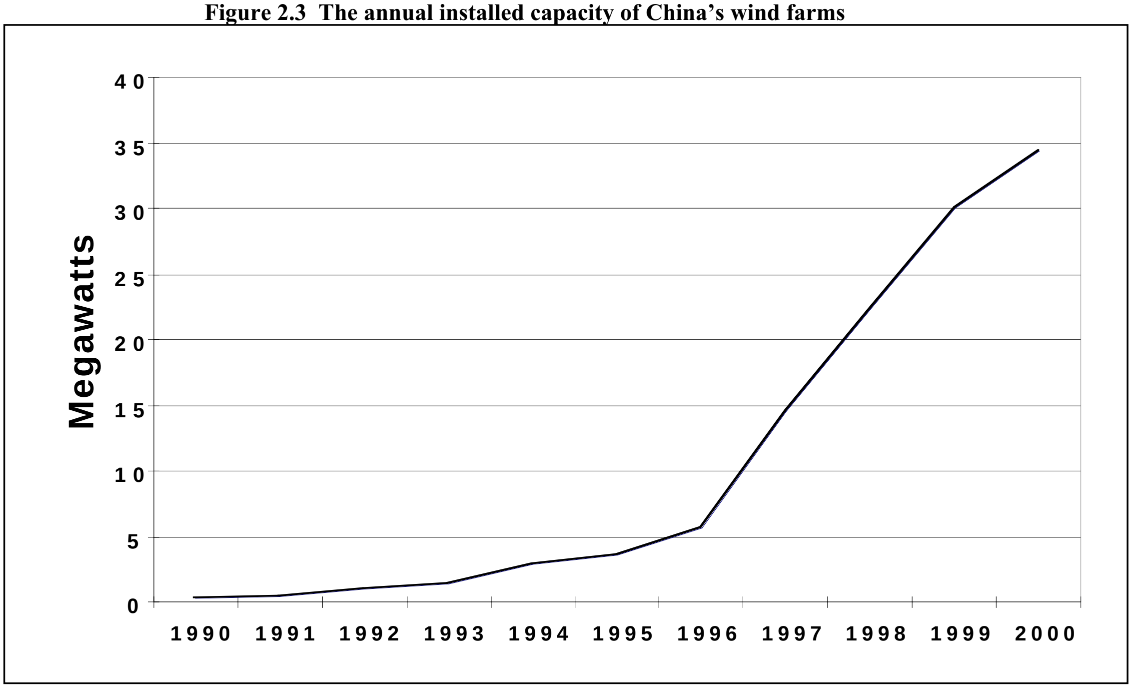


Table 2-3 Distribution of wind farms in China

No	Name of Wind Farm	Number of Turbines in the Wind Farm	Installed Capacity (kW)	Number of Turbines in Province	Installed Capacity in Province (kW)
	Hebei Province:			**24**	**9,850**
1	Zhangbei	24	9,850		
	Inner Mongolia:			**135**	**56,905**
2	Zhurihe	38	7,500		
3	Shangdu	17	3,875		
4	Xilin	10	2,980		
5	Huitengxile	61	36,100		
6	Keshiketeng	9	6,450		
	Liaoning Province:			**86**	**46,005**
7	Donggang	26	12,205		
8	Hengshan	20	5,000		
9	Jingzhou	1	600		
10	Xianrendao	11	7,200		
11	Dandong	28	21,000		

No	Name of Wind Farm	Number of Turbines in the Wind Farm	Installed Capacity (kW)	Number of Turbines in Province	Installed Capacity in Province (kW)
	Jilin Province:			**49**	**30,060**
12	Tongyu	19	30,060		
	Shandong Province:			**14**	**5,675**
13	Rongcheng	3	165		
14	Changdao	11	5,510		
	Zhejiang Province:			**62**	**30,355**
15	Sijiao	10	300		
16	Hedingshan	19	10,255		
17	Kuocangshan	33	19,800		
	Fujian Province:			**26**	**13,055**
18	Pingtan	16	7,055		
19	Dongshan	10	6,000		
	Guangdong Province:			**153**	**69,980**
20	Nan'ao	131	56,780		
21	Huilai	22	13,200		
	Hainan Province:			**19**	**8,755**
22	Dongfang	19	8,755		
	Gansu Province:			**4**	**1,200**
23	Yumen	4	1,200		
	Xinjiang Province:			**155**	**72,950**
24	Dabancheng1	32	12,100		
25	Dabancheng2	116	59,800		
26	Buerjin	7	1,050		
	Total			**727**	**344,790**

The boom in the China's wind power industry from 1996-1998 was chiefly the result of government attention and support. The State Economic and Trade Commission supported the construction of three wind farms, with a total installed capacity of 80 MW, under the auspices of the 'Shuangjia' Project. In addition, the former Ministry of Power issued the 1994 '*Provisions for On-Grid Wind Farm Management,'* which not only stipulated that power companies were required to purchase all the electricity produced by wind farms, but also specified that the difference between the price of wind power and the average price of conventionally generated power should be absorbed by the grids. There is no doubt that this policy was enormously helpful in promoting the development of wind power in China. However, the reforms to the national management system and the state power system created obstacles to the functioning of this wind power pricing policy, so that it is no longer very useful in promoting wind power development. The effective collapse of this policy is one of the main reasons for the slower pace of development in the wind power industry over the last couple of years.

Table 2-3 shows the distribution of wind farms in China. The majority of wind turbines have been installed in Dabancheng (Xinjiang), Nan'ao (Guangdong), Inner Mongolia, remote areas of the Northeast and on various islands. The exploitation of wind resources in these regions has resolved local power supply problems, and promoted the development of the local economy.

2) The rate of localization and the capacity for producing key equipment domestically both increased

Over the past few years one of the main factors limiting the development of local wind power capacity was the dependence on imported wind turbines, low design capacity, and the fact that key parts, such as turbine blades, could not be manufactured domestically. This led to high wind power generation costs and hindered the commercialization of the industry. However, one of the key national research projects since the Seventh Five-Year Plan involved the research into large wind turbines and their connection to power grids.

Following the principles of introducing foreign technology, assimilating it into the Chinese market, and then learning to develop similar equipment domestically, Chinese manufacturers have begun to master the technologies needed for the production of large wind turbines. The main equipment needed for wind power generation can now be manufactured domestically. Nationally developed 200 kW wind turbines are now mass-produced and safely operate for 35,000 hours to generate 2 GWh of electricity. Chinese manufacturers have also developed 250 kW and 300 kW wind turbines, which in practical tests in the early 1990s performed almost as well as wind turbines developed by world leaders in the field. Xinjiang Wind Power Co. also made 10 sets of 600kW wind turbines by introducing technology developed by the German energy company Jacobs, and one of these turbines has been connected to the grid for more than two and a half years. The main components, including the generator, gearbox, control system, blade, yawing system, hub, and tower were all domestically produced, and the localization rate was over 70 percent. Baoding Airscrew Factory Blades produces blades that safely operate for 600 kW wind turbines for more than 2,000 hours. By integrating the technologies of the Austrian PEHR company, the Beijing based company Wandian Ltd. designed and produced a 600kW wind turbine with a localization rate of over 80 percent, which successfully passed practical tests on a wind farm site. A joint venture set up by the China No.1 Tractor Group and the Spanish renewable energy company MADE produces 660 kW wind turbines while another joint venture, the Xi'an Weide Wind Power Co., produces 600 kW wind turbines. Both types of turbine have localization rates of over 40 percent and are connected to the grid at the Yingkou Wind Farm in Liaoning Province. The next main goal of these two joint ventures is to improve the localization rate to 70 percent or above. Gearboxes for 300kW and 600 kW wind turbines made by the Chongqing Gearbox Company Ltd., the Nanjing High Speed Gearbox Factory, and the Hangzhou Qianjin Gearbox Group are also in use at several wind farms. Their high performance standards and reliability match those of the world leaders in the field.

3) The start of the industrialization of wind power technology and the establishment of specialized factories.

The start of the industrialization of wind power generation in China has accompanied the advances in wind power technology and the development of wind farms. At present the amount of electricity generated by wind farms in China each year exceeds 1 TWh, with a production value of more than two billion Yuan. The wind power industry has begun to influence the social and economic life of Chinese citizens, particularly in those regions, such as Xinjiang and Guangdong, where installed capacity is more than 70 MW and wind generated power constitutes a considerable proportion of the electricity on their local grid. Wind power has not only changed the composition of the energy supply and reduced pollution, but also has encouraged the development of the local economy and provided new job opportunities.

In order to promote the development of the wind power industry, the government is working to standardize various aspects of wind farm construction and management. It is currently drawing up rules and regulations that cover such areas as the selection of wind farm sites, the nature and content of feasibility studies, and the operation and maintenance of wind farms. Some of these regulations are already in operation. The key features of the management methods now used in Chinese wind farms are a limited liability system, independent accounting systems, and sole responsibility for profits and losses. With the development of wind farms over the past decade, experts in this sector have accumulated a great deal of experience and learnt many lessons about planning, site selection, investment, construction, operation, maintenance, and management of wind farms. This should help to lay a strong foundation for the more widespread development and use of wind power under the Tenth Five-Year Plan.

In order to strengthen the domestic wind power industry and increase the percentage of turbines that are manufactured domestically, the government has also begun to pay more attention to the wind turbine manufacturing industry. There are several equipment and component manufacturers, among which the major wind turbine producers are:

_ **Xinjiang Jinfeng (Gold Wind) Co., Ltd.**

Xinjiang Jinfeng (Gold Wind) Co., Ltd. is a company that deals with both the manufacture of wind turbines and the development of wind farms. The installed capacity of the Dabancheng wind farm, which is owned by Jinfeng, reached 12 MW by the end of 2000, so Jingfeng is clearly a company with technical ability and relevant experience. In 1997, Jinfeng purchased the rights to technology used in Jacobs 600 kW wind turbines and used it to develop their own Jacobs wind turbines, which are now in use at the Dabancheng wind farm. In September 2000, the company was certified under the ISO 9001 quality certification system.

_ **MADE - China No. 1 Tractor Group Joint venture**

MADE is a joint venture between the China No. 1 Tractor Group and the Spanish renewable energy company MADE. The joint venture was set up in 1998 and has a registered capital of three million USD. The two investors both own 50 percent of the stock in the joint venture. The main products of the company are 330 kW and 660 kW stall-controlled wind turbines. One 600 kW wind turbine was produced in 1999 and installed on the Yingkou wind farm, where it has operated for nearly a year. Six other sets of 600 kW wind turbines and 19 sets of 330 kW wind turbines are currently under production.

_ **Weide - Xi'an Airplane Group's Joint venture**

Weide is a joint venture established in 1999 by the Xi'an Airplane Group and the German energy company Nordex, and has a registered capital of 2.1 million Yuan. The Xi'an Airplane Group hold 60 percent of the joint venture stock while Nordex holds the remaining 40 percent. Its main products are 600 kW wind turbines. One wind turbine was produced in 1999 and installed at the Yingkou wind farm where it has operated for nearly a year. Another 16 wind turbines are currently under production.

_ **The Institute of Electromechanical Research and Design, Zhejiang**

The institute used the results from the national research program into wind energy that was undertaken during the Eighth and Ninth Five-Year Plans to manufacture 250 kW wind turbines.

Altogether, it has produced six sets, which are installed in the Cangnan wind farm in Zhejiang and the Nan'ao wind farm in Guangdong. Two prototype 600 kW wind turbines are currently in production.

_ **Wandian Aerospace Co., Ltd.**

In 1996, the Beijing based Wandian Company began working with the Austrian company PEHR on the design and production of large-scale wind turbines. With the support of the former Ministry of Aerospace, the company invested nearly 20 million Yuan to develop wind turbines. A 600 kW wind turbine was produced and installed in Inner Mongolia and at present Wandian is the only domestic producer of pitch-regulated wind turbines whose product has been tested and appraised.

_Shenxin Co. Ltd., Shanghai

Shenxin was established in 1999 with the support of the Shanghai Electric Group; the company's stock is shared among its employees. The main goal of Shenxin is the development of wind turbines and so far they have produced two sets of 600 kW wind turbines in cooperation with the Xinjiang Provincial Government.

The Zhejiang Electric Manufacturing and Repair Factory, the Inner Mongolia Manufacturing and Repair Factory, and the Shanghai Lantian (Blue Sky) Company also entered this market a few years ago. A joint venture company set up by Nordex and Micon has established its own factory to assemble wind turbines. VESTAS, a famous Danish wind turbine producer, has also announced that it plans to establish a factory in China.

The main manufacturers of wind turbine components are detailed below.

_ **Gearboxes**

There are several manufacturers involved in research and production of gearboxes for wind turbines, including the Nanjing High-speed Gearbox Factory, the Hangzhou Gearbox Factory, the Chongqing Gearbox Factory, and the Luoyang No. 1 Tractor Group. The 600 kW gearboxes currently available can meet all present needs, and larger gearboxes are in the trial stage.

_ **Generators**

Generators for wind turbines need to have high energy conversion efficiency and large slippage. At present the Lanzhou Electric Machinery Factory, the Xiangtan Electric Machinery Factory and the Shanghai Electric Machinery Factory are involved in the manufacture of generators for wind turbines. The asynchronous generators used for 600 kW wind turbines can meet all current requirements, but the manufacture of trial versions of variable-speed and constant-frequency generators and of larger generators needs to begin as soon as possible.

_Yawing Systems

The yawing system in wind turbines are used to aim the turbine blades in the direction of the wind. They normally consist of two to three sets of servo devices and an electronic control system. The basic principles and requirements of yawing systems remain almost constant regardless of the size of the wind turbine. Today there are many manufacturers in China who would be able to develop and manufacture this type of equipment, as it does not present any particularly challenging technical difficulties.

_ Control Systems

The control system is used to adjust the operating status of wind turbines. The principles and requirements of the control systems for stall wind turbines with asynchronous generators are relatively simple. The Nanjing Automation Institute, the Central Academy of Sciences' Electrical Engineering Institute, the Xinjiang Engineering Institute, the Zhejiang Institute for Electromechanical Research, the Luoyang No. 1 Tractor Group and Xi'an Aerospace Group are all involved in producing this type of equipment. However for wind turbines with variable pitch or ones with variable speed and constant frequency generators, the principles and requirements of control systems are a great deal more complex, and at present no domestic manufacturers have succeeded in producing one. The Institute of Electrical Engineering has been researching variable-speed and constant frequency wind power technology since the 1980s. Twenty-kilowatt wind generators with variable-speed and constant frequency were designed, manufactured and operated successfully during the Seventh Five-Year Plan.

_ Blades

The blade is one of the most important components of a wind turbine. Over the last few years, China has greatly progressed in the area of research into blade production, as follows: (1) The Shanghai Institute for Fiberglass Epoxy Research has made small batches of stall-controlled blades for 300 kW wind turbines. The quality of the blades is very high and the production of larger blades is now in the research phase. (2) Stall-control blades for 600 kW wind turbines made by the Baoding Blade Factory (also in small batches) have passed technology and quality appraisals. In addition the Baoding Blade Factory and the Airplane Engine Group plan to set up a joint venture with the American company Meiteng. The new joint venture company will be located in the Baoding technology exploration zone and will produce blades on a large scale. (3) The Wandian Company, set up by the former Aerospace Ministry developed a set of pitch blades for 600 kW wind turbines. They perform well and are good quality, although, because their raw material is carbon fiber, they are a little expensive.

In addition, the largest blade producer in the world, the Danish company LM is planning to set up a factory in China. They have already selected a factory site in Tianjin, the preparatory stage of work is finished, and the company trained Chinese managers in Denmark. Three months after construction commences, the factory should start selling its first blades on the market.

Since China can now locally manufacture blades for 600 kW wind turbines, and for larger ones, large-scale domestic production of wind blades should be achieved in the near future.

3. Main Problems Hindering the Development of Wind Power in China

Despite considerable progress in the area of wind technology, there are still a wide variety of obstacles to wind power development in China. The main problems are related to resource assessment, equipment manufacturing, wind farm construction and operation, cost and pricing levels, and government policy mechanisms.

3.1. Resource assessment

One of the most pervasive problems at the moment is a scarcity of reliable data on dependable wind resources. The lack of reliable data is a serious obstacle to the planning of wind farm projects, choosing wind farm locations, and deciding on the scale of wind farms. It has also caused delays in the development schedule for wind power and led to wind farms being built before the projects are properly evaluated. Undue haste has led to needless economic losses. All existing data originate from the Academy of Meteorological Science, but to date no entity has investigated or assessed wind resources on a national scale. As part of the Eighth Five-Year Plan researchers drew up an assessment of national wind resources at a height of ten meters using existing data from nearly 900 weather observatories. Undoubtedly, these results will be of use in any strategic plans for renewable energy development, however they do not meet the requirements of engineers building wind farms.

Another problem that needs to be addressed in resource assessment is that data quality standards must be established and made clear. At present, even for a 100 MW wind farm, there are no regulations covering data quality, or data collection requirements (e.g. minimum requirements for the number and layout of wind observatory sites, or the type and frequency of wind measurements to be made). If this problem remains unresolved, it will negatively effect the development of wind power capacity.

A need still exists for an assessment of inshore wind resources. The Chinese coastline is very long and also located close to national load centers. The inshore area is rich in wind resources and should be developed into a national center for wind power generation.

3.2. Equipment manufacturing

1) **Imported wind turbines still dominate the market.**

At present 95 percent of the wind turbines installed in China are imported. Although the excellent performance record of imported wind turbines enhances efficiency by guaranteeing greater stability, their very high prices make it difficult to bring down the cost of wind power, and the reliance on imported wind turbines is hindering the development of the local wind power industry.

2) **Domestically manufactured wind turbines rarely undergo field tests.**

After a long period of research, Chinese scientists have mastered the knowledge needed for the design of wind power systems and the manufacture of key equipment for large capacity wind turbines, and wind farms have already put into operation some of the products that they designed. However because of the short development period and the small size of the market, the products (such as blades, control systems etc) are seldom adequately field-tested. Particularly because most products fail to get any kind of certification from an authoritative agency, enterprises are wary about the quality and reliability of locally produced wind turbines. So it is vital to enlarge the scale of demonstrations showing the equipment's viability and to build up national organizations that can arrange testing and provide quality assurances.

3) **The development of a capacity to manufacture turbines domestically is hindered by high product prices.**

At present the price of a domestically produced wind turbine in China (when the localization rate is assumed to be 60 percent) is about 3.12 million Yuan (including the tower), or 66 percent of the total installed cost. Of the various components, the tower (40 meters high and 40 tons in weight) costs 0.42 million Yuan (9 percent of the total system cost). There are a variety of reasons why prices are so high, but the most important one is that the scale of production is too small.

3.3. Wind farm construction

1) **The scale of wind farms is too small.**

China's wind farms are too small, which has led to the following problems:

- The price of equipment is slow to decrease because the amount of wind power equipment purchased is relatively limited.
- The percentage of total costs spent on affiliated facilities (e.g. construction of a

central management office) is relatively high, which does not help to decrease the end power price.

_ Small wind farms increase the percentage of the per unit power price spent on management costs.

The average installed capacity of China's 26 wind farms is only 15 MW, which is far below the production scale needed to reduce wind power prices.

2) **Few experienced developers.**

Experiences on wind power farms in other countries clearly demonstrate the importance of trained and experienced developers (such as wind power management company RES in the UK and American Seawest in the U.S.) for the successful development of wind power. The developers usually provide a variety of services such as the assessment of wind resources, the design of the wind farm, the selection and installation of equipment, and the operation and management of the wind farm. These experts help reduce costs in the emerging wind power market, improve management efficiency, and actively participate in developing wind power capacity. The appearance of developers is a sign that wind power development has reached as stage of specialization and expansion of scale, which helps to decrease the costs of wind power. China in this regard lags far behind other wind power producers; on most Chinese wind farms the developer is also the owner. They are all inexperienced and the learning costs are very high.

The lack of relevant commercial experience or industry standards is one of the main reasons for the low annual use of wind turbines. In the four wind farms we investigated in 1999, the average annual generation hours ranged from 1,733 to 3,025 hours. The 2nd project of the Dabancheng No. 2 Wind Farm in Xinjiang Province had the highest number of utilization hours; 3,025 for that year, and the capability factor of the plant reached 34.9 percent. The corresponding figures for the Zhangbei Wind Farm in Hebei Province are 2,220 and 25 percent, respectively. The turbines in the Nan'ao Wind Farm in Guangdong Province generated power for up to 3,000 hours in the year, while Kuocangshan Wind Farm in Zhejiang Province had the worst results, with utilization figures of 1,773 hours and a capability factor of 19.7 percent.

The low utilization efficiency of many wind turbines in China and the low power output rate are associated with inefficient resource assessment and wind farm operation. It is vital to the future development of China's wind power capacity that we improve our capacity for accurate and appropriate wind resource assessment, site selection, micro-siting, and choice of turbines.

3.4. Generation costs and the on-grid power price

High generating costs and high on-grid power prices are two of the most salient features of wind power generation in China and the main obstacles to its widespread commercialization. Current data show that the average generation cost of wind power is about 0.32 Yuan/kWh. The on-gird price of wind generated power is 0.64 Yuan/kWh when the value-added tax (VAT) is included and 0.55 Yuan/kWh when the VAT is not included (Please refer to the following sections and the appendix on tax rates and power prices for further details). The generation costs of wind power exceed those of a newly constructed coal fired power plant by 33-60 percent, and the on-grid price of wind power (including VAT) is 68-94 percent higher than the on-grid price of power generated using conventional combustion methods.

There are two main reasons for the high cost of wind power. First, the fixed depreciation costs are large and the depreciation rate is high; the depreciation rate constitutes 20-22 percent of the generation cost of power from a newly constructed coal fired power plant, but 53 percent of the generation cost of power from a wind farm. Also, on a percentage basis, the maintenance costs for wind power equipment are much higher than for conventional generating equipment, as shown in Table 3-1.

Table 3-1 Comparison of generation costs for wind power and coal-fired power plants (unit: percentage of total generation cost)

	Wind power	Coal-fired power (2_350MW, newly constructed, without desulfurization equipment)
Total Cost	100.0	100.0
Depreciation	53.0	21.0
Maintenance	32.0	11.7
Salary & Welfare	1.0	1.2
Interest on loans	9.0	8.2
Fuel	0.0	43.4

Second, the limited generation period (because of variations in wind speed) and the small scale of wind farms increase generation costs. When their capacities are equal, the electricity generated by a wind farm over a given period will still be only about half of the electricity generated by a coal-fired power plant. Thus, the cost of wind power is still higher than the cost of power generated in coal-fired plants, although the wind farm does not have to pay any resource costs and consumes no fuel.

From an economic perspective, the price of wind power is further increased due to the burden of tax costs and loan repayments. Table 3-2 shows the on-grid costs for power from wind farms and coal-fired power plants. Although generation costs are higher for coal-fired power than for wind power, the tax on wind power can constitute up to 27 percent of the total price (with VAT and related taxes of up to 15.4 percent), which is 8 percent higher than the tax on coal-fired power. At the same time, wind farms must set aside 8.6 percent of their profits for loan repayments, 7.3 percent more than for coal-fired generating plants. In real terms, the tax per kWh paid on coal-fired power is only 0.07 Yuan, while that paid on wind power is 0.173 Yuan, almost three times as high.

Table 3-2 Comparison between the on-grid prices of wind power and coal-fired power (%)

	Wind power	Coal-fired power (2x350MW, newly constructed, without desulfurization)
Average on-grid price	100.00	100.00
Generation Costs	49.70	64.47
Tax	26.90	18.96
VAT & surtax	15.40	10.80
Income tax	11.50	8.16
Profit after tax	23.30	16.57
Profit set aside for loan repayments	8.60	1.18
Shareholder profit	10.90	12.90
Contributions to the Statutory reserve & public welfare funds	3.90	2.49

3.5. Policy mechanisms

1) Lack of clear objectives

The government has drawn up various plans for the development of the wind power industry in China. The former Ministry of Power proposed that installed wind power capacity should reach 1 GW by 2000, and the '*Plan for New Energy and Renewable Energy Development in China, 1996-2001*', a report compiled by the former SPC (the State Planning Commission, now known as the State Development and Planning Commission (SDPC)), the State Economic and Trade Commission (SETC) and the former SSTC (the State Science and Technology Commission, now known as the Ministry of Science and Technology), stipulated that installed wind power capacity in China should reach 300-400 MW by the end of year 2000. At the same time, various relevant departments of the SDPC included development plans for renewable energy in every 5-Year Plan since the 1980s, which has had a considerable influence on the development of wind power in China. Recently, the Basic Industries Departments of the SDPC and the State Power Corporation (SPC) brought out a new plan, which stipulates that installed wind power capacity nationwide should reach 1.2 and 3 GW by 2005 and 2010, respectively. Although this plan has not been formally published, it has still helped promote the development of wind power. However, the government did not define its vision of the status and role of wind power in the current power generating system, and failed to establish clear objectives for wind power development. There is no sense of whether the proposed increase in wind power capacity is designed to help reduce CO_2 emissions and protect the environment or to increase the national electricity supply or both. As a result, the responsibilities of those involved in the development of wind power have not been clearly defined, and it will be hard to ensure that government targets are met. At present, the SDPC is trying to initiate co-operation with the relevant departments at SPC to draw up renewable energy policies, of which a priority will be to establish a fixed proportion of market demand that should be met by wind generated power.

2) **Lack of targeted incentive policies**

Some departments responsible for wind power development have introduced incentive policies to promote progress in this area. In 1994, the former Ministry of Power issued a report that stipulated that power companies were required to (1) connect wind farms to the electricity grid at a location as near to the site of generation as possible, and (2) purchase all wind generated power at a price made up of the cost of the system plus a reasonable profit. In addition, the ministry introduced a policy of low import duties for imported wind turbines, and exemption from import duties for imported components. However, there was no further clarification of these policies, which led to confusion. For example the 1994 policy document issued by the former Ministry of Power mentioned above, stipulated that the on-grid price of wind power be the sum of credit repayment costs plus a reasonable profit. Although this sounded impressive, in practice there were problems with its implementation. Local power companies usually have the right to choose the price at which they purchase wind power, as well as the contract terms and conditions, which meant that there were no problems when the policy was applied to wind farms established by the local power companies themselves, but they were unwilling to apply it to competing wind farms established by other investors. As a result, potential investors tend to feel that developments in the wind power industry are unpredictable, at least in the near future, and so they are unwilling to risk investing their capital in the industry. Of the large-scale wind farms that have already been constructed, the majority received their investment from local power companies or their subsidiaries. A shortage of commercial investment and independent developers in the wind power industry will prevent the industry from developing commercially.

Another serious problem is how to deal with the difference between the on-grid price of wind power and the average on-grid power price. According to the specifications of the former Ministry of Power, the grid should absorb this difference, but the document offers no clear definition of the word 'grid'. It could be interpreted as referring to provincial grids, regional grids, or the national grid in different contexts, and this lack of clarity makes it impossible to implement the policy effectively. As a result, the burden of higher wind generated power prices is borne by investors or concentrated unfairly on the provincial grids in regions with excellent wind resources and large wind farms. For example, installed wind power capacity in Inner Mongolia has reached 53 MW. The on-grid price of wind power is 0.72 Yuan, but the average on-grid power price in Inner Mongolia is only 0.24 Yuan/kWh. If the high price of power generated by wind farms was absorbed by the Western Mongolian grid alone, it would wipe out a large part of the grid's profits, since the company's total sales income is only 6 billion Yuan annually. If, instead, local grids alone absorbed the higher cost of wind power, strain on the grids would almost certainly obstruct the further development of wind power. Since wind power generation is an efficient way of reducing CO_2 emissions and improving air quality, and the environmental benefits of wind power generation are shared by the whole of society, it is reasonable that the whole of society, rather than just local consumers, should subsidize wind power development. The government needs to develop policies to specify the scope and methods that will allow the price burden to be shared.

3) Lack of capital and scarcity of suitable long-term loans for the wind power industry

The government has provided a large amount of investment capital to promote the development of the wind power industry. The Shuangjia Project devised and implemented by SETC and the former Ministry of Power provided 800 million Yuan of investment in 1995 and 1996, in the form of interest allowance loans. As a direct result of these loans, the installed wind power capacity increased from 80 MW in 1995 to 160 MW in 1997. At the same time, work began on a few commercial projects like the Nan'ao Wind Power Project, a joint venture between the Guangdong based Nan'ao wind farm and the Dutch energy corporation NUON.

However, because wind farms require vast initial investment, have high generation costs, and do not make a profit in the short term, financial organizations are reluctant to invest in them, so that the lack of capital has become a serious obstacle to the rapid development of the wind power industry. One major source of capital funding is bilateral government loans, which have been used to finance the development of many of China's wind farms. However, the wind farms financed by the loans are often little more than stages to demonstrate available technology and equipment rather than genuine commercial projects. Because these wind farms are usually constructed on a smaller scale than commercial projects, equipment costs are high and the price of the wind power generation from these projects is sometimes more than 1 Yuan/kWh. From a long-term perspective, the price of wind-generated power must be reduced if the wind industry is to develop commercially and on a large scale. Therefore, it is vital that a discussion is initiated on how to use bilateral loans in the most efficient way possible, and how to develop a commercially viable wind power industry.

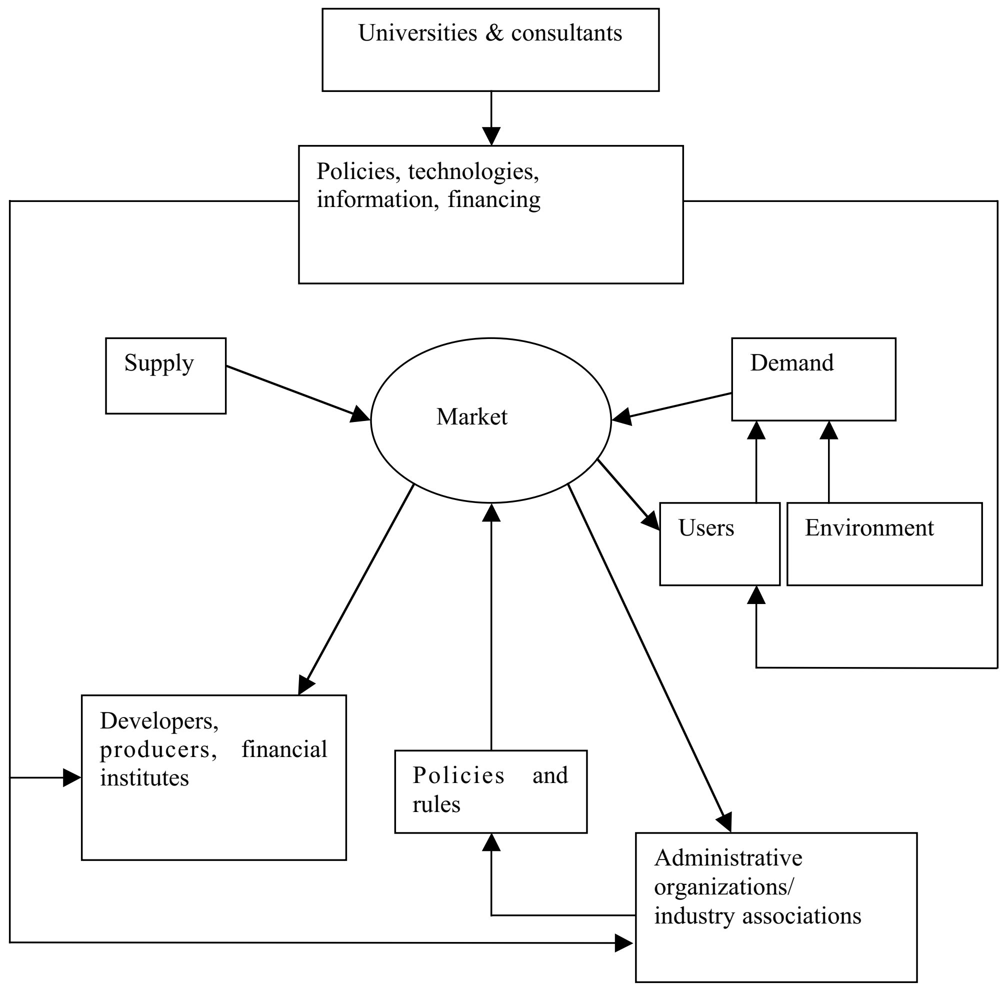
The lack of long-term preferential loans is another factor that is having a negative effect on the development of the wind power industry. At present, the repayment period for a normal commercial loan is about 5-8 years. Since the on-grid price of wind power is currently calculated by combining the cost of loan repayments and a reasonable profit, short-tem loans mean wind power prices remain high in the short term. This kind of short-term loan not only places a heavy burden on the power grid, but also diminishes the potential for lowering the price of wind power in the near term. According to financial analysis of wind power projects, if current short-term loans were replaced by long-term loans, the cost of wind power generation would drop by 20 percent due to the reduction of capital costs.

Some commercial banks (such as the China Construction Bank) consider wind power generation a high-risk industry, which also makes it harder to secure financing for wind power projects.

4) The Lack of Commercialized Operating Systems

The owners of wind farms in China are mostly local power companies or their subsidiaries (stock or other companies controlled by the local power companies). There are very few independent developers, to the extent that wind farm construction has became a government project rather than a commercial activity. The wind power market in China was developed with the support of subsidies, preferential policies, and international donations. If these supports were removed, the market would immediately contract. For the time being, the government needs to nurture the wind power market; as a growth industry wind power needs more economic and administrative measures to regulate the management and operation of wind farms, and control the wind power market. However, in the long run, wind power generation should become more and more economically viable, as generation costs and on-grid power prices decrease as a result of technological advances and commercialization. As this occurs, it is important to work to reduce the wind power industry's dependence on the government.

As with the markets for other renewable energies, there are four main factors that affect the wind power market: supply, demand, administrative organizations/industry associations, and research/consulting institutes. The relationships between them are shown in the diagram below.



The wind power market in China is currently both small and unstable, while related industries, such as equipment manufacturing and the construction of wind farms remain underdeveloped. Poor quality, the lack of reliability, and high generation costs result in a low operating efficiency in comparison with more advanced wind power markets in other parts of the world. As discussed above, a steadily expanding market is necessary for the reduction of generating costs and to encourage the development of relevant technologies. However as there are no clear objectives for the development of the wind power industry in China, the prospects of the wind power market remain uncertain, which discourages investors. Administrative departments appear to be unconfident about formulating specific policies, and this further reduces the confidence of potential investors. The only way to improve operating standards and reduce generating costs is to establish a permanently expanding market. At present wind power cannot compete directly with conventional power, and if there is no competition, the generating costs of wind power will not decrease, so the market will not expand. To resolve this rather paradoxical situation, the government needs to develop policies that use market mechanisms appropriate for the specific conditions in China to give wind power an artificial competitive ability.

The government needs to take the following steps:

_ Refine the national financial system and introduce commercial banks. Financial institutions are currently unfamiliar with renewable energy industries, including the wind power industry.

_ Encourage more companies to participate in the development of wind power projects and set up an appropriate competition mechanism. At present there are no specific regulations governing investment in wind power projects, so the majority of wind farms in China are funded, operated, and managed by power companies, and it is difficult for other investors to enter this field.

_ Reform the system for examination and approval of on-grid power prices. When the majority of wind farm owners are given permission to start construction, their focus is not on the project costs, but setting their on-grid power price. Once they are given permission to charge a high on-grid power price, their profits are assured regardless of the costs of generation. There is an urgent need for reforms to the current examination and approval system, under which the on-grid power price is set by wind farms themselves and approved by the Price Bureau. On-grid power prices should be based on bidding so that costs can be reduced.

_ In order to promote the development of the wind power market and establish a fair competition mechanism, the government should establish industrial associations or organizations.

_ Research and consultancy institutes should function as intermediaries in the wind power market. To facilitate the exchange of information and help establish the market, these institutes should encourage connections between different market participants, such as governments, banks and other financial organizations, power enterprises, power users, technology and information suppliers.

_ An improved electricity market is a fundamental requirement for the successful development of the renewable energy industry, so competition should be introduced into the electricity market as soon as possible.

5) Conclusions

The obstacles to the development of wind power can be divided into two main categories: internal problems (related to wind farm construction) and external problems (related to government policies, financing regulations etc). Resource assessment, equipment certification, the lack of skilled developers, investment, cost & price, etc. would be considered part of the former category, while incentive policies and operating mechanisms would be considered part of the latter category. These two types of problem feed into each other to form a vicious cycle that hinders the development of wind power. In order to break the cycle, we should first deal with the external problems, since they cause the majority of internal problems.

Thus the lack of targeted incentive policies and efficient operating mechanisms are the key factors behind the slow development of the wind power industry in China.

4. Policies That Provide Strong Incentives for Renewable Energy Programs Are the Key to Overcoming Obstacles and Speeding Up Development.

4.1 Successful programs in other countries

4.1.1. The United States

The American wind power market is one of the largest in the world. At the end of 2000, the total installed wind power capacity was 2,495 MW. The policies and laws that have facilitated this development are described below.

- **The *Public Utility Regulatory Policies Act* of 1978 (PURPA)**

This Act stipulates that power corporations must allow small-scale power plants that meet certain conditions to be integrated into the electricity grid, and to sell their energy at the avoided cost. Small-scale power plants have to meet set standards of efficiency in energy conversion and scale of generation, or else they must generate their power from renewable resources such as wind energy. In some states, power corporations have to negotiate long-term energy-purchase agreements with power plants involved in renewable energy generation.

- **The *Energy Tax Act* of 1978**

This Act laid out various preferential tax policies and allowed a five-year accelerated depreciation for renewable energy technology, such as that used on wind farms. Apart from the five-year accelerated depreciation, most of the preferential policies established under this act helped ensure that installed wind power capacity exceeded 1,000 MW by 1985. These policies have now been abolished.

- **The *Energy Policy Act* of 1992**

This Act established three incentive measures to promote the development of renewable energy:

(1) 10 percent of the capital construction cost of solar and geothermal projects can be deducted from federal income tax.

(2) For wind power projects implemented before 1999 there is a 10 year, 1.5 ¢/kWh production tax credit that reduces federal income tax payments (this incentive has subsequently

been extended to projects installed before the end of 2003).

(3) Wind power plants that are state-owned or city-owned (and thus exempt from income tax), receive 10-year federal cash subsidies of 1.5 ¢/kWh.

- **System Benefits Charge**

This approach involves a small fee included in the electricity price that is used to subsidize the development of renewable energy (such as wind power), energy efficiency, and other 'public goals' related to electric power. At present, fifteen states have established this type of system, although there are a variety of charges, collection methods, and uses. For example, in California the additional charge is 0.3¢/kWh, while in Illinois 50¢ per month is added to every individual electricity bill. Total revenue from such charges is expected to reach $3.5 billion through 2012, money that will be used for renewable energy incentives. The system benefits charge has proven to be a practical and effective method to collect funds for the development of renewable technologies that have with high capital investment requirements.

- **Renewable Portfolio Standard & Set-Asides**

This is a special policy used in twelve U.S. states to support the development of renewable energy capacity. Its fundamental premise is that renewable energy projects should make up a certain proportion of energy projects constructed in a given area (state, county etc). In some U.S. states the policy has already been put into practice. For example, renewable portfolio standards in Massachusetts require 1 percent of its power to come from eligible renewable energy sources by 20004, with an increase of 0.5 percent annually from 2004 to 2009, and a 1 percent annual increase after 2009. The state of Texas has the most successful renewable portfolio standard at present, with 900 MW of wind power capacity installed in 2001 under the policy.

- **Net Metering**

This preferential pricing system provides a strong incentive for individual consumers to develop their own renewable energy capacity. The more electricity consumers generate themselves, the less energy for which they have to pay a power supplier, and the lower their electricity bill. To date, 23 states have established systems of this kind.

4.1.2. The United Kingdom

The British government has explored a wide variety of policies designed to increase the capacity of renewable energy. Initially the main form of support was government subsidies, of which the *Non-Fossil Fuel Obligation* (NFFO) was the most common. The NFFO was first implemented in England and Wales, and later in Scotland and Northern Ireland. Under the NFFO, power distributors are obligated to purchase the electrical output of certain renewable energy projects at fixed prices for 15 years. The distributors recover the market cost of these purchases through a levy on electricity output, much like the system benefits charge used in the United States. The government selects renewables projects based on an open bidding process; the lowest power purchase agreement wins the bid.

The main aims of NFFO are (1) to control the use of fossil fuels so as to reduce environmental pollution and limit the damage caused by emissions, and (2) to support the development of renewable energy technology by establishing reliable funding channels.

The main components of NFFO and related policies are: (1) A target that renewable energy generation reaches 3 percent of electricity generated nationwide by 2003. (2) A tax on power enterprises that use fossil fuels, in order to establish a development fund to support research into, and the construction of, renewable energy projects. The tax is 1.5 percent on the price of the electricity they sell. (3) Public bidding on the development of renewable energy projects. Companies that propose the lowest electricity prices win the tender. The government requires power distributors to purchase renewable power at the bid price, with any over-market costs imposed on the distributors reimbursed through the fossil fuel tax.

The NFFO policy has the following three advantages: (1) The tax burden imposed on consumers is low. (2) The power purchase agreement encourages investment by stabilizing the revenue stream of renewable projects and protecting the interests of banks and investors. (3) The public bidding process ensures competition, which should reduce the cost of renewable power generation, help make the renewable energy industry competitive, and significantly reduce the levels of government subsidies for renewable energy projects.

Since the implementation of NFFO, the price of wind-generated power has fallen from € 0.16 /kWh in 1990 to 0.06—€ 0.08 /kWh in 1997 (see Table 4-1).

To date there have been five periods in which more than 1,000 renewable projects have been signed up according to NFFO (the table below shows the first four periods). From the data of the first, second, and third phases we can conclude that the power from renewable energy has increased, the power cost has decreased, and government subsidies have continuously declined. The policy target that renewable energies become more competitive has been attained. See Table 4-2.

The implementation of NFFO has led to the reduction of carbon emissions, but still falls short of government goals to promote renewable energy development. The government is therefore actively exploring more effective measures.

Table 4-1 A Comparison of the Highest Contract Power Prices Under the British Non-Fossil Fuel Obligation Policy Between 1990 and 1997

<table>
<tr><th rowspan="2">Type of renewable energy generation technology</th><th colspan="4">Highest contract power price €/kWh</th></tr>
<tr><th>NFFO1 (1990)</th><th>NFFO2 (1991)</th><th>NFFO3 (1994)</th><th>NFFO4 (1997)</th></tr>
<tr><td rowspan="2">Wind power</td><td rowspan="2">0.16</td><td rowspan="2">0.17</td><td>0.08(>1.6MW)[1]</td><td>0.06(>1.6MW)</td></tr>
<tr><td>0.09(<1.6MW)</td><td>0.08(<1.6MW)</td></tr>
<tr><td>Small-scale hydro-power</td><td>0.12</td><td>0.09</td><td>0.08</td><td>0.07</td></tr>
<tr><td>Landfill gas</td><td>0.10</td><td>0.09</td><td>0.06</td><td>0.05</td></tr>
<tr><td rowspan="2">Combustion of urban and industrial waste</td><td rowspan="2">0.09</td><td rowspan="2">0.10</td><td rowspan="2">0.06</td><td>0.05(FBC)[2]</td></tr>
<tr><td>0.04(CHP)[3]</td></tr>
<tr><td>Biogas</td><td>–</td><td>–</td><td>0.14</td><td>0.09</td></tr>
</table>

Notes 1. The wind farms production capacity >1.6MW declared net capacity 2. Fluidized bed combustion technology 3. Cogeneration of heat and electricity

Table 4-2 the impact of implementing NFFO

NFFO phase	First phase	Second phase	Third phase
Power output from renewable energy sources (millions kWh)	627	843	1,177
Unit cost (€/kWh)	0.07	0.05	0.04
Total government subsidies (million Euros)	81.3	57.9	25.0

In 1997, the UK attended the Tokyo International Energy and Environmental Protection Summit. At the conference, the UK government promised a 12.5 percent reduction in CO_2 emissions by 2010, and has an even higher internal aim of a 20 percent reduction. The government has calculated that to achieve this goal, 10 percent of the nation's power must be generated from renewable resources by 2010. The NFFO program has ended, although its provisions remain effective for those renewable energy projects established under its auspices. In

July 1997, a new Act based on similar principles to those that motivated the NFFO policy, known as *The Renewable Energy Obligation* was drawn up. This is a renewables portfolio standard policy with many similarities to those established in a number of U.S. states.

The Act was passed by the House of Commons in 1999 and was put into practice in April 2002. To ensure the sustained development of renewable energy generation and continued technological developments in this field, the Act will remain effective until at least 2025. The main components of the Act are listed below.

- To reach the attainment of wider governmental goals, public power suppliers must ensure that by 2010 at least 10 percent of the power they produce comes from renewable resources, with intermediate targets beginning in 2002. Penalties are imposed on those who do not comply.
- A well-run renewable energy credit system will be set up to help companies reach their quota and promote the use of renewable energy. Those power corporations that generate more than 10 percent of their energy from renewable resources will be given tradable renewable energy certificates, while those companies that fail to reach the quota will be able to buy green certificates from the higher performing companies. This system will provide more incentives for the introduction of renewable energy technology.
- A pollution tax is now imposed on businesses in the power generation industry. The tax rate is as follows: natural gas-generated power at € 0.002 /kWh, coal-generated power at € 0.018 /kWh and liquefied petroleum gas-generated power at € 0.001 /kWh. These taxes should provide an annual revenue of approximately 1.564 billion Euros, which could then used to support a variety of projects, including research on low carbon emission technology, and the acceleration of the annual depreciation rate for energy conservation equipment (currently fixed at 100 percent). Part of the revenue could be used to subsidize enterprises, i.e. fund a 0.3 percent reduction in the national insurance contributions paid by employers for their employees. These measures would encourage enterprises to increase the number of their employees and reduce the amount of energy-consuming equipment in use, thereby boosting employment and tackling pollution at the same time.

4.1.3. Germany

In the early 1990s, Germany introduced preferential policies to promote the use of renewable energy sources. As a result of these policies, the installed wind power generating capacity increased rapidly from 15 MW in the late 1980s to 2,800 MW at the end of 1998, 4,400 MW at the end of 1999, and 6,100 MW at the end of 2000. Germany has the largest installed wind power generating capacity in the world. The policies that helped fuel this rapid development are detailed below.

- In 1991 the *Renewable Energy Generation Act* was passed. The Act stipulates that power corporations must purchase power generated from renewable resources at a fixed price. For wind power this was initially set at 90 percent of the average on-grid power price. The National Statistics Office average calculates the on-grid price every year according to the price two years previously. Since its implementation, the Act has considerably advanced the development and use of wind power technology.
- The development of various different kinds of renewable energy technologies was the basic motivation behind the formulation of the *Renewable Energy Act*. Its main aim is to promote the development of energy supplies while ensuring that the environment is protected and that the percentage of total electricity generated from renewable resources increases. The Act obligates the electric power grid to accept all power produced from renewable resources at prices prescribed by the government. The Act prescribes the power prices of various renewable energies as follows. See Table 4-3.

Table 4-3 Germany's fixed prices for power generated from renewable resources.

Generation technology	Fixed power price €/kWh	Further comments
Wind power	0.10	Five-year validity period may be prolonged in some places, with 0.05€/kWh later
Hydropower, landfill gas, and goal gas power	0.08	
Biogas power (capacity ≤ 500kW)	0.11	
(capacity ≤ 5000kW)	0.10	
(capacity >5000kW)	0.09	
Geothermal power (capacity ≤ 20 MW)	0.10	
(capacity > 20 MW)	0.08	
Photovoltaic power	0.54	

In addition, the government has provided investment allowances for renewable energy projects of up to 25 percent of the total investment needed, and the German Policy Bank can supply up to 80 percent of investment financing needed for small- and medium-scale wind farms with annual sales of under € 255 million.

In February 2000, the German Congress passed a new law concerning wind power, which came into effect in March 2001. A standard power output was established as a reference point for every kind of wind turbine. For example, one million kWh/year is the standard for a 500/600 kW wind turbine (where there is an average annual wind speed of 5.5 m/s at a height of 30 meters). Then two separate prices (one high and one low) are calculated for the electricity generated by the specified turbine. The higher price is € 0.11/kWh, a price that covers the cost of construction, transportation etc for the turbine. The lower price is € 0.09/kWh, a profit-generating price (after funds from the higher price have been used to pay back debts). How long the wind-generated power is sold at the higher price is calculated using the following formula:

Y=5+[(150-P)/0.75]*2/12-50%X (year)

Where

Y is the number of years the wind power should be sold at the higher price (unit: year);

P is the actual annual power output of the wind turbine in units of 10,000kWh

X is the number of years the wind turbine has been in operation, in units of a year. For a new turbine, X=0.

Below are the results for a variety of turbines in a variety of situations, calculated according to the formula above:

(1) For a wind turbine installed after Jan 1st 2000:

If the turbine is in an area with strong winds, where power output is approximately 1.5 million kWh/year, then Y=5 years. This means that for the first five years the wind power generated by this turbine will be sold at a price of € 0.11/kWh, and after 5 years the price will be lowered to € 0.09/kWh.

If the turbine is in an area with weak winds (where power output is approximately 750 thousand kWh/year), then Y=22 years.

(2) For a wind turbine installed before Jan 1st 2000:

If the turbine is situated in an area with strong winds, where power output is approximately 1.5 million kWh/year, and X=8 years, then Y=1 year. *i.e.* the wind power generated by this turbine should be sold at a price of € 0.11/kWh for one year, after which the price should go down to is € 0.09/kWh.

If the turbine is situated in an area with weak winds, where power output is approximately 750,000 kWh/year, and X=8 years, then Y=14 years. This means that for 14 years the wind power generated in this area will be sold at a price of € 0.11/kWh, but after this period the price will drop to € 0.09/kWh.

This new policy encourages a more enthusiastic attitude towards the development of wind power projects in areas with limited wind resources, creates a balance between different areas developing wind power projects, and ensures that there are not unacceptably high profits in areas with rich wind resources.

4.1.4. Denmark

There are large supplies of wind energy in Denmark, one of the earliest countries to start exploiting wind power on a large scale. The government has historically created clear long-term objectives, strong policy measures and a wide variety of financing channels to support wind power technology development and installation. At the end of 2000 the installed capacity was 2,300 MW, the fourth highest in the world.

- In 1985 the Danish government signed an agreement with the Danish Power League. This agreement guaranteed that the state-owned power corporation would purchase electricity generated from renewable resources at 85 percent of the average price for electricity. In addition, the owners of businesses that are not involved in power generation can obtain refunds on CO_2 and energy taxes (including VAT on energy prices) by buying renewable energy.
- Denmark has adopted various economic incentive policies to promote renewable energy use, including capital and production incentives. (1) For renewable energy projects, construction awards of up to 30 percent of installation costs are available but, since 1989, this allowance has not been offered for wind power projects. This is because when the market conditions for a certain type of renewable energy become relatively well developed, the allowance is no longer offered for that field. (2) During the three-year plan from 1994 to 1996, the total subsidy available for replacing old-style wind turbines with new-style turbines was € 4 million, equal to 15 percent of total investment costs, which was the lowest subsidy rate available. During that period, production awards were based on the power output of individual wind farms. In Denmark, wind farms can earn about € 0.08 / kWh made up of the following three parts: € 0.04 from sales to the electricity grid, € 0.01 from CO_2 tax rebates, and € 0.02 from a government allowance. These policies unquestionably helps promote rapid and large-scale development of the wind power industry.

  Because of increasing difficulties in finding locations for wind farms, the Danish government adopted various incentive measures to make wind farm siting easier. Local governments are required to submit proposals for expanding wind farm capacity, carry out research on how to improve the efficiency of existing wind farms, make economic and technical assessments of offshore wind farms, develop ways for individual investors to own and operate wind turbines, and formulate wind power development strategies. One evaluation of local wind power drawn up in December 1995 suggested that if certain available technologies were utilized, generating capacities could be increased by at least 1,000 MW, which would be enough to reach Denmark's 2005 renewable energy target.

4.1.5. The Netherlands

The Dutch also began harnessing wind power at an early stage. By the end of 2000, installed capacity was about 450 MW. The Dutch government has developed several policies to encourage the widespread exploitation of wind power.

- **Investment allowances.** Historically, the Ministry of Energy Resources and the Environment subsidized up to 35 percent of the total investment costs in renewable energy projects, but it stopped in 1996 because of a reduction in the budget for energy projects. After 1996, the emphasis shifted to supporting renewable energy projects through tax incentives rather than government funds. The value-added tax for energy generated from renewable resources was reduced from 17.5 percent to 6 percent.
- **Green pricing systems.** A number of electricity corporations are putting green pricing ideas into practice. EDON's policy, for example, provides a subsidy of € 0.00018/kWh for each consumer. In contrast, PNEM's policy is that consumers only pay an extra € 0.00032/kWh when they buy power generated from renewable rather than conventional resources. PNEM's policy encourages consumers to use more wind power than EDON's policy. By the end of 1996 there were about 10,000 consumers of green power in the Netherlands. More recently, incentives offered for renewable energy purchases have made green power cost competitive with traditional energy sources. As a result, green power sales have increased dramatically, and hundreds of thousands of households are now purchasing green power in the Netherlands.
- **The establishment of a 'green certificates' trading system.** In order to further facilitate the development of 'green' power, the Dutch established a 'green certificate' trading system in 1997. Under this system, the country's 19 power suppliers are required to generate a certain amount of power from renewable resources (for example, 1700 MWh in 2000) and, for every 10MWh generated and placed on the grid, they receive one green certificate. They must

accumulate enough green certificates to demonstrate by the end of the year that they have fulfilled their quota of renewable energy generation. The green certificates are valid only in the year the power is generated, and the quota is adjusted according to relevant weather conditions over the year. So, for example, if a company does not obtain any of its green certificates from wind power, then changes in wind conditions will not be taken into account when calculating their quota. Those suppliers that cannot fulfill their quota of green certificates at the end of the year have to purchase the outstanding certificates from suppliers who have extra, at a price 50 percent higher than the market price.

While much effort went in to the design of the green certificate system in the Netherlands, the quota for renewable energy sales was never made mandatory – it was based on voluntary agreements. As a result, the quota system itself has not been successful, though green certificates continue to be used to track voluntary green power sales.

4.1.6. India

For a long time India has been plagued by problems of wasted funds, inadequate supplies of energy resources and power shortages. Even now there is a 14 percent shortage in the national power supply, which rises to more than 28 percent at times of peak demand, and 41 percent of rural areas still have no power supply at all. Together with the development of conventional energy capacity, India has been focusing on the development of wind and solar energy capacity as crucial to future economic development. At present India's installed wind power capacity is more than 1,000 MW, far higher than China's and fifth in the world. The key to this success has been the government's strong support for the development of renewable energy projects through relevant policies. These include:

- The establishment of a Ministry of Non-Conventional Energy Resources to focus on supporting the development of renewable energy projects.
- The establishment of an investment corporation to provide renewable energy projects with loans at low interest rates and other financial assistance.
- Government subsidies of 10–15 percent of the total investment costs for wind power projects.
- High import duty on pre-assembled wind turbines of 25 percent. If the turbines are imported in parts, import duty is zero.
- The annual depreciation rate for wind turbines is set at 100 percent for the first year. The owners of turbines are permitted to add the depreciation to the cost of other projects they manage and receive an allowance by a deduction from income taxes.

- Wind power projects are granted a five-year income tax deduction.
- In some states, there exist preferential policies that allow the sales tax on wind-generated power to be reduced.
- Power corporations are obliged by law to provide the following preferential conditions for wind-power generators: 1. Corporations must provide convenient connections to the grid for wind power producers. 2. A corporation can charge no more than 2 percent of the standard electricity fee as a handling charge on those clients who generate power only for themselves. 3. During periods when strong winds produce large quantities of wind energy, if wind power producers are not able to use all the power they produce immediately, they can reserve the power on grid for up to eight months. 4. Wind power producers can sell their power to third parties through the electricity grid, and pay only a handling charge to the grid. 5. Different districts have different on-grid power prices, which are usually between U.S.$ 0.058 and 0.074/kWh.

4.2 China's renewable energy efforts

The development of renewable energy technologies is a priority for the Chinese government, which considers them an important part of national energy resources, and has incorporated them into all major energy related policies. China has taken the lead in signing the *Rio Declaration*and the *Framework Convention on Climate Change* in 1992. In the same year, China developed the *Ten Great Countermeasures for China's Environment*.

4.2.1 Legislation

- The 1995 *Electricity Act of the People's Republic of China*. This Act is the first to deal exclusively with the issue of energy resources. The first chapter explicitly points out that the government encourages and supports the use of clean and renewable energy resources for electricity generation. The second chapter discusses the importance of developing and using renewable energy resources in the construction of rural power generating capacity and agricultural power consumption.
- In the *Ninth Five-Year Plan* for the development of the national economy and Chinese society and in the *Guidelines for long-term goals for 2010,* the government established its basic strategy for the development of energy resources. Electricity generation was to be increased, with coal as the primary source, but the exploitation of petroleum and natural gas reserves and the development of new energy resources were also to be encouraged. The strategy emphasized the importance of developing small-scale hydro, wind, solar, geothermal, and biomass power projects, as well as improving the structure of the energy

industry.

- The *China Electricity Law* of 1998. This Act reaffirmed and re-emphasized the strategic importance of renewable energy technologies for optimizing the use of energy resources, reducing emissions levels, and improving the environment.

4.2.2 Economic incentive policies

- **Reductions of import duties.** Recently, Chinese import duties have mostly been reduced to 23 percent after several adjustments. At present there are preferential measures for wind power and photovoltaic (PV) equipment, so that the import duty on parts for wind turbines is around 3 percent, while for the wind turbine it is zero, and the rate for PV equipment is 12 percent.
- **Preferential value-added tax (VAT) rates.** Although at present there is not a preferential VAT rate for renewable energies at the national level, in some provinces, such as Hebei, Liaoning, Jilin, and Guangdong, the VAT rate for wind power is only 6 percent. In Xinjiang, foreign-owned and joint-venture wind power enterprises are able to obtain a preferential VAT rate if they have been in operation for more than 10 years.
- **Income tax deductions.** After 40 years of development, the Chinese income tax system is in good shape. At present, the average income tax rate is 33 percent. Because income tax is a local tax, the central government does not usually issue policies and regulations that affect it. However some provincial governments, such as in Inner Mongolia and Xinjiang, have developed preferential policies to support the development of renewable energy generation projects. They allow for an initial two-year exemption from income tax followed by three years at 50 percent of the normal rate, and then fifteen years at a rate of 15 percent.
- **Loans with interest allowance.** In 1987, the Chinese government established a special fund to provide a loan with interest allowance aimed at extending rural energy reserves, and supporting renewable energy projects, such as wind power projects. In 1996, the amount available for funding these loans was increased to 120–120–130 million Yuan. A central finance committee provides approved projects with a loan that has interest rates 50 percent lower than commercial rates. In 2001, the State Economic and Trade Commission introduced a policy of providing loans at low interest rates in order to promote the development of nationwide wind power projects. The interest allowance is available for between one and three years depending on a variety of local conditions.
- **Subsidy policies.** Central government allowances are mainly used to fund research into technological developments in the renewable energy field. Provincial government subsidies

are used partly to support scientific research into renewable energies, but the majority of funds are used for the popularization and installation of small-scale wind power systems and solar photovoltaic systems. For example, in Mongolia and Xinjiang, users of these generating systems can obtain subsidies of 200 to 300 Yuan per set.

4.2.3 Research and development

The government supports the research and development of renewable energy technology through subsidies and through policy development and implementation.

Some government subsidies cover all administrative expenses. Others cover all or part of the costs of scientific research on renewable energy technology. There is no way to calculate the total value of these subsidies due to the shortage of relevant data, but it is reasonable to assume that it is a large amount given the number of scientific teams researching renewable energy and the amount of research work they have undertaken

A second type of subsidy provides support for key technological projects. Wind power generation has been considered one of the key technological priorities over the last ten years. According to the writer’s incomplete statistics, the cost of subsidies for national technological projects alone exceeded one hundred million Yuan during the Ninth Five-year Plan.

A third type of subsidy provides funding for the central government to develop blueprints for the future direction of development in the renewable energy field. For example, in 1996 the State Development Planning Commission, the Science and Technology Commission, and the State Economic and Trade Commission drew up the document, *Outlines for the development of China’s energy and renewable energy production from 1996 to 2010*, which provided the general outline for concrete the development of energy, including the requirements for wind power projects.

This section (Section 4) has illustrated that if renewable energy, such as wind power, is to become sustainable, governments must maintain support for the development of renewable energy resources, especially in the initial stages of the industry’s development. Although every country is in a different position and has adopted different policies to suit its individual circumstances, government support is a common denominator for the successful development of a renewable energy industry. When drawing up renewable energy policies, China should study the experiences of other countries.

5. Types of Policy Incentives and the Drafting of New Policies

5.1. Policy types and their characteristics

Four main types of incentive policies have been implemented worldwide.

1) Mandatory policies, based on legal restraints or obligations. This type of policy consists of (a) relevant laws, regulations, and government mandates passed at any level of government, (b) regulatory and technological policies drawn up by relevant governmental departments, and (c) other mandatory regulations. Examples of this type of policies include the *Chinese National Power Law*, the *American Public Utilities Regulatory Policies Act*, the *Danish Renewable Energy Law*, the *German Power Law*, the quota system used in some U.S. states, and the mandate regarding access rights to renewable energy resources established by some U.S. states. This type of policy is coercive and universal in its scope, and has a high degree of authority.

2) Economic policies. This category covers a wide variety of economic policies and measures drawn up by governments, but can be divided into two main policy types. First, policies which provide economic incentives for renewable energy development, such as a variety of subsidies, preferential pricing, income tax rebates, loans with interest allowance, and loans at low interest rates (See details in Figure 5-1). Second, policies that provide economic deterrents and disincentives for the use of conventional energy resources, such as pollution charge systems, CO_2 and energy taxes. Both types of economic policies influence the decisions of enterprises by using market mechanisms to affect their income. Although these policies are not coercive, they can provide strong compulsion for enterprises to adapt their practices. The emphasis of this paper is on these types of policy.

3) Research and development policies. This type of policy relates to the attitude of the central government and the measures it takes to support the research and development of renewable energy technology. Examples include the Chinese national plan for the development of renewable energy technology and the U.S. plan for wind power development. As research is only at the first stage of technological development, these policies generally do not provide direct, near term economic or other benefits, but are instead designed to produce scientific results. This paper emphasizes the importance of economic policies.

4) Management policies and operating mechanisms. These policies cover a variety of strategic decisions and new measures introduced to make the management and operating mechanisms of the energy industry more efficient in promoting the development of renewable resources. Examples include inviting public bidding for renewable energy such as under the Non Fossil Fuel Obligation in the United Kingdom, the green certificate system that was planned in

Denmark, the ‘green power’ exchange system in the Netherlands, and the system benefits charge used in California. This type of policy is characterized by its attempts to use a combination of market mechanisms and administrative management methods.

Figure 5-1 Types of Policies supporting renewable energy development

Types of policies

- Mandatory policies
  - Laws
  - Codes
  - Regulations
  - Provisions
  - Guidelines
  - Governmental orders
- Economic policies
  - Incentive policies
    - Preferential investment policies
      - Interest allowance loans
      - Loans at low interest rates Or loans with no interest
      - Prolonged repayment period
      - Accelerate depreciation
      - Investment sharing
      - Investment subsidy
    - Preferential tax policies
      - Rebates on value-added import tax and surtaxes
      - Rebates on value-added production tax and surtaxes
      - Income tax rebates
      - Export drawback tax
    - Preferential pricing policies
      - Price subsidy
      - Price balance sharing
  - Deterrent policies
    - Drainage charge system
    - CO_2 tax
    - Energy tax
- Research and development policies
  - Appropriating funds of financial enterprises
  - Appropriating funds of financial research expenses
  - Special research funds
- Management policies and operating mechanisms
  - Uniform management systems
  - Public bidding and fair competition
  - Special funds, rolling development
  - Standards and regulations

5.2 Analysis and evaluation of the practicality of each policy type

1) Mandatory legal policies

Both domestic and overseas experiences demonstrate that it is vital to provide legal protection and promotion for the development of renewable energy. One of the main reasons why the United States has achieved so much in the areas of wind power, solar power, and biomass generation technologies is that renewable energy generation technology has been consistently protected and promoted by federal and state laws over a relatively long period of time. For example, the *Public Utility Regulatory Policies Act* of 1978 stipulated that power companies must purchase power generated by cogeneration or from renewable energy even if it came at a higher cost. This policy provided a more level playing field for renewable energy generation technology to compete with fossil fuel technology. In 1992, energy policy legislation established further requirements to help promote renewable energy development. The legislation provided income tax deductions for projects developing and using renewable energy technology, and authorized the Department of Energy to fund projects demonstrating and commercializing renewable energy technology. In recent years, some state governments have established a quota system for the development of renewable energy in order to adapt to the changes brought about by the reform of the electricity industry.

In 1995, the Chinese government enacted the first *Electric Power Law*, which actively encourages the exploitation of renewable energy sources such as solar energy. At the same time, the former Ministry of Power established interconnection regulations for connecting wind power generators to the grid. These policies were undoubtedly of great importance in promoting the development of renewable energy and have assisted the rapid development of wind farms within China in recent years.

2) Economic incentive policies

- Subsidy policies

Three main types of subsidies exist:

(1) Investment subsidies that are given to entities who are willing to invest in renewable energy generation. For example, in 1978 the United States government provided tax credits for 15 percent of the investment costs for entities who invested in wind power generation. Although this particular policy has been terminated, this kind of subsidy can be used to attract investors, thereby increasing production capacity and enlarging the scale of the industry. The disadvantage of this kind of subsidy is that it is unrelated to management and production conditions within the industry

and so it sometimes does not encourage enterprises to modernize existing technology or reduce their costs as much as other incentive policies.

(2) An output subsidy. A subsidy is provided according to the production levels of renewable energy generation equipment and as an incentive to increase production and reduce costs. These subsidies enhance the economic performance of an enterprise. This type of subsidy is used in the United States and in some Western European countries, but not currently in China.

(3) Subsidies provided to consumers. This type of subsidy is used throughout China as an incentive. Apart from being widely used to stimulate sales of equipment for micro-scale wind power generation it is also used to help popularize new and experimental renewable energy technology. Governments in the U.S., Germany, and Japan have all adopted similar policies to encourage consumers to buy small scale wind power and/or photovoltaic power systems. This kind of subsidy can increase market demand by stimulating consumption and, as a result, increase production capacity. However, considerable uncertainty exists about whether the subsidies can actually help achieve this aim, as success is, to a large degree, dependent on the size of the consumer market for renewable energy. A large consumer market requires a large amount of funds, which would be difficult to provide through subsidies alone. Nonetheless, a consumer subsidy policy is, at the current stage of renewable energy development, a practical measure. Both domestic and overseas experiences prove that when the renewable energy market has reached China's current scale, this kind of subsidy policy has demonstrable effects.

However, in light of previous experience, it is vital that the following two problems are solved before the subsidy policy is implemented on a large scale in China.

(1) Sources of subsidies. U.S. and Western European experiences demonstrate that it is possible to raise money to fund a subsidy either through a system benefits charge or by collecting a fossil fuel tax. A present, the main source of funds for the subsidy in China is from the government, but this is not economically viable in the long term, as China is a developing country with a limited amount of funds.

(2) Subsidy strategies. It is important to consider who should receive a subsidy and what mechanism should be used to distribute such subsidies. Subsidies will be most effective if given to investors rather than to users. If public bidding is introduced, and if a fair mechanism is used to assign contracts, then subsidies could

be used to simultaneously enlarge production scale and reduce costs.

- Tax revenue policy

There are two different types of tax revenue polices: one is incentive-based and the other coercive. The incentive-based tax policies involve providing a preferential tax rate, for example, reductions of import duty, value-added tax, and income tax. Reductions in tax rates do not require direct government funding, and lead only to slight reductions in central and local government incomes. In addition, they do not directly affect the overall national revenue balance and can be easily implemented because of the small scale of the renewable energy industry. However, they sometimes have little affect in encouraging enterprises to modernize their technology, enhance their efficiency or reduce their costs, because most taxes are not included in production costs (apart from import duty) and they affect only the final price of the industry's product and the industry's profits.

An example of a coercive tax policy is charging polluters a tax related to the amount of pollution they discharge, such as urban waste or sewage from livestock farms. Practical experience in many countries has demonstrated that this kind of policy not only promotes the use of renewable energy resources but also encourages enterprises to modernize their equipment regularly. Such policies contribute to more rapid technological advances, particularly when high minimum standards and high charges are in place. All this makes coercive taxation an indispensable policy tool. The aim of a policy for reducing tax rates is to promote technological progress and the commercialization of technological advances, so the benefits of each tax policy should be measured according to this aim.

- Preferential pricing policies

Most countries with successful renewable energy commercialization strategies have adopted some kind of preferential pricing policy for renewable energy because the cost of renewable energy is normally higher than that of energy generated from conventional sources. For example, under the U.S. E*nergy Policy Law*, public electricity companies have historically been required to purchase energy generated from renewable resources. The success of wind development in Germany, Spain, and Denmark are all directly related their preferential pricing policies. In China, the former Ministry of Electric Power set up a preferential pricing policy for the on-grid price of wind generated power.

Noticeable differences exist in the scale and objectives of preferential pricing policies in China and elsewhere. In the U.S. under PURPA and in other countries, preferential pricing policies cover all power generated using renewable energy technology, while in China they are limited to wind-generated power. Also, in the U.S. and other countries, the pricing regulations were drawn up by the federal government and enacted as law, while in China the regulations were drawn up and authorized by ministries and commissions. (This is partly because the legislative mechanisms of the two countries are different. The U.S. President and the departments under his jurisdiction have no legislative power, while any documents drawn up and ratified by the ministries and commissions of the Chinese government have legal force, even if they have not been approved by the State Council and the National People's Congress) .

Both theoretical analyses and practical experience show that preferential pricing systems function effectively as incentives to develop the renewable energy industry. However two basic problems with preferential pricing policies exist.

First, how to subsidize the price difference between renewable and conventional power. Funds can come from a mixture of government sources, electrical power companies and users, or entirely from one source (for example, in China they come entirely from power users). One potential method for raising money is through a slight increase in the price of electricity. As the scale of the renewable energy industry is still relatively small, the amount of money needed to subsidize it is also relatively low, which makes this method a practical one.

Second, what is the basis for setting the preferential price? (See the discussion in the subsidy policies discussed above).

- Loans at low interest rates or loans with interest allowance

Loans at low interest rates or loans with interest allowance can reduce the burden on the industry over the repayment period and can also help reduce production costs. The disadvantage of this kind of policy is that the government has to raise funds to support a subsidy on the interest allowance or the lower interest rates. When the size of the loans and the interest allowances are larger, the amount of money that must be raised clearly is larger as well. The state of the supply of funds is the key factor that will determine the long-term effectiveness of the policy. There are few preferential loan policies in The U.S at present, though such policies do exist in Europe. The scale of the Chinese program is small enough for the government to be able to support it financially without any difficulty.

In order to maximize the economic benefits from loans with interest allowance, it is vital that the recipients of the loans are chosen carefully and that the loan program is well managed.

3) Research and development policies

The research and development of renewable energy technology is a priority both in China and in other countries. It provides a foundation for the sustainable development of the renewable energy industry. Since the 1970s the Chinese government has implemented a series of scientific research and development plans, and has established a set of national level laboratories and research teams. However, in comparison with other countries, the amount of money invested by the Chinese government in research and development of renewable energy technology is relatively low. During the Ninth Five-year Plan, the entire amount available for all national scientific projects was less than a hundred million Yuan. In addition, Chinese enthusiasm for renewable energy is largely limited to the central government. Provincial governments and industry groups remain uninvolved or participate without any real enthusiasm. Although the situation is improving gradually, the amount of time, energy, and material resources devoted to developing renewable energy capacity remains minimal. Practical experience shows that it will be impossible for China to maintain its momentum in the development of renewable energy technology if the government will not invest in research and development.

4) Management policies and operating mechanisms

Practical experience increasingly proves that problems with operation mechanisms are a more serious challenge to the development of renewable energy technology than technological and economic obstacles. From a technological perspective, an enormous variety of technical barriers that originally seemed insurmountable have been overcome or are currently being tackled. The problems arising from economic obstacles were solved or ameliorated following the improvement of the technical barriers. However, problems with operating mechanisms are often difficult to solve because they involve wider and more complex factors such as the national political and economic systems. So China and other countries need to prioritize enhancing their management methods and improving their operating mechanisms.

5.2. Formulating a new policy

1) The basic goal of a new policy

The majority of western governments have been paying attention to the importance of renewable energy technologies since the 1970s. Governments and other bodies have taken action in the fields of politics, economics, and technology and have developed policies with the basic goal to accelerate the development and exploitation of renewable energy technology. The policies have aimed to make renewable energy an important source of energy for society as early as possible. In addition, these policies aimed to achieve the following:

(1) To establish a strong foundation upon which to build research and development capacity, and with the support of relevant policy measures, use this foundation to continually improve wind power generation technology while reducing product cost.

(2) To increase the scale and proficiency of the production of equipment for wind power generation, increase demand, perfect a service and support market, regularize and harmonize supply and demand relationships in the wind power market, co-ordinate gradual increases in the size of the wind power market, and facilitate the commercialization of wind power generation technology.

2) New incentive policies and programs

The following table contains details of a variety of potential incentive policies to promote renewable energy development.

Table 5-2 Economic incentive policies and their structure

Policy program		**Economic implication**
Preferential financing policies	**Time period**	
S1.1 loan with interest allowance	one year	Provide a one-year preferential loan with interest allowance
S1.2 loan with interest allowance	two years	Provide a two-year preferential loan with interest allowance
S1.3 loan with interest allowance	three years	Provide a three-year preferential loan with interest allowance
S1.4 Prolonged repayment period	ten years	Prolong repayment period from current seven years to ten years
S1.5 Prolonged repayment period	fifteen years	Prolong repayment period from current seven years to fifteen years
Preferential taxation policies		
S2.1 Exemption from customs duty		Reduction in import duty for wind turbine parts from current 3% to 0%. Value-added tax on imported parts is 0%.
S2.2 50% deduction on the value-added tax (VAT) rate on fixed assets		Permit a 50% reduction on the VAT rate for fixed capital assets.

Policy program	Economic implication
S2.3 Total exemption from VAT on fixed assets	Permit a total exemption from VAT on fixed capital asserts
S2.4 Exemption from value-added tax on power produced	Permit a total exemption from VAT on all power produced annually
S2.5 Income tax rebates	When power generation starts on a regular basis, allow exemption from income tax for the first three years and collect income tax at half the usual rate (16.5%) in the fourth and fifth years.
S2.6 Income tax is charged at half the usual rate	Income tax is charged at a rate of only 16.5% (usually 23%).
S2.7 Exemption from income tax	Income tax is zero.
Multiple component policies	
S3.1 Three years of loan with interest allowance plus a fifteen year repayment period	The same as the implications of the relevant policies as discussed above
S3.2 Exemption from import duties plus exemption from all VAT	The same as the implications of the relevant policies as discussed above
S3.3 Exemption from import duties, exemption from all VAT, and a fifteen year repayment period	The same as the implications of the relevant policies as discussed above
S3.4 Exemption from import duties, exemption from all VAT, a fifteen year repayment period, exemption from income tax for 3 years, and a reduction in income tax for 2 years	The same as the implications of the relevant policies as discussed above
S3.5 Exemption from import duties and exemption from VAT on fixed assets	The same as the implications of the relevant policies as discussed above
S3.6 Exemption from VAT on fixed assets and a fifteen year repayment period	The same as the implications of the relevant policies as discussed above
S3.7 Exemption from import duties and exemption from VAT on fixed assets and income tax rebates	The same as the implications of the relevant policies as discussed above
S3.8 Exemption from import duties, exemption from VAT on production, and exemption from income tax rebates	The same as the implications of the relevant policies as discussed above
S3.9 Exemption from import duties, exemption from VAT on production, and income tax rebates + fifteen-years repayment period	The same as the implications of the relevant policies as discussed above

Policy program	Economic implication
Preferential financing policies	
S3.10 Three year interest allowance, fifteen year repayment period, and exemption from import duties	The same as the implications of the relevant policies as discussed above
S3.11 Three year interest allowance, fifteen year repayment period, and exemption from import duties + exemption from VAT on fixed assets	The same as the implications of the relevant policies as discussed above
S3.12 Three year interest allowance, fifteen year repayment period, exemption from import duties, exemption from VAT on fixed assets, and exemption from income tax	The same as the implications of the relevant policies as discussed above
S3.13 Three year interest allowance, fifteen year repayment period, fifteen year depreciation, exemption from import duties, exemption from VAT on fixed assets, and income tax rebates	The same as the implications of the relevant policies discussed above
S3.14 Three year interest allowance, fifteen year repayment period, exemption from import duties + exemption from VAT on fixed assets, income tax rebates	The same as the implications of the relevant policies as discussed above
S15 Three year interest allowance, fifteen year repayment period, exemption from import duties, exemption from VAT on fixed assets, and income tax charged at half the usual rate	The same as the implications of the relevant policies as discussed above
S16 Three year interest allowance, fifteen year repayment period, exemption from import duties, exemption from VAT on production, and income tax rebates	The same as the implications of the relevant policies as discussed above
S17 Fifteen year repayment period, exemption from import duties, exemption from VAT on production, income tax rebates, investment by RMB 7500 Yuan/KW, and add the time of power generation to 2,600 hours	The same as the implications of the relevant policies as discussed above
Preferential power price policy	
S4.1 Full subsidy	The difference between the on-grid price for wind generated power and the on-grid price for power from a newly constructed coal fired power plant is paid for by the government or by society.

6. Impact of Incentive Policies on the Price of Wind-Generated Power

6.1. The composition of the price of wind power in China and factors that influence it

The price of wind power in China is derived from a combination of components, which are detailed below.

On-grid power price = power generation cost + tax + profit after tax

Power generation cost = depreciation cost + maintenance cost + wage and welfare costs + insurance costs + materials expenses + loan + amortization charge + interest + any other not listed

Tax = value-added tax + value-added surtax + income tax

Value-added tax = sales income for wind power _ 17%

Value-added surtax = value-added tax _ 8% (which consists of a 5% urban construction tax and a 3% education tax)

Income tax = (sales income – power generation cost – value-added tax – value-added surtax) _ 33%

Profit after tax = sales income – power generation cost – taxes including income tax, VAT and VAS

Many factors influence the price of wind power, among which the major ones are:

- Resource conditions: based on the wind conditions at the power-generating site.
- Costs of a generating system: cost of a generator set and support facilities.

- Finance conditions: lending rate, time limit for repayments, etc.

- Calculation methods: Power prices vary according to the calculation method chosen. Enterprises either assess the average power price on the basis of an operating period or alter their power prices during and after a loan repayment period.

- Policy factors: preferential treatment in enterprise tax rates, loan funding, pricing, etc.

- Market conditions: whether there is a stable and expanding market. Production costs and power prices are closely connected to market size and the amount of market demand.

- Operating mechanisms: whether a competitive mechanism is in place to encourage enterprises to reduce production and service costs at all stages of the business process, from the manufacturing of wind power equipment to the construction and operation of wind farms.

6.2. Determining a target price for wind generated power

6.2.1. The concept of a target power price

The ‘target power price’ is a concept established to suit the purposes of this paper. The ‘target price’ is considered to be the on-grid price of wind-generated power under a series of policies and measures that make it equal to the on-grid price of power from a newly-built coal-fired power plant. So the ‘target price’ is one that would allow wind-generated power to compete equally with power generated using conventional technologies.

The target power price is relative and determined mainly by the price of coal-generated power. It varies over time and across different regions in relation to seasonal and regional variations in the on-grid price of coal-generated power. However, to facilitate research into wind power pricing at a national level, it is important to establish a standard and consistent target power price.

6.2.2. Determining a standard target power price

Determining a standard target power price involves determining the average price of coal-generated power for the whole of China. Here, to make it slightly simpler, only newly built power stations of the 2_300 MW and 2_350 MW types will be used to calculate the average national power price. Since these types of generator sets are among the most common and popular models in China, they are relatively representative.

A. Capital costs of coal-fired power plants

Taking 1997 prices as a reference, the investment required to purchase a domestically manufactured coal-fired power generator set (recommended by the Institute of Power Planning and Design) is roughly as follows:

- The per-unit investment for a newly built 2_300 MW generator set is 4464 Yuan/kW, with total investment costs of around 2.68 billion Yuan.
- The per unit investment for expanding a 2_300 MW generator set is 3795 Yuan/kW, with total investment costs of around 2.28 billion Yuan.
- The per unit investment for a newly built 4_300 MW generator set is 4130 Yuan/kW, with total investment costs of around 4.96 billion Yuan.

Land value, labor costs, raw material prices, and transportation costs vary between different regions. In some places, the investment costs may be a little bit higher than the above figures. In general, however, the price index has basically remained constant or been in decline since 1997, the current investment costs for coal-fired power plants should be basically the same as costs in the years between 1997 and 2000.

Summarizing the investment conditions for coal-fired power plants detailed above, the construction costs per kW for domestic 2_300 MW generator sets can be assumed to be 5000 Yuan, with total investment of 3 billion Yuan. With desulfurization equipment added in, the investment per kW is 5500 Yuan and the total investment 3.3 billion Yuan. The construction costs per kW for imported 2_350 MW generator sets can be assumed to be 5500 Yuan, with total investment of 3.85 billion Yuan; with desulfurization equipment added in, the investment per kW is 6000 Yuan and the total investment is 4.2 billion Yuan. (All these figures include interest paid during plant construction).

At present very few of the power plants in China use desulfurization equipment. One of the models is Huaneng Luohuang Power Plant, which uses the 'wet' desulfurization method with a desulfurization efficiency of about 95 percent. Desulfurization equipment costs and construction expenses for the first generator totaled around 230 million Yuan. Adopting the same methods for the second generator, investment totaled 360 million Yuan, which is equal to a per-unit investment of 500Yuan/kW. Investment in operating expenses for the desulfurization equipment came to 85 million Yuan in 1996, 90 million Yuan in 1997, 101 million Yuan in 1998, 134 million Yuan in 1999 and 140 million Yuan in 2000. (There are over 40 personnel involved in operating the equipment).

The construction period for 2_300 MW and 2_350 MW coal-fired generator sets is being gradually reduced. For a newly constructed power plant, the period between the laying of the cornerstone and the first day of operation of the first generator set rarely lasts more than 24 months, while the second generator set will usually be functioning in less than an additional six months. The total construction period generally lasts about three years so, by the beginning of the fourth year of the plant's existence, two generator sets will be in operation. Investment should ideally be distributed as follows: 20 percent of investment used in the first year, 40 percent used in the second year and 40 percent in the third. It is expected that, on average, 20 percent of investment will come from capital reserves, while the other 80 percent will come from bank loans. It is also assumed that an equal proportion of loaned money and capital funds are invested each year.

Table 6-1 Investment distribution for a 2_300 MW domestically manufactured generator set without desulfurization equipment (unit: Million Yuan)

	Year 1	Year 2	Year 3	Total
Investment Percentage (%)	20	40	40	100
Amount Invested	600	1,200	1,200	3,000
Amount from Capital Funds	120	240	240	600
Amount from Loan	480	960	960	2,400

Table 6-2 Investment distribution for 2 × 300 MW domestically manufactured generator set (with desulfurization equipment) (unit: Million Yuan)

	Year 1	Year 2	Year 3	Total
Investment Percentage (%)	20	40	40	100
Amount Invested	660	1,320	1,320	3,300
Amount from Capital Funds	132	364	264	660
Amount from Loan	528	1,056	1,056	2,640

Table 6-3 Investment distribution for 2 × 350 MW imported generator set (without desulfurization equipment) (unit: Million Yuan)

	Year 1	Year 2	Year 3	Total
Investment Percentage (%)	20	40	40	100
Amount Invested	770	1,540	1540	3,850
Amount from Capital Funds	154	308	308	770
Amount from Loan	616	1,232	1,232	3,080

Table 6-4 Investment distribution for 2 × 350 MW imported generator set (with desulfurization equipment) (unit: Million Yuan)

	Year 1	Year 2	Year 3	Total
Investment Percentage (%)	20	40	40	100
Amount Invested	840	1,680	1,680	4,200
Amount from Capital Funds	168	336	336	840
Amount from Loan	672	1,344	1,344	3,360

The main costs involved in the construction of a coal-fired power plant are equipment purchase, construction work, and installation expenses. Of these, the cost of equipment accounts for about 40 percent of investment, construction work accounts for about 25 percent, installation expenses account for about 18 percent and other miscellaneous expenses for about 17 percent. These percentages vary somewhat between different projects.

B. Basic principles for the calculation of the on-grid power price for newly built coal-fired power plants

The generating costs for power from coal-fired plants generally consist of two main components: financial outlay and production costs for power generation.

Production costs include depreciation costs, fuel costs, maintenance costs, wages and welfare costs, and other similar expenses. Financial outlays include interest and capital repayment on loans, profit and losses on exchange rates during transactions with foreign companies, etc.

The on-grid power price has to cover production costs for power generation, financial outlay, the value-added tax on power generation, the value-added surtax on power generation (specifically urban construction and education surtaxes), income tax, statutory reserve fund contributions, public welfare fund contributions, profits for the repayment fund, and shareholder's profits. The repayment fund is mainly designed to cover depreciation costs, a certain proportion of which are also paid by post-tax profits.

There are two main ways to calculate the power price; calculation in sequence and reverse calculation. Calculating the power price in sequence involves calculating the rate of return on capital funds according to a set power price; while reverse calculation involves working out a power price based on the production costs for power generation, financial outlay, amount of taxation, and the internal rate of return on capital funds. The reverse calculation method involves two types of price: constant and variable. The constant price type consists of numerous trials of sequential calculations, while the variable price type involves calculating power prices for various preceding years, presupposing that shareholders' profits over these years do not include short-term loans.

C. Basic set of data needed for calculation of on-grid power prices

- Expected operating period: 20 years.
- Depreciation period: 15 years.
- Rate of formation of fixed assets: 95 percent.
- Salvage value rate: 5 percent.
- Number of hours that equipment can be used annually: 5500.
- The rate of power consumption within the plant: 6 percent (without desulfurization equipment), 8 percent (with desulfurization equipment).
- The annual interest rate on bank loans: currently it is 6.21 percent (with interest paid quarterly), so the actual annual interest is 6.36 percent.
- Repayment period: 15 years (including the construction period). the repayment method chosen was payment of an equivalent capital sum.
- Maintenance costs: 2.5 percent of total investment.
- Employment needs: 440 employees if run without using desulfurization equipment, 460 if run with desulfurization equipment.
- Average annual wages for employees: at present an average of 15,000 – 38,000 Yuan/Person/Year, with welfare fund contributions of 14 percent of each employee's annual salary. Here the average annual wage is taken to be 20,000 Yuan/Person/Year.
- Cost of raw materials: usually 7–8.5 Yuan/MWh. Here an average value of 8 Yuan/MWh will be used for calculations.
- Other expenses: usually 15–22 Yuan/MWh (including water costs). Here a value of 20 Yuan/MWh (including water costs) will be used for calculations.
- Price of coal: the average price of domestically mined coal in the Eastern part of China is 350 Yuan/ton while in the Northern part of China it is 260 Yuan/ton. The average price of imported coal is U.S.$50/ton so, for these calculations, a standard cost of 300 Yuan/Ton will be used.
- Coal consumption: a value of 320 g/kWh will be used.

- Rate of income tax: 33 percent (with the total amount of profits as a cardinal number).
- Value-added tax: 17 percent. However, after preferential tax rates are taken into account, the value-added tax rate levied on power generation is usually only 8–10 percent. For these calculations a value of 10 percent will be used.
- Urban maintenance and construction surtax: 5 percent of value-added tax.
- Education surtax: 3 percent of value-added tax.
- Statutory reserve fund contributions: 10 percent of profit after tax.
- Public welfare fund contributions: 5 percent of profit after tax.
- The rate of return on the capital fund is calculated to be 12 percent.

1. Results of power price calculations

The results of calculations using this data are shown in Table 6-5.

Table 6-5 Generation costs for coal-fired power plants and on-grid power prices for electricity generated with and without desulfurization equipment (the constant price method was used for these calculations)

		Power generation cost (Yuan/MWh)	On-grid power price (Yuan/MWh)
2_300 MW	Without desulfurization equipment	20.56	33.38
	With desulfurization equipment	21.36	35.99
2_3500 MW	Without desulfurization equipment	21.33	35.19
	With desulfurization equipment	22.13	37.84

Please refer to Tables 6-6, 6-7, 6-8 and 6-9 for more detailed results.

Table 6-6 Power generation costs and the on-grid power price for power from a newly constructed 2 × 300 MW coal-fired power plant

Category	Unit	2 × 300 MW	
		Without desulfurization equipment	With desulfurization equipment
Investment	Million Yuan	3,000	3,300
Capital fund (part of investment)	Million Yuan	600	660
Loans	Million Yuan	2,400	2,640
Volume of power generation	Million MWh	66	66
Rate of power consumption in plant	%	6	6
Volume of power supply	Million MWh	62	61
Production costs for power generation	Million Yuan	12,574	13,004
Depreciation costs	Million Yuan	2,708	2,978
Fuel costs	MillionYuan	6,336	6,336
Maintenance costs	Million Yuan	1,500	1,650
Raw materials costs	Million Yuan	528	528
Wage and welfare expenses	MillionYuan	182	192
Other expenses	Million Yuan	1,320	1,320
Financial outlay	Million Yuan	992	1,091
Total cost of power generation	Million Yuan	13,566	14,095.2
Per unit cost of power generation	Yuan/MWh	206	214
Per unit cost of supplying power to consumers	Yuan/MWh	219	232
On-grid power price	Yuan/MWh	334	360
Sales income	Million Yuan	20,709	21,853
Power generation tax and	Million Yuan	2,237	2,360

Category	Unit	2 × 300 MW	
		Without desulfurization equipment	With desulfurization equipment
surtax			
Sales profit	Million Yuan	4,906	5,398
Income tax	Million Yuan	1,619	1,781
Profit after tax	Million Yuan	3,287	3,617
Statutory reserve fund contributions	Million Yuan	329	362
Public welfare fund contributions	Million Yuan	164	181
Repayment profit	Million Yuan	234	258
Shareholder profit	Million Yuan	2,560	2,817
Internal rate of return on capital fund	%	12	12

Table 6-7 Power generation costs and the on-grid power price for power from a newly constructed 2 × 350 MW coal-fired power plant

Category	Unit	2_350 MW	
		Without desulfurization equipment	With desulfurization equipment
Investment	Million Yuan	3,850	4,200
Capital fund (part of investment)	Million Yuan	770	840
Loans	Million Yuan	3,080	3,360
Volume of power generation	Million MWh	77	77
Rate of power consumption in plant	%	6	6
Volume of power supply	Million MWh	72	71
Production costs for power generation	Million Yuan	15,148	15,648
Depreciation costs	Million Yuan	3,475	3,791
Fuel costs	Million Yuan	7,392	7,392
Maintenance costs	Million Yuan	1,925	2,100

Category	Unit	2_350 MW	
		Without desulfurization equipment	With desulfurization equipment
Raw material costs	Million Yuan	616	616
Wage and welfare expenses	Million Yuan	201	210
Other expenses	Million Yuan	1540	1540
Financial outlay	Million Yuan	1,273	1,389
Total cost of power generation	Million Yuan	16,422	17,037
Per unit cost of power generation	Yuan/Maw	213	221
Per unit cost of supplying power to consumers	Yuan/MWh	227	241
On-grid power price	Yuan/MWh	352	379
Sales income	Million Yuan	25,471	26,802
Power generation tax and surtax	Million Yuan	27,501	2,895
Sales profit	Million Yuan	6,298	6,870
Income tax	Million Yuan	2,078	2,267
Profit after tax	Million Yuan	4,220	4,603
Statutory reserve fund contributions	Million Yuan	422	460
Public welfare fund contributions	Million Yuan	211	230
Repayment profit	Million Yuan	300	328
Shareholder profit	Million Yuan	3,287	3,585
Internal rate of return on capital fund	%	12	12

Table 6-8 The components of the power generation cost for coal-fired power plants (unit: %)

	2_300 MW		2_350 MW	
	Without desulfurization equipment	With desulfurization equipment	Without desulfurization equipment	With desulfurization equipment
Total cost of power generation	100	100	100	100
Production costs for power generation	92.69	92.26	92.25	91.85
Depreciation costs	19.96	21.13	21.16	22.25
Fuel costs	46.70	44.95	45.01	43.39
Maintenance costs	11.06	11.71	11.72	12.33
Raw material costs	3.89	3.75	3.75	3.62
Wage and welfare expenses	1.34	1.36	1.22	1.23
Other expenses	9.37	9.36	9.38	9.04
Financial outlay	7.31	7.74	7.75	8.15

Table 6-9 The components of the on-grid power price for coal-fired power plants (unit: %)

	2_300 MW		2_350 MW	
	Without desulfurization equipment	With desulfurization equipment	Without desulfurization equipment	With desulfurization equipment
On-grid power price	100	100	100	100
Total cost of power generation	65.51	64.50	64.47	63.57
Value-added tax and surtax on power generation	10.80	10.80	10.80	10.80

	2_300 MW		2_350 MW	
	Without desulfurization equipment	**With desulfurization equipment**	**Without desulfurization equipment**	**With desulfurization equipment**
Sales profit	23.69	24.70	24.73	25.63
Income tax	7.82	8.15	8.16	8.46
Profit after tax	15.87	16.55	16.57	17.17
Statutory reserve fund contributions	1.59	1.65	1.66	1.72
Public welfare fund contributions	0.79	0.83	0.83	0.86
Repayment profit	1.13	1.18	1.18	1.22
Shareholder profit	12.36	12.89	12.90	13.38

2. Actual on-grid power price level in various regions

The results displayed above should be regarded as providing a theoretical guide to power prices. In reality, regional differences and the varying performances of different generator sets result in significant differences in on-grid power prices, which range from 0.20 Yuan/kWh to 0.52 Yuan/kWh. Table 6-10 provides further details.

Table 6-10 Average on-grid power prices for newly built coal-fired Power plants in some of China's provinces (data from 2000)

Province	Power price (Yuan/kWh)	Province	Power price (Yuan/kWh)
Shandong	0.34	Hebei	0.29
Xinjiang	0.18	Jiangsu	0.28
Guangdong	0.51	Zhejiang	0.42
Inner Mongolia	0.20	Liaoning	0.30
Qinghai	0.26	Jilin	0.30
		Fujian	0.41

Although the figures presented in the table are only estimates compiled by the project team on the basis of research and interviews, they provide a relatively accurate picture of regional variations in actual on-grid power prices. It is clear that power prices are generally relatively low in coal producing regions, such as Xinjiang, Inner Mongolia, and Qinghai, where power prices lie well below 0.30 Yuan/kWh. In contrast, power prices are noticeably higher in the southeastern coastal regions, which lack their own coal supply, averaging around 0.45 Yuan/kWh. Guangdong prices are even higher, at around 0.50 Yuan/kWh.

3. Brief summary

The above analysis indicates that the theoretical on-grid power price calculated here reflects average national power prices. However, given that the object of these calculations was to provide reference criteria to compare two different power generation methods, it seems appropriate at the current stage of China's coal-fired power development to choose the figures for a coal-fired power generator set without desulfurization equipment. This would set the on-grid power price for undesulfurized coal at 0.35 Yuan/kWh. Therefore, if the on-grid price of wind-generated power can be reduced to around 0.35 Yuan/kWh, then wind power enterprises would be in a position to compete with conventional thermal power enterprises.

6.3. Determining the basic price of wind power

6.3.1. The meaning of 'basic power price'

The term 'basic power price' refers to an on-grid power price when no preferential policies have been taken into account. It assumes that wind power would be operating entirely unprotected in a commercial market. To determine the basic power price correctly, it is important to design a calculation method that not only reflects wind power's current situation, but also takes into account the direction of future developments, so as to provide a scientific foundation for further calculations and analysis.

6.3.2. Base case and set of parameters

The enlargement of both individual wind turbines and wind power plants as a whole has become a noticeable trend in the international development of wind power capacity. For this reason, it is possible to assume that an average eind farm would consist of a large wind farm consisting of 160-170 600kW wind turbine sets and a total capacity of around 100 MW).

To establish the basic parameters for these calculations, the project team visited power plants in Dabancheng, in Xinjiang Province, Zhangbei in Hebei Province, and Cangnan in Zhejiang Province. On the basis of this research, combined with information from the report, 'Estimated Budget for Electricity Projects' issued by the former Ministry of Power, and research data on the actual circumstances of wind power plants at present, we established estimates of the investment needed for the development of current and future wind power plants of over 100 MW capacity in China. For further details please refer to Table 6-11.

Below are listed some of the factors affecting the cost of wind-generated power.

1_ Generator sets. This term is used to refer to wind power generating sets, excluding the tower, whose costs are given below. The per-unit purchasing cost of these sets today has been calculated at 4500 Yuan/kW. The proportion of these sets manufactured domestically is 60 percent, while those using imported parts account for 40 percent or around 1800 Yuan/kW including import tariffs and value-added tax.

2_ Towers for generator sets used in China are made domestically and then transported to the site of a wind power plant. The overall cost for a single tower is estimated at around 700 Yuan/kW.

3_ Construction of a 110kV transformer substation and a power transmission line is estimated to cost around 900Yuan/kW.

4_ Construction of a wind power plant requires the repair or construction of roads to and through a plant. The per-unit cost of road construction is estimated at 400 Yuan/kW.

5_ Construction of a wind power plant involves various other construction projects, such as a central management building, foundations for wind turbine sets, and installation of a transformer. The per-unit share of construction costs for these items is estimated at around 300 Yuan/kW.

6_ Intangible costs and deferred capital costs are estimated as 180 Yuan/kW.

7_ Other miscellaneous expenses are estimated at around 560 Yuan/kW.

8_ Twenty percent of investment in a wind power project comes from capital funds, while the remainder comes from domestic bank loans, with an interest rate of

6.21 percent and a seven-year repayment period.

9_ The rate of import duty is 3 percent, while the value-added tax rate on imports is 17 percent.

Table 6-11 Technological and economic parameters of 100 MW wind power plants

	Domestically manufactured generator set
Unit capacity (kW)	600
Capacity of whole power plant (kW)	100,200
Number of hours that a plant is fully operative annually	2,300
Percent of power generated that is connected to grid	100 %
Price of one wind power generator in Yuan/kW (including tax)	4,500
Import duties, value-added tax, and surtaxes	1.21 %
Cost of Tower framework in Yuan/kW	700
Installation costs for wind power generators and tower frameworks in Yuan/kW	170
Costs of power transmission and transformation projects in Yuan/kW	900
Road construction costs in Yuan/kW	400
Costs of related building work, including foundations for turbines, in Yuan/kW	300
Other miscellaneous costs in Yuan/kW	560
Intangible costs and deferred capital costs in Yuan/kW	180
Operating period for wind power plants, after a one-year construction period, in years	20
Average number of employees required at wind power plant	20
Average annual wage in Yuan	20,000
Maintenance expense ratio (%/year)	1.5
Overhaul fund percentage (%/year)	1.5
Percent of project costs covered by equity investment (%)	20

	Domestically manufactured generator set
Loan interest rate (%)	6.21
Loan repayment period (year)	7
Depreciation rate (%)	8
Depreciation period (year)	12
Amortization method for intangible and deferred capital	Equal amount
Amortization period for intangible and deferred capital (year)	10
Value-added tax rate for wind power plants (%)	17
Income tax rate for wind power plants (%)	33
Internal return ratio on total investment (%)	8

6.3.3. Results of Calculations

Using methods currently popular in the domestic wind power industry, combined with the assumptions above, we have calculated the cost and basic price of wind power below (please refer to Tables 6-12 and 6-13 for further details):

Power generation cost: 0.32 Yuan/kWh (divided equally over 20 years)

Average power price including tax: 0.64 Yuan/kWh (over 20 years)

Average power price not including tax: 0.55 Yuan/kWh (over 20 years)

These power prices are significantly higher than the target power price, for reasons already discussed (see Tables 3-1 and 3-2). The results will be analyzed further to develop an appropriate and effective method to reduce this power price to the target level.

Table 6-12 The costs of various basic programs (Unit: million Yuan)

No.	Item	Ratio	Total	Construction period	Normal running period																			
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	Total cost of power generation		14.6	0	129.7	123.1	116.6	110.0	103.5	96.9	90.3	90.3	90.3	90.3	88.5	88.5	57.7	26.8	26.8	26.8	26.8	26.8	26.8	26.8
1	Depreciation costs	8	7.7	0	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	30.9	0	0	0	0	0	0	0
2	2.1 Maintenance costs		2.4	0	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
	2.2 Overhaul fund		2.4	0	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
3	Wage and welfare expenses		0.11	0	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
4	Insurance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Raw material	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6-12 The costs of various basic programs (Unit: million Yuan)

No.	Item	Ratio	Total	Construction period	Normal running period																			
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	costs																							
6	Foreign bank loans		1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Amortization cost		18.0	0	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	0	0	0	0	0	0	0	0	0	0
8	Interest Expenses		137.8	0	39.4	32.8	26.3	19.7	13.1	6.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Other expenses		50.2	0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	Fixed costs		939.1	0	103.5	96.9	90.4	83.8	77.3	70.7	64.1	64.1	64.1	64.1	62.3	62.3	31.4	0.56	0.56	0.56	0.56	0.56	0.56	0.56
	Variable costs		524.1	0	26.2	26.2	26.2	26.2	26.2	26.2	26.2	26.1	26.2	26.2	26.2	26.2	26.2	26.2	26.2	26.2	26.2	26.2	26.2	26.2
	Total costs		1463.2	0	129.7	123.1	116.6	110.0	103.5	96.9	90.3	90.3	90.3	90.3	88.5	88.5	57.7	26.8	26.8	26.8	26.8	26.8	26.8	26.8
	Of these: operating costs		535.4	0	26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8

Table 6-15 The effect on the price of wind power when generation time and system costs are changed at the same time Unit_Yuan/kWh

Annual generation time (hour) / System cost Per KW_Yuan/kW_	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200
5000	0.279	0.263	0.250	0.237	0.226	0.216	0.206	0.198	0.190	0.182	0.176	0.169	0.164	0.158	0.153	0.148
5500	0.305	0.288	0.273	0.259	0.247	0.236	0.226	0.216	0.207	0.199	0.192	0.185	0.179	0.173	0.167	0.162
6000	0.331	0.313	0.296	0.282	0.268	0.256	0.245	0.235	0.225	0.217	0.209	0.201	0.194	0.188	0.182	0.176
6500	0.357	0.337	0.320	0.304	0.289	0.276	0.264	0.253	0.243	0.234	0.225	0.217	0.209	0.202	0.196	0.190
7000	0.383	0.362	0.343	0.326	0.310	0.296	0.283	0.272	0.261	0.251	0.241	0.233	0.225	0.217	0.210	0.204
7500	0.409	0.387	0.366	0.348	0.331	0.316	0.303	0.290	0.287	0.268	0.258	0.249	0.240	0.232	0.255	0.218
8000	0.436	0.411	0.390	0.370	0.353	0.337	0.322	0.309	0.296	0.285	0.274	0.264	0.255	0.247	0.239	0.231
8500	0.462	0.436	0.413	0.392	0.374	0.357	0.341	0.327	0.314	0.302	0.291	0.280	0.271	0.262	0.253	0.245
9000	0.488	0.461	0.436	0.415	0.395	0.377	0.361	0.345	0.332	0.319	0.307	0.296	0.286	0.276	0.267	0.259
9500	0.514	0.485	0.460	0.437	0.416	0.397	0.380	0.364	0.349	0.336	0.324	0.312	0.301	0.291	0.282	0.273
10000	0.540	0.510	0.483	0.459	0.437	0.417	0.399	0.382	0.367	0.353	0.340	0.328	0.317	0.306	0.296	0.287

Table 6-16 The effect of on the price of wind power when generation time and system costs are changed at the same time Unit_Yuan/kWh

Annual generation time _hour_ / System cost Per KW_Yuan/kW_	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200
5000	0.558	0.527	0.499	0.475	0.452	0.431	0.412	0.395	0.379	0.365	0.351	0.339	0.328	0.316	0.306	0.297
5500	0.612	0.578	0.547	0.520	0.495	0.473	0.452	0.434	0.416	0.400	0.386	0.371	0.359	0.347	0.336	0.325
600	0.665	0.628	0.595	0.565	0.538	0.513	0.492	0.471	0.452	0.435	0.419	0.404	0.390	0.377	0.365	0.353
6500	0.718	0.679	0.642	0.610	0.581	0.555	0.531	0.509	0.488	0.470	0.452	0.437	0.421	0.407	0.395	0.382
7000	0.771	0.729	0.691	0.656	0.625	0.596	0.570	0.547	0.525	0.505	0.486	0.469	0.453	0.437	0.424	0.410
7500	0.825	0.779	0.739	0.701	0.668	0.637	0.610	0.584	0.561	0.540	0.520	0.502	0.484	0.468	0.452	0.439
8000	0.879	0.830	0.786	0.747	0.712	0.679	0.649	0.623	0.598	0.575	0.554	0.534	0.515	0.498	0.482	0.467
8500	0.933	0.881	0.835	0.793	0.154	0.720	0.689	0.660	0.634	0.609	0.587	0.566	0.547	0.528	0.511	0.496
9000	0.985	0.930	0.881	0.838	0.798	0.761	0.729	0.698	0.670	0.645	0.621	0.598	0.578	0.559	0.540	0.524
9500	1.039	0.982	0.930	0.883	0.841	0.803	0.768	0.736	0.707	0.679	0.654	0.631	0.609	0.589	0.570	0.552
10000	1.093	1.031	0.978	0.928	0.884	0.844	0.807	0.774	0.742	0.715	0.688	0.663	0.641	0.620	0.599	0.581

6.4.4. The influence of policy on wind power price

Table 6-17 presents the effects of different incentive policies on wind power price. The findings are discussed below.

- The effect of preferential investment and financing policies on power price.

It is clear that investment and financing policies have a significant impact on power prices. Of all these types of policy, prolonging the repayment period has the most noticeable effect. The State Development Bank has already developed relevant regulations covering loans to wind power farms. If commercial banks follow suit it will greatly encourage the development of the wind power industry.

Table 6-17 The effect of various incentive policies on the generation cost and on-grid price of wind power

No	Policy	Unit cost Yuan/ KWh	On-grid power price Yuan/ kWh	Effect on Power Price (in comparison with the control case)	
				Generation Cost (%)	On-grid power price (%)
0	Control case	0.32	0.64	0	0
1	**Preferential treatment for investment**				

No	Policy	Unit cost Yuan/ KWh	On-grid power price Yuan/ kWh	Effect on Power Price (in comparison with the control case)	
				Generation Cost (%)	On-grid power price (%)
	and financing				
S1.1	1-year interest allowance loan	0.31	0.63	–2.6	–1.6
S1.2	2-year interest allowance loan	0.30	0.62	–5.7	–3.1
S1.3	3-year interest allowance loan	0.29	0.61	–8.9	–4.8
S1.4	Prolonging the repayment period to 10 years	0.33	0.59	4.0	–8.7
S1.5	Prolonging the repayment period to 15 years	0.35	0.51	10.8	–20.6
2	**Preferential treatment for tax**				
S2.1	Exemption from import duties on imported parts for domestically manufactured turbine sets	0.306	0.617	–3.8	–3.9
S2.2	VAT deduction for equipment costs	0.318	0.620	0.0	–3.4
S2.3	VAT deduction for 50% of equipment costs	0.318	0.629	0.0	–2.0
S2.4	Exemption from VAT	0.318	0.541	0.0	–15.7
S2.5	3-year exemption from and 2-year reduction in income tax	0.318	0.604	0.0	–5.9
S2.6	50% deduction in income tax	0.318	0.620	0.0	–3.4
S2.7	Exemption from income tax	0.318	0.566	0.0	–11.0
3	**Combinations of incentives**				
S3.1	3-year interest allowance loan and prolonging the repayment period to 15 years	0.352	0.480	10.8	–25.2
S3.2	Exemption from import duties and reduction in VAT	0.306	0.595	–3.8	–7.3
S3.3	Exemption from import duties and VAT	0.306	0.520	–3.8	–19.0
S3.4	Exemption from VAT and prolonging the repayment period to 15 years	0.352	0.430	10.8	–33.0
S3.5	Exemption from import duties and reductions in income tax and VAT	0.306	0.559	–3.8	–12.9
S3.6	3-year interest allowance loan, prolonging	0.339	0.438	6.5	–31.8

No	Policy	Unit cost Yuan/ KWh	On-grid power price Yuan/ kWh	Effect on Power Price (in comparison with the control case)	
				Generation Cost (%)	On-grid power price (%)
	the repayment period to 15 years, and exemption from import duties				
S3.7	Exemption from VAT and import duties, 3-year exemption, and 2-year reduction in income tax	0.306	0.489	–3.8	–23.8
S3.8	Prolonging the repayment period to 15 years, exemption from import duties, and a reduction in VAT	0.339	0.467	6.5	–27.3
S3.9	3-year interest allowance loan, prolonging the repayment period to 15 years, exemption from import duties, and a reduction in VAT	0.339	0.438	6.5	–31.8
S3.10	Prolonging the repayment period to 15 years, exemption from import duties and VAT, and a 3-year exemption, and 2-year reduction in income tax	0.339	0.414	6.5	–35.5
S3.11	Prolonging the repayment period to 15 years, exemption from import duties, reduction in VAT, 3-year exemption, and 2-year reduction in income tax	0.339	0.467	6.5	–27.3
S3.12	3-year interest allowance loan, prolonging the repayment period to 15 years, exemption from import duties, a reduction in VAT, 3-year exemption, and 2-year reduction in income tax	0.339	0.438	6.5	–31.8
S3.13	3-year interest allowance loan, prolonging the repayment period to 15 years, exemption from import duties, a reduction in VAT, and a 50% reduction in income tax.	0.339	0.438	6.5	–31.8
S3.14	3-year interest allowance loan, prolonging the repayment period to 15 years,	0.339	0.389	6.5	–39.4

No	Policy	Unit cost Yuan/ KWh	On-grid power price Yuan/ kWh	Effect on Power Price (in comparison with the control case)	
				Generation Cost (%)	On-grid power price (%)
	exemption from import duties and VAT, 3-year exemption, and 2-year reduction in income tax				
S3.15	3-year interest allowance loan, prolonging the repayment period to 15 years, 15-year depreciation allowance, exemption from import duties, reduction in VAT, 3-year exemption, and 2-year reduction in income tax	0.339	0.416	6.5	–35.2
S3.16	Investment of 7500Yuan/kW, annual utilization of 2600 hours, prolonging the repayment period to 15 years, exemption from import duties and VAT, a 3-year exemption, and 2-year reduction in income tax	0.285	0.348	–10.5	–45.8
4	**Preferential power price (fully subsidized)**	**0.318**	**0.35**	**0.0**	**–45.5**

- The effect of preferential taxation policies on power prices.

Table 6-17 shows that preferential taxation policies noticeably decrease on-grid power prices. Exemption from value-added tax or income tax has a particularly significant effect, decreasing prices by 15.7 percent and 11.0 percent respectively.

- The effect of combined policies on power prices

Combined policies have a more significant effect on power prices than individual measures. Except for policies 3.2, 3.3, and 3.5, all the combined policies reduce the on-grid price of wind power by more than 20 percent. The most effective policy reduces the on-grid price by 45.8 percent, bringing it down to the target power price.

- The effect of preferential pricing policies

On the basis of the calculations carried out so far, the preferential pricing policy (no. 4 in the chart above) appears to have the greatest effect on power prices and is therefore the policy most likely to provide the greatest stimulus for investment in the wind power industry. Table 6-17 demonstrates that, if a subsidy is provided to pay for the difference between the on-grid price and the target price of wind power, then wind power will be able to compete equally with conventional power generation. This kind of subsidy would greatly encourage investor confidence in the wind power industry.

- In summary:

1) Although different kinds of incentive policies can reduce the on-grid price of wind power to some degree, there are significant differences in the extent of the reductions.

2) Apart from the preferential pricing policy, there is no single policy that has prominent influence. Policies that decrease the on-grid price by less than 5 percent include one-, two- and three-year interest allowance loans, exemptions from import duties, part or full deductions of equipment expenses, and a 50 percent reduction in income tax rates. The other policies (which include prolonging the repayment period to 15 years, and exemptions from value-added tax and income tax) reduce prices by more than 5 percent but less than 21 percent.

3) Combinations of the above policies reduce the on-grid power price significantly, particularly the combination of preferential investment and financing policies, preferential taxation policies, and overall investment cost reductions. These combinations would reduce the on-grid power price to below 0.35 Yuan/kWh. However, practical experience has shown that the greater the number of preferential policies a government introduces, the more difficult their implementation becomes. Therefore, before making a decision as to which policy or policies would be the most effective and useful in practical terms, and to ensure that the final recommendation is a rational and scientific one, it is vital to provide further analysis and comparison of the different options. Table 6-18 provides further information about the effects in real terms of the more powerful incentive policies (those that can reduce on-grid prices by more than 20 percent) to help make further discussion clearer and more productive.

4) The preferential pricing policy appears to be very effective and certainly merits further discussion.

Table 6-18 Powerful Preferential Policies and their Effects

Case	Initial investment (Yuan/kW)	Interest allowance (Year)	Repayment period (Year)	Depreciation period (Year)	Annual utilization hours (hour)	Import duties for wind turbine parts (%)	VAT rate on imports (%)	VAT rate on power sales (%)	Income tax (%)	VAT reducti on fix assets (
Control case	7,900	0	7	13	2,300	3	17	17	33	0
S4.1	7,900	0	7	13	2,300	3	17	17	33	0
S3.16	7,500	0	15	13	2,600	0	0	0	3-year exemption and 2-year deduction	0
S3.14	7900	3	15	13	2,300	0	0	0	3-year exemption and 2-year deduction	0
S3.10	9900	0	15	13	2,300	0	0	0	3-year exemption and 2-year deduction	0
S3.15	7,900	3	15	15	2,300	0	0	17	3-year exemption and 2-year deduction	Exempt (full deducti
S3.4	7,900	0	15	13	2,300	3	17	0	33	0
S3.6	7,900	3	15	13	2,300	0	0	17	33	0
S3.12	7,900	3	15	13	2,300	0	0	17	50% deduction of income tax	3-yea exempt and 2-y deducti
S3.13	7,900	3	15	13	2,300	0	0	17	33	3-yea exempt and 2-y deducti
S3.11	7,900	0	15	13	2,300	0	0	17	3-year exemption and 2-year deduction	Exempt (full deducti
S3.10	7,900	0	15	13	2,300	0	0	0	3-year exemption	0

Case	Initial investment (Yuan/kW)	Interest allowance (Year)	Repayment period (Year)	Depreciation period (Year)	Annual utilization hours (hour)	Import duties for wind turbine parts (%)	VAT rate on imports (%)	VAT rate on power sales (%)	Income tax (%)	VAT reducti on fixe assets (
									and 2-year deduction	
S3.1	7,900	3	15	13	2,300	3	17	17	33	0
S3.7	7,900	0	7	13	2,300	0	0	0	3-year exemption and 2-year deduction	0

-

7. Cost-benefit analysis and evaluation of incentive policies

7.1. Evaluation criteria

(1) With any policy, the government has to be prepared to put money forward before it will receive any benefits or achieve the policy's desired aim. One of the crucial criteria used to judge whether a policy is economically feasible is whether its net present value (NPV) is greater than zero, that is, whether policy incentives to promote the development of the wind power industry today will return a net positive value in the future. A policy may only be economically attractive when NPV ≥ 0. However, it depends how 'value' is defined in any particular case.

(2) Incentive policies are not the ultimate goal. The aim of the policies is to promote the development of wind power, reduce generation costs and on-grid prices, and eventually achieve the commercialization of the industry. So another key criterion when determining the feasibility of a policy is whether it can promote the commercialization of wind power technology effectively, since commercialization is a sign of technological maturity and an economic advantage. From the perspective of a cost-benefit analysis, a policy with NPV ≤ 0 could still be implemented if the incentive it provides is strong enough to promote the development of the wind power industry effectively and lead to long-term economic benefits. On the other hand, a policy with NPV ≥ 0 but with an incentive mechanism that is not strong enough to drive the development of wind power technology and the commercialization of the industry is useless for all practical purposes, and should not be implemented.

Relative costs and benefits of wind power policies

(1) Costs

The extra cost of wind power relative to the cost of coal-fired power is composed of the balance in power generation costs and the cost of incentives.

The **balance in power generation costs,** Cm, is the balance between the average power generation costs for wind power and those for coal-fired power.

The **cost of incentives,** Cp, is the extra expense incurred by the government from funding incentive policies to promote the development of wind power. For an incentive policy that involves giving an interest allowance loan and prolonging the repayment period, the incentive costs will be composed of the cost of the interest allowance and the loss sustained as a result of the delay in repayments.

(2) Benefits

There are four types of benefits from the use of wind power: environmental benefits, Be, tax benefits, Bt, resource benefits, Br, and social benefits, Bs.

Environmental benefits, *Be*

Substituting wind power for coal-fired power reduces pollution significantly. Coal combustion is the main source of power industry pollution. Reducing pollution also leads to a reduction in economic losses, such as damages to human health, buildings, and farm produce caused by pollution.

The main gaseous pollutants produced by coal combustion are: smoke, gaseous oxides of sulfur, nitrogen oxide, carbon dioxide, carbon monoxide, and small quantities of gaseous fluorine and chlorine.

Wastewater is water containing any combination of industrial effluent, chemical effluent, or sanitary waste. In 1999, the average rate of discharge of untreated wastewater at large coal-fired power generators in China was 0.49 $m^3/s•GW$; and only an average 80 percent of water discharged by power stations reached government environmental protection standards. The rate of discharge for wastewater that exceeds safe pollution levels is 0.1 $m^3/s•GW$, or 0.353 kg/kWh.

Clinker—which contains coal ash collected by a coal plant's ash separator—and slag—discharged by its boiler—are the main solid wastes produced by the power industry. If they are not dealt with properly they will also pollute the environment.

Table 7-1 Environmental and Economic Damage Caused by Pollution

Pollutant	Environmental and Economic damage.
Smoke	Damage to human health, crops and livestock.
SO_x[2]	Damage to human health; corrosion of building materials (stone, bricks etc) and metals; deforestation caused by acid rain.
NO_x	Damage to human health; acidification of ground water and soil.
CO_2	'Greenhouse' effect, in which excess carbon dioxide traps heat from the sun, thus increasing surface and atmospheric temperatures.
Wastewater	Flooding, contamination of ground water and soil.
Clinker	Damage to human health, crops and livestock.

Measuring the effects of pollutants on the external environment is a complex task, and the results are often controversial. In order to achieve the most scientific and least controversial results possible, this report uses the pollution charges set by the Chinese Environmental Protection Department as a standard measurement of the economic effects of pollution. Over the last few years, the relevant departments at the Environmental Protection Department, in consultation with various experts have been carrying out a long-term and wide-ranging program of research into the above-mentioned pollutants and their effect on the environment. They have drawn up a relatively comprehensive set of pollution charges (detailed in the report *Reform of the Mechanism for Setting Charges for the Emission of Pollutants in China*), which are far more scientific and realistic than the set of *Standard Charges for the Discharge of Pollutants* which is currently in effect, as they reflect the actual cost of environmental damage in China much more closely. The figures below are taken from the new report.

Table 7-2 Standard charges for the emission of air pollutants

Pollutant	Charge by degree of pollution (Yuan/kg)	
	High	Standard
SO_x	1.26	0.52
NO_x	2.00	0.83
Smoke	0.55	0.35

Source: *Reform of the Mechanism for Setting Charges for the Emission of Pollutants in China*

Table 7-3 Standard charges for the emission of wastewater

	Charge for Wastewater Emissions (Yuan/t)
General industries	0.20
Special industries	2.00
Sanitary waste	0.38

Source: *Reform of the Mechanism for Setting Charges for the Emission of Pollutants in China*

Table 7-4 Standard charges for clinker pollution

Type of Waste	Unit charge (Yuan/t)

[2] The 'x' indicates the existence of more than one oxide, for example, sulfur monoxide, SO, and sulfur dioxide, SO_2.

Refined clinker	25.00
Coal dust	30.00
Slag	25.00
Coal stone	5.00
Tail clinker	15.00
Other waste	25.00

Source: *Reform of the Mechanism for Setting Charges for the Emission of Pollutants in China*

Rising carbon dioxide emissions, leading to rising levels of the gas in the atmosphere, is a global problem, the most serious consequence of which potentially is climate change. Global warming may have an enormous impact on humans and on the environment, although its effects are quite difficult to quantify. They include (1) the displacement of agricultural production, as climate changes make traditional crops unviable in many areas, as incidences of diseases among crops and livestock increase, and as soil moisture changes, (2) an increase in extreme weather events, such as typhoons, and (3) rising sea levels.

In this paper, the economic benefits of reducing carbon dioxide emissions through the use of wind power are calculated in the following way: the reduction of carbon dioxide emissions is treated as a resource in a fictitious market, and then the equilibrium price in the market is taken as the value of the economic benefit of reducing carbon dioxide emissions. Dr. Yang Yanlin of Qinghua University in his dissertation *An Investigation into the Price Theory for Reducing Carbon Dioxide Emissions* calculated the equilibrium price to be 208.5 Yuan/tons of carbon using data on marginal reductions in emissions cost from the Massachussetts Institute of Technology. This figure is considered to represent an economic benefit gained from reducing CO_2 emissions.

Tax benefits, Bt

Wind farms provide more tax revenue to the government than coal-fired power generators, which is mainly reflected in VAT payments. Under the present rules governing VAT on production, there are no discounts for wind farms and, as a result, VAT accounts for 17 percent of the on-grid price of wind-generated power. However, in coal-fired power plants VAT accounts for only 8–10 percent of the on-grid price of power, as coal-fired power plants get VAT discounts based on fuel consumption. Wind power is therefore contributing more tax revenue on a kWh basis than coal fired generation.

Resource benefits, Br

Wind power has the obvious advantage of economizing on coal and water usage. Replacing coal-fired power with wind power slows the resource exhaustion process since wind power largely consumes renewable wind resources. At present the average level of coal consumption in typical coal-fired power plants is 0.32 kg/kWh, and the conservation tax is 0.3—5 Yuan/ton of coal. But the current conservation tax imposed in China is only designed to regulate the differences between coal mines with different quality coal, and does not take into account national rights to resources, the sustainability of the levels of exploitation of coal resources, or the environmental cost of coal consumption. Estimates drawn up by Chinese experts after a comprehensive evaluation of the issues involved suggest that the conservation tax on coal should be 14 Yuan/t (*An Analysis of Policy Design for Renewable Resource Technology and an Evaluation of its Influence on Society, Resource Consumption and the Environment*).

Coal-fired power plants also consume copious amounts of water, exacerbating water shortages in several regions. The average water consumption level for large thermal power plants was 1.42–1.56 m^3/s GW in the 1980s, 0.91 m^3/s GW in the 1990s and 0.8 m^3/s GW in 1999. Water consumption for several typical large thermal power plants (of unit generator capacity over 300MW) is given below.

Table 7-5 Water consumption levels at large thermal power plants in 1999

Power Plant Name	Location (Province)	Generator Capacity (MW)	Water Consumption Levels (m/s GW)
Laite	Inner Mongolia	2_330	0.920
Shihuang	Shangdong	4_300	0.697
Pucheng	Shanxi	2_330	0.700
Xibaipo	Hebei	2_300	0.894
Shouyang	Henan	2_300	1.020
Pengcheng	Jiangsu	2_300	0.860

Source: investigation results.

Water is a valuable resource essential for human survival and for industrial and agricultural production. China has limited water resources, with per capita amounts that are only one-quarter of the world's average. In addition, existing water resources are distributed quite unevenly around China, so that water shortages are quite serious in most cities in the north of China. The price of water for industrial use varies significantly between different cities, as shown in the following table.

Table 7-6 Price of Water for Industrial Use Across China

City	Province	Price of water for industrial use (Yuan/t)
Hohhot	Inner Mongolia	1.00
Qingdao	Shandong	1.35
Xian	Shanxi	1.86
Shijiazhuang	Hebei	1.65
Luoyang	Henan	1.00
Nanjing	Jiangsu	1.25
Beijing	Beijing Autonomous City	2.40
Guangzhou	Guangdong	1.17
Urumqi	Xinjiang	0.80
Average		1.44

Resource: investigation results.

These water prices do not include any kind of compensation costs for unsustainable consumption. Coal-fired power plants do not have to pay any kind of environmental tariff, even though they consume vast amounts of water. Replacing coal-fired power with wind power obviously conserves significant amounts of water, but it is difficult to calculate sustainability costs for water so, in this paper, the benefits gained from water conservation can only be analyzed qualitatively rather than quantitatively.

Social benefits, Bs

The development of the wind power industry will fuel the development of related manufacturing and installation industries leading to new economic development opportunities, and creating new jobs. However, it is difficult to separate the effects of wind power development on different sectors of society, or to measure those effects quantitatively. In addition, it is relatively difficult to collect the basic data required for this kind of analysis. The theories and methods for measuring social benefit quantitatively also are not yet fully developed. For these reasons, the present paper analyzes the social benefits of wind power development qualitatively rather than quantitatively.

7.2. Methods of evaluating incentive policies

According to current economic evaluation criteria there are two indicators frequently used to determine whether an incentive policy is economically viable or not: net present value and the cost-benefit ratio.

1) Net present value (NPV) is calculated by subtracting the current value of total costs from the current value of total benefits, taking into account a period of time over which the costs and benefits apply.

$$\text{NPV} = \sum \{[B_e(t) + B_t(t) + B_r(t) + B_s(t)] - [C_m(t) + C_p(t)]\}(1+r)^{-t}$$

where B and C are benefits and costs, respectively, as defined above, r is a discounting rate (conventionally, around 5 percent per annum) and t is a time-period. The expression within the curly brackets describes total value as the sum of benefits minus costs, and the expression $(1+r)^{-t}$, adjusts this value according to the rate at which the future is valued against the present. A higher value of r represents the greater discounting of future value.

Incentive policies are considered economically viable when NPV ≥ 0 and unviable when NPV < 0.

.

2) Cost-benefit ratio: This figure is calculated by dividing the total current value of future benefits by the total current value of future costs.

$$\text{Cost-benefit ratio} = \sum [B_e(t) + B_t(t) + B_r(t) + B_s(t)](1+r)^{-t} / \sum \ [C_m(t) + C_p(t)](1+r)^{-t}$$

The incentive policy is economically viable when the cost-benefit ratio is greater than or equal to one and unviable when the ratio is less than one. Policies with larger cost-benefit ratios are considered more economically beneficial than those with smaller ratios.

7.3. Cost-benefit analysis for policy S1.3 (3-year interest allowance loan)

Although a large number of potential incentive policies were outlined above, only those that may actually be implemented in the future will be subjected to a cost-benefit analysis below. The first cost-benefit analysis will be for policy S1.3 (3-year interest allowance loan).

1) Cost

- **The Balance in Power Generation Costs** Cm

Comparison between a wind farm and a coal-fired power plant:

Balance in generation costs per unit	0.1041(Yuan/kWh)
Balance in annual power generation costs	24 (million Yuan)
Balance in total power generation costs (present value)	218 (million Yuan)

Where:

Balance of generation costs per unit (Yuan/kWh) = generation costs per unit for wind power (Yuan/kWh) – generation costs per unit for coal-fired power (Yuan/kWh)

Balance of annual power generation costs (million Yuan) = balance of generation costs per unit (Yuan/kWh) _ quantity of power generated annually (230.46 million kWh)

Balance of the total power generation costs (present value) (million Yuan) =

$$\sum_{j=2}^{21}\left(\frac{balanceofannualpowergenertation\cos ts}{(1+8\%)^{j}}\right)$$

where j is a year of operation. Year 1 is a construction period; hence, j ranges from 2 to 21.
8% is the government assisted discount rate.

- **The Cost of the Incentive** Cp

The cost of this incentive is the interest allowances from banks implementing policy S1.3. These costs are displayed in the table below:

Table 7-7 Interest allowances from relevant banks

	Construction period	Normal running period				Accumulated (present value)
Year	1	2	3	4	5-21	
Interest allowance (Million Yuan)	0	39.37	32.81	26.25	0	79.10

2) Benefits

- **Environmental benefits**

Using the actual rate of emission of pollutants from coal-fired power plants and the charges suggested in *Reform of the Mechanism for Setting Charges for the Emission of Pollutants in China*, the environmental benefits of replacing coal-fired power with wind power can be calculated in financial terms.

Table 7-8 Benefits from the reduction in smoke emissions

Coal consumption (kgce/kWh)	0.32
Quantity of smoke emitted by coal (kg/kgce)	0.017
Smoke emissions from coal-fired power generation (kg/kWh)	0.005
Charges for smoke emission (Yuan/kg)	0.55
Annual benefits from the reduction of smoke emissions (million Yuan)	0.69
Total benefits from the reduction of smoke emissions (million Yuan, present value)	6.3

Table 7-9 Benefits from the reduction in SO_2 emissions

Coal consumption (kgce/kWh)	0.32
Quantity of SO_2 emitted by coal (kg-SO_2/kgce)	0.022
SO_2 emissions from coal-fired power generation (Kg/kWh)	0.007
Charges for SO_2 emissions (Yuan/kg)	1.26
Annual benefits from the reduction of SO_2 emissions (million Yuan)	2.04
Total benefits from the reduction of SO_2 emissions (million Yuan, present value)	18.6

Table 7-10 Benefits from the reduction in NO_x emissions

Coal consumption (kgce/kWh)	0.32
Quantity of NO_x emitted by coal (kg- NO_x /kgce)	0.01
NO_x emissions from coal-fired power generation (kg/kWh)	0.003
Charges for NO_x emissions (Yuan/kg)	2.00
Annual benefits from the reduction of NO_x emissions (million Yuan)	1.5
Total benefits from the reduction of NO_x emissions (million Yuan, present value) 10^4	13.4

Table 7-11 Benefits from the reduction in CO_2 emissions

Coal consumption (kgce/kWh)	0.32
Quantity of CO_2 emitted by coal (kg- CO_2/kgce)	0.73
CO_2 emissions from coal-fired power generation (kg/kWh)	0.23
Charges for CO_2 emissions (Yuan/kg)	0.21
Annual benefits from the reduction in CO_2 emissions (million Yuan)	11.2
Total benefits from the reduction in CO_2 emissions (million Yuan, present value)	101.5

Table 7-12 Benefits from the reduction in clinker emissions

Annual coal consumption (t/year)	103,000
Clinker emissions from coal-fired power generation (t/year)	29,000
Charges for clinker emissions (Yuan/t)	25
Annual benefits from the reduction in clinker emissions (million Yuan)	0.72
Total benefits from the reduction in clinker emissions (million Yuan, present value)	6.6

Table 7-13 Benefits from the reduction in wastewater emissions

Wastewater emissions from coal fired power generation (kg/kWh)	0.35
Annual wastewater emission (t/year)	81,000
Charges for wastewater emissions (Yuan/t)	0.20
Annual benefits from the reduction in wastewater emissions (Yuan)	16,300
Total benefits from the reduction in wastewater emissions (Yuan, present value)	148,000

Table 7-14 Total environmental benefits (million Yuan)

Benefits from reducing smoke emissions	6.3
Benefits from reducing SO_2 emissions	18.6
Benefits from reducing NO_x emissions	13.4
Benefits from reducing CO_2 emissions	101.5
Benefits from reducing clinker emissions	6.6
Benefits from reducing wastewater emissions	0.15
Total environmental benefits	146.5

- **Tax benefits** Bt

Wind power contributes more in VAT payments than coal-fired power.

Table 7-15 Actual VAT payments by wind power and coal-fired power plants

	Wind power	Coal-fired power
Average VAT (during operating period) (Yuan/kWh)	0.109	0.035

The table above demonstrates that the VAT payment per unit from wind farms is triple that from coal-fired power plants. The relative VAT benefits of wind power are shown in the table below.

Table 7-16 VAT benefits of wind farms as compared with coal-fired power plants

VAT balance per unit power (Yuan/kWh)	0.0687

Annual VAT balance (million Yuan)	15.84
Total VAT balance during operating period (million Yuan, present value)	144.03

Where:

VAT balance per unit power (Yuan/kWh) = VAT payment per unit wind power (Yuan/kWh) – VAT payment per unit coal-fired power (Yuan/kWh)

Annual VAT balance (million Yuan) = VAT balance per unit power (Yuan/kWh) _ annual power generation quantities (230.46 kWh)

The total VAT balance during operating period (Yuan, present value).

$$= \sum_{j=2}^{21} \left(\frac{AnnualVATbalance}{(1+8\%)^{j}} \right)$$

- **Resource benefits**

Table 7-17 Benefits from conservation of coal supplies

Annual coal consumption (t/year)	103287.39
Benefits of coal conservation (Yuan/t)	14.0
Annual benefits from coal conservation (million Yuan)	1.45
Total benefits from coal conservation (million Yuan, present value)	13.15

3) Cost-benefit analysis

The results of the full cost-benefit analysis for policy S1.3 are shown in Table 7-18.

Table 7-18 Cost-benefit analysis for policy S1.3

Wind farm compared with coal-fired power plant			
Costs (million Yuan)		Benefits (million Yuan)	
Balance of power generation costs	218.10	Environmental benefits	146.48
Incentive costs	79.09	Tax benefits	144.03
		Resource benefits	13.15
Total costs	297.19	Total benefits	303.66
Conclusions	Net profits (million Yuan)	6.5	
	Cost-Benefit Ratio (Total benefits / Total costs)	**1.02**	

7.4. Cost-benefit analysis for policy S1.5 (Prolonging the repayment period to 15 years)

1) **Cost**

- **The Balance in Power generation Costs** *Cm*

Comparison between a wind farm and a coal-fired power plant (values can be calculated using Tables 6-7 and 6-11).

Balance in generation costs per unit of power	0.1383 (Yuan/kWh)
Annual balance in generation costs	31.87 (million Yuan)
Total balance in generation costs (present value)	289.75 (million Yuan)

- **Costs of the Incentive** *Cp*

The costs of this incentive policy are the losses sustained as a result of the delay in repayments that are a result of prolonging the repayment period.

Table 7-19 Cash flow at the bank giving the loan (control case) (unit: Million Yuan)

	Construction period	Normal Repayment Period						Accumulated (present value)
	1	2	3	4	5	6	7	
Cash outflow	634.0							634.0
Cash inflow	0	145.0	138.5	131.9	125.4	118.8	112.2	

Cash inflow (present value)	0	134.3	118.7	104.7	92.1	80.9	70.7	601.4

Table 7-20 Cash flow at the bank making the loan (for policy S1.5)
(unit: Million Yuan)

_	Construction period	Repayment Period														Accumulated (present value)
_	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Cash outflow	634.0	_	_	_	_	_	_	_	_	_	_	_	_	_	_	634.0
Cash inflow	0	84.7	81.9	79.0	76.2	73.4	70.6	67.8	65.0	62.2	59.4	56.5	53.7	50.9	48.1	_
Cash inflow (present value)	0	78.9	70.2	62.7	56.0	50.0	44.5	39.6	35.1	31.1	27.5	24.3	21.3	18.7	16.4	575.7

So the costs of the incentive policy S1.5 are:
601.4-575.7 = 25.73 x10^6 (Yuan)

BENEFITS

- **Environmental benefits (the same as for policy S1.3)**
- **Tax benefits**

A wind farm compared with a coal-fired power plant:	
VAT balance per unit power (Yuan/kWh)	0.05
Annual VAT balance (Yuan)	1187.88
The total VAT balance during operating period (Yuan, present value)	10,798.90

(Where all figures are calculated as for policy S1.3)

- **Resource benefits (the same as for policy S1.3)**

3) Cost-benefit analysis for policy S1.5.

Table 7-21 Cost-benefit analysis for policy S1.5

For a wind farm compared with a coal-fired power plant			
Costs (million Yuan)		Benefits (million Yuan)	
Balance of power generation costs	289.75	Environmental benefits	146.8
Cost of Incentives	25.76	Tax benefits	107.99
		Resource benefits	13.15
Total costs	315.51	Total benefits	267.61
Conclusions	Net profit (Yuan)	-4790	
	Benefit-Cost Ratio (Total benefits / Total costs)	**0.85**	

7.5. Cost-benefit analysis for policy S2.2 (exemption from VAT)

The basic parameters for a policy of complete exemption from VAT, as shown in Tables 6-7 and 6-16, are given in the table below.

Table 7-22 Basic parameters for policy S2.2

	Wind farm	Coal-fired power plant
Average on-grid power price (Yuan/kWh)	0.61	0.35
Average power generation cost (Yuan/kWh)	0.32	0.21
VAT (Yuan/kWh)	0.07	0.04

1) Costs

- **The balance of power generation costs** Cm

A wind farm compared with a coal-fired power plant over their whole operating period:

Balance of generation costs per unit of power	0.10 (Yuan/kWh)
Annual balance of generation costs	24 (million Yuan)
Total balance of generation costs (present value)	218 (million Yuan)

- **Costs of the Incentive** Cp

The cost of this incentive policy is the total amount of VAT owed annually by each wind farm.

Total Annual VAT discount =(Annual depreciation / 1.17) _17%

Table 7-23 VAT discounts (unit: Million Yuan)

	Normal running period													Accumulated (present value)
	2	3	4	5	6	7	8	9	10	11	12	13	14	
Depreciation	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	30.9	
VAT discounts	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	4.5	
VAT discounts (present value)	7.7	7.1	6.6	6.1	5.7	5.2	4.9	4.5	4.2	3.9	3.6	3.3	1.5	64.1

2) BENEFITS

- **Environmental benefits (the same as for policy S1.3)**
- **Tax benefits**

A Wind farm compared with a coal-fired power plant:	
VAT balance per unit power (Yuan/kWh)	0.0332
Annual VAT balance (million Yuan)	7.7
Total VAT balance over the operating period (million Yuan, present value)	69.6

- **Resource benefits (the same as for policy S1.3)**

2) **Cost-benefit analysis for policy S2.2.**

Table 7-24 cost-benefit analysis for policy S2.2

A wind farm compared with a coal-fired power plant			
Costs (million Yuan)		Benefits (million Yuan)	
Balance of power generation costs	143.7	Environmental benefits	146.5
Cost of the incentive	64.1	Tax benefits	69.6
		Resource benefits	13.1
Total costs	207.9	Total benefits	229.2
Conclusions	Net profits (million Yuan)	-53.0	
	Benefit-Cost Ratio (Total benefits / Total costs)	**0.81**	

7.6. Cost-benefit analysis for policy S3.1 (3-year interest allowance loan and prolonging the repayment period to 15 years)

1) **Costs**

- **The balance of power generation costs (the same as for policy S1.5)** Cm

- **The cost of the incentives** Cp

The total costs of the incentives (million Yuan, present value)	113.3
The cost of the interest allowance (million Yuan, present value)	87.6
The cost of losses incurred as a result of the delay in repayment (million Yuan, present value)	25.8

2) Benefits

- **Environmental benefits (the same as for policy S1.3)**

- **Tax benefits**

For a wind farm compared with a coal-fired power plant:	
VAT balance per unit power (Yuan/kWh)	0.05
Annual VAT balance (million Yuan)	10.7
Total VAT balance over the operating period (million Yuan, present value)	97.2

- **Resource benefits (the same as for policy S1.3)**

2) Cost-benefit analysis for policy S3.1.

Table 7-25 Cost-benefit analysis for policy S3.1

A wind farm compared with a coal-fired power plant			
Costs (million Yuan)		Benefits (millionYuan)	
Balance of power generation costs	289.8	Environmental benefits	146.5
Cost of incentives	113.3	Tax benefits	97.2
		Resource benefits	13.1
Total costs	403.2	Total benefits	256.9
Conclusions	Net profits (million Yuan)	-146.2	
	Benefit-Cost Ratio (Total benefits / Total costs)	**0.64**	

7.7. Cost-benefit analysis for policy S3.9 (3-year interest allowance, prolonging the repayment period to 15 years, exemption from import duties, reduction in VAT)

1) Cost

- **The Balance of Power Generation Costs** Cm

For a wind farm compared with a coal-fired power plant over their operating periods:

Balance of generation costs per unit of power	0.1248 (Yuan/kWh)
Annual balance of generation costs	28.8 (million Yuan)
Total balance of generation costs (present value)	261.5 (Million Yuan)

- **Cost of the Incentives** Cp

There are a variety of different incentive costs for this policy, as it consists of so many different incentive mechanisms. Of these costs, the total accumulated reduction in VAT is 61.53 million Yuan, as shown in Table 7-26:

Table 7-26 Cost of VAT reduction (unit: million Yuan)

	Normal running period													Accumulated (present value)
_	2	3	4	5	6	7	8	9	10	11	12	13	14	
Depreciation	59.24	59.24	59.24	59.24	59.24	59.24	59.24	59.24	59.24	59.24	59.24	59.24	29.62	
VAT reduction	8.61	8.61	8.61	8.61	8.61	8.61	8.61	8.61	8.61	8.61	8.61	8.61	4.30	
VAT reduction (present value)	7.38	6.83	6.33	5.86	5.42	5.02	4.65	4.31	3.99	3.69	3.42	3.17	1.47	61.53

The total cost of all the incentive mechanisms:

The total cost of the incentives (million Yuan, present value)	205.57

The cost of the interest allowance (million Yuan, present value)	87.58
Cost of loss incurred as a result of delay in repayments (million Yuan, present value)	25.76
Cost of exemption from import duties (million Yuan, present value)	30.70
Cost of VAT reduction (million Yuan, present value)	61.53

2) Benefits

- **Environmental benefits (the same as for policy S1.3)**

- **Tax benefits**

For a wind farm compared with a coal-fired power plant:	
VAT balance per unit power (Yuan/kWh)	0.008
Annual VAT balance (million Yuan)	1.85
Total VAT balance over the operating period (million Yuan, present value)	16.78

- **Resource benefits (the same as for policy S1.3)**

3) Cost-benefit analysis for policy S3.9

Table 7-27 cost-benefit analysis for policy S3.9

Wind farms compared with coal-fired power plants			
Costs (million Yuan)		Benefits (million Yuan)	
Balance of power generation costs	187.09	Environmental benefits	146.48
Costs of incentives	205.57	Tax benefits	16.78
		Resource benefits	13.15
Total costs	392.67	Total benefits	176.41
Conclusions	Net profits (million Yuan)	-290.64	
	Benefit-Cost ratio (Total benefits / total costs)	**0.38**	

7.8. Cost-benefit analysis for policy S3.12 (3-year interest allowance, prolonging the repayment period to 15 years, exemption from import duties, reduction in VAT, 2-year deduction and 3-year exemption from income tax)

The total cost of the incentives consists of the following components:

Total incentive costs (million Yuan, present value)	229.29
Interest allowance (million Yuan, present value)	87.58
Cost of losses incurred as a result of delay in repayment (million Yuan, present value)	25.76
Cost of exemption from import duties (million Yuan, present value)	30.70
Cost of VAT reduction (million Yuan, present value)	61.53
Cost of income tax exemption and reduction – for further detail see chart below (million Yuan, present value)	23.72

Table 7-28 Cost-benefit analysis for policy S3.12

Wind farms compared with coal-fired power plants			
Costs (million Yuan)		Benefits (million Yuan)	
Balance of power generation costs	261.47	Environmental benefits	146.48
Cost of incentive measures	229.29	Tax benefits	16.78
		Resource benefits	13.15
Total costs	490.76	Total benefits	176.41
Conclusions	Net profits (million Yuan)	-314.35	
	Benefit-cost ratio (Total benefits / Total costs)	**0.36**	

Table 7-29 Costs of the 2-year reduction and 3-year exemption from income tax (unit: million Yuan)

	Normal running period					Accumulated (present value)
	2	3	4	5	6	
Profits	29.75	29.75	29.75	0.048	2.75	
Calculated income tax payment	9.82	9.82	9.82	0.02	0.91	
Actual income tax payment	0	0	0	0.008	0.45	
Total income tax reduction	98.12	98.12	9.82	0.008	0.45	
Total income tax deduction (present value)	8.42	7.79	7.22	0.005	0.29	23.72

7.9. Cost-benefit analysis for policy S3.14 (3-year interest allowance, prolonging the repayment period to 15 years, exemption from import duties and VAT, 2-year deduction, and 3-year exemption from income tax)

1) Costs

- **Balance of Power Generation Costs** Cm

For a wind farm compared with a coal-fired power plant over their operating period:

Balance of generation costs per unit of power	0.1248 (Yuan/kWh)
Annual balance of generation costs	28.76 (million Yuan)
Total balance generation costs (present value)	261.47 (million Yuan)

- **Incentive costs** Cp

Total cost of incentives (million Yuan, present value)	302.35
Cost of interest allowance (million Yuan, present value)	87.58
Costs incurred as a result of the delay in repayments (million Yuan, present value)	25.76
Cost of exemption from import duties (million Yuan, present value) 10^4	30.70
Cost of exemption from VAT (million Yuan, present value)	138.49
Cost of reduction and exemption from income tax (million Yuan, present value)	19.82

2) Benefits

- **Environmental benefits (the same as for policy S1.3)**
- **Tax benefits (These are negative as the wind farm is exempt from VAT)**

Wind farms compared with coal-fired power plants:	
VAT balance per unit of power (Yuan/kWh)	-0.0352
Annual VAT balance (million Yuan)	-8.11
Total VAT balance over the operating period (million Yuan, present value)	-73.73

- **Resource benefits (the same as for policy S1.3)**

3) Cost-benefit analysis for policy S3.14

Table 7-30 Cost-benefit analysis for policy S3.14

For wind farms compared with coal-fired power plants			
Costs (million Yuan)		Benefits (million Yuan)	
Balance of power generation costs	261.47	Environmental benefits	146.48
Cost of incentive measures	302.35	Tax benefits	-73.73
		Resource benefits	13.15
Total costs	563.81	Total benefits	85.90
Conclusions	Net profits (million Yuan)	-477.91	
	Benefit-Cost ratio (Total benefits / Total costs)	**0.29**	

7.10. Cost-benefit analysis for policy S3.16 (3-year interest allowance, prolonging the repayment period to 15 years, exemption from import duties and VAT, 2-year reduction and 3-year exemption from income tax, maintaining an investment level of under 7500 Yuan/kW, and increasing annual power generation hours to 2600).

1) Cost

- **Balance of Power Generation Costs** Cm

A wind farm compared with a coal-fired power plant over their operating period:

Balance of generation cost per unit of power (Yuan/kWh)	0.0713
Annual balance of generation costs (million Yuan)	18.57
Total balance of generation costs (million Yuan, present value)	168.81

- **Costs of Incentive Measures** Cp

Table 7-31 Cost of VAT exemption (unit: million Yuan)

VAT exemption per unit of power (Yuan/kWh)	0.0591
Annual cost of VAT exemption (million Yuan)	15.40
Total cost of VAT exemption (million Yuan, present value)	139.97

Table 7-32 Costs of income tax deduction and exemption (unit: million Yuan)

	Normal running period					Accumulated (present value)
	2	3	4	5	6	
Profits	0.27	2.82	5.38	7.94	10.50	
Calculated income tax repayment	0.087	0.93	1.78	2.62	3.46	
Actual income tax payment	0	0	0	1.31	1.73	
Total income tax deduction	0.087	0.93	1.781	1.31	1.73	
Total income tax deduction (present value)	0.07	0.74	1.31	0.89	1.09	4.10

The total costs of the incentive measures are as follows:

Total cost of incentive measures (million Yuan, present value)	302.35
Cost of interest allowance loan (million Yuan, present value)	87.58
Cost of loss resulting from delay in repayments (million Yuan, present value)	25.76
Cost of exemption from import duties (million Yuan, present value)	30.70
Cost of VAT exemption (million Yuan, present value)	139.97
Cost of income tax exemption and reduction (million Yuan, present value)	4.10

2) Benefits

- **Environmental benefits**

Table 7-33 The total environmental benefits of policy S3.16 (unit: million Yuan)

Benefits from the reduction in smoke emissions	7.09
Benefits from the reduction in SO_2 emissions	21.01
Benefits from the reduction in NO_x emissions	15.16
Benefits from the reduction in CO_2 emissions	114.72
Benefits from the reduction in clinker emissions	6.59
Benefits from the reduction in wastewater emissions	0.17
The total environmental benefits	165.58

- **Tax benefits (These are negative as wind farms are VAT exempt under this policy)**

Wind farms compared with coal-fired power plants:	
VAT balance per unit of power (Yuan/kWh)	-0.04
Annual VAT balance (million Yuan)	-9.17
Total VAT balance over the operating period (million Yuan, present value)	-83.34

- **Resource benefits**

Table 7-34 Benefits from conservation of coal resources

Annual coal consumption (t/year)	116759.66
Benefits of coal resource conservation (Yuan/t)	14
Annual benefits from conservation of coal resources (million Yuan)	1.63
Total benefits from conservation of coal resources (million Yuan, present value)	14.86

3) Cost-benefit analysis for policy S3.16

Table 7-35 Cost-benefit analysis for policy S3.16

For wind farms compared with coal-fired power plants			
Costs (million Yuan)		Benefits (million Yuan)	
Balance of power generation costs	168.80	Environmental benefits	165.58
Costs of incentive measures	288.12	Tax benefits	-83.34
		Resource benefits	14.86
Total costs	456/92	Total benefits	97.10
Conclusions	Net profits (million Yuan)	-359.82	
	Benefit-Cost ratio (Total benefits / Total costs)	**0.21**	

7.11. Cost-benefit analysis of the preferential pricing policy (S4.1)

1) Costs

- **Balance of Power Generation Costs** Cm

  These are 2182 million Yuan, the same as for the control case.

- **Cost of the Incentive Measure** Cp

Table 7-36 Cost of the Incentive for policy S4.1

Price of wind power (Yuan/kWh)	Price of coal-fired power (Yuan/kWh)

0.6420	0.3519
Price subsidy per unit of power = price of wind power minus price of coal-fired power = 0.2901 Yuan/kWh.	
Annual subsidy = 0.2901 Yuan/kWh (price subsidy per unit power) _ 230.46 million kWh (total annual generation) = 66.86 million Yuan	
Total subsidy over the operating period (present value) = 607.78 million Yuan	

2) Benefits

- **Environmental benefits (the same as for policy S1.3)**
- **Tax benefits**

For wind farms compared with coal-fired power plants:	
VAT balance per unit of power (Yuan/kWh)	0.02
Annual VAT balance (million Yuan)	5.68
Total VAT balance over the operating period (million Yuan, present value)	51.61

- **Resource benefits (the same as for policy S1.3)**

3) Cost-benefit analysis for policy S4.1.

Table 7-37 Cost-benefit analysis for policy S4.1

Wind farms compared with coal-fired power plants			
Costs (million Yuan)		Benefits (million Yuan)	
Balance of power generation costs	218.20	Environmental benefits	146.48
Cost of incentive measure	607.78	Tax benefits	51.61
	_	Resource benefits	13.15
Total costs	825.98	Total benefits	211.23
Conclusions	**Net profits (million Yuan)**	**-614.75**	
	Benefit-Cost Ratio (Total benefits / Total costs)	**0.26**	

7.12. Summary of all incentive policies based on the cost-benefit analyses above

Table 7-38 Results of the Cost-benefit analyses of all the policies

Policy _	**Incentives**	**On-grid Power Price (Yuan/kWh)**	**Degree of Price Reduction (%)**	**Wind farms compared with Coal-fired power plants**	
				Net profits (million Yuan)	**Benefit to Cost ratio**
S1.3	3-year interest allowance loan	0.6114	4.77%	6.47	1.02
S1.5	Prolonging the repayment period to 15 years	0.5102	20.53%	-47.90	0.85
S2.2	VAT exemption	0.6141	4.35%	-53.04	0.81
S3.1	3-year interest allowance loan and prolonging the repayment period to 15 years	0.4799	25.25%	-146.24	0.64
S3.9	3-year interest allowance loan, prolonging the repayment period to 15 years, exemption from import duties and reduction in VAT	0.4351	32.23%	-290.64	0.38
S3.12	3-year interest allowance loan, prolonging the repayment period to 15 years, exemption from import duty, reduction in VAT, reduction in income tax	0.4351	32.23%	-314.35	0.36

Policy –	Incentives	On-grid Power Price (Yuan/kWh)	Degree of Price Reduction (%)	Wind farms compared with Coal-fired power plants	
				Net profits (million Yuan)	Benefit to Cost ratio
S3.14	3-year interest allowance loan, prolonging the repayment period to 15 years, exemption from import duties and VAT, 2-year deduction and 3-year exemption from income tax	0.3888	39.44%	-477.91	0.15
S3.16	Prolonging the repayment period to 15 years, exemption from import duties and VAT, 2-year deduction and 3-year exemption from income tax, keeping investment levels below 7500Yuan/kW, increasing annual power generation time to 2600 hours	0.3477	45.84%	-359.82	0.21
S4.1	Subsidy of wind power prices so that they are equal to coal-fired power prices	0.3519	45.19%	-614.75	0.26

Conclusions from the Analyses above

Table 7-38 clearly shows from the perspective of a cost-benefit analysis, that single incentive policies are the most economically feasible of the options outlined above. However, the incentives they offer are not strong enough to push the price of wind power down to a level that would lead to a significant expansion of the wind power market. Instead, policies that combine a variety of incentives, particularly S3.16 and S4.1, are powerful enough to reduce wind power prices significantly and promote the rapid growth of the wind power market. In addition, the cost-benefit analysis above does not include the social benefits of each policy, so the results in Table 7-38 cannot be considered a complete evaluation, as the multiple incentive policies are likely to become more economically feasible when social benefits are quantified and taken into account. In addition, although economic feasibility is an important criterion when making policy decisions, it is not the only one. So it is essential that a thorough assessment of all the other qualities of incentive policies is made before any decisions are reached about which policies are appropriate for promoting the development of wind power.

8. Analysis and Evaluation of the Role of Incentive Policies in Promoting the Commercialization of Wind Power

The previous chapter analyzed the economic viability of various incentive policies, Conclusion is that to implement such incentive policies, we have to pay high price. Especially when these are high-incentive policies, the cost estimate may be substantially higher. The following section will examine the long-term impact of such policies on the wind power technology industry, in order to provide a scientific basis for their implementation. The basic principle of the analysis is that, like all other industries, the development of the wind power technology industry will follow a sigmoid (S-shaped) “learning” curve. The larger the scale of production, the lower the cost. When the cost goes down, the product will gain a larger market share and in turn, when the market is well exploited, it will create a demand for a larger scale of production, which will then reduce the cost further. Eventually this process should lead to the complete commercialization of the wind power technology industry.

8.1. The stages of development of wind power technology

Both in China and internationally, wind power technology will almost certainly have to pass through several stages before it develops into a fully commercialized industry. These stages are anticipated to be:

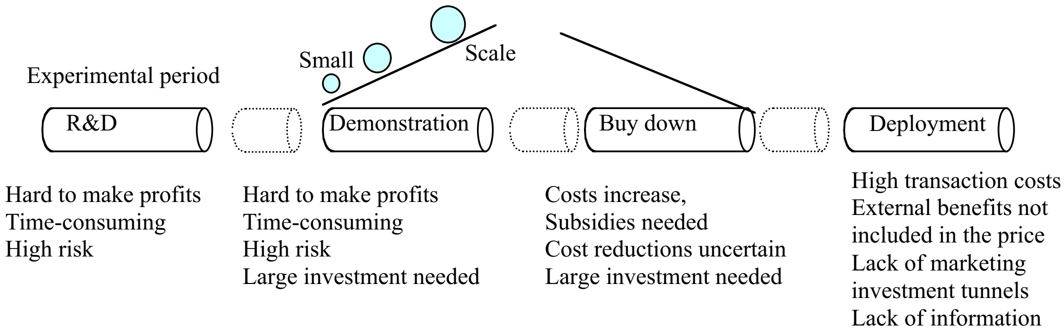
1) A research and development (R&D) stage
2) A technological demonstration and commercial demonstration stage
3) A buy-down stage
4) A deployment stage

The actual development process is obviously more complex than these four clear steps would suggest. The different stages are integrated with each other and overlap constantly. For example, throughout the whole process, R&D activities continue, helping to shorten production cycles through the application of new technologies to new products. Similarly, the experience gained in the demonstration and deployment stages can be fed back into the process to develop further targets for the research department, and more sophisticated goals for those responsible for applied technological development. During these stages, the development process is affected by a combination of technological factors and investment and organizational factors. Capital investment involves co-operation and networking between public capital and private capital. At other stages of development, co-operation is necessary for the success of joint research projects, joint technological demonstrations and public subsidies.

Figure 8.1 The growth of new technologies

Large

Moderate Costs fall as scale expands



Different sorts of technologies suit different locations and economic environments, so it is important to fully integrate technology with investment and system design. If the development of technology is to follow the stages detailed above, co-ordination and co-operation between the public sector and private sector is vital. This should help ensure that (1) both public and private investment can be used effectively at every step in the development of a new technology, (2) the cost of transactions and the risk for the public or private sector are minimized, (3) competition mechanisms are used effectively to reduce costs, (4) technological performance is improved, and (5) openness is maximized and costs are minimized.

In different stages of this development, special factors must be considered and emphasized. These are discussed below.

8.1.1. R&D stage

During this stage, capital investment from the private sector is far lower than from the public sector. Private investors cannot be sure of a return on their investment, since the R&D stage takes a long time, risks are high and returns are low. Any additional benefits gained from dealing with air pollution problems do not translate into financial gains. So the public sector needs to play a major role in the development of new energy-generating technologies, in attracting the participation of the private sector, and in encouraging the commercial application of new energy technologies.

8.1.2. Demonstration stage

In the demonstration stage, one or more energy technology manufacturer becomes involved, and the scale of equipment used for production is increased in order to test the potential commercial viability of a new technology. A variety of obstacles to private sector investment at the demonstration stage still exist, as, although the returns period is shorter than at the R&D stage, it is still long in private-sector terms. Also the risks are still high, as innovations in the energy technology field may make little or no profit. Even commercial-scale pilot projects find it difficult for their products to compete with conventional energy products supplied by manufacturers with low profit margins. In addition, a large amount of capital (which is always hard to come by) is needed during this stage.

8.1.3. Buy-down stage

When a technology has passed the demonstration stage and appears to be commercially viable, it still has a long way to go. During this next period (the commercialization phase) it is vital to ensure that a series of generating systems operating on the same scale are set up to increase the scale of equipment manufacturing, thus reducing the costs of equipment manufacturing, system installation, operation and maintenance to a competitive level. In order to enable a new technology to compete effectively in the market, the difference between its actual price and that of established technologies has to be subsidized. The process of absorbing this difference is called buy-down. To drive costs down fast, some industries, such as the semi-conductor industry, adopt a pricing strategy called ‘forward pricing’, in which manufacturers sell their products at prices lower than their production costs, so that they can enlarge their market share rapidly, and thus reduce costs substantially. In these industries, the forward price can usually be a little higher than the price of the older products, as a new product often is substantially more powerful than an older one. Even though the sale price of new products may initially be lower than their production costs, a manufacturer’s losses are usually both small and short-term.

The situation is somewhat different in the energy industry, where many obstacles to the adoption of a forward price strategy exist. The price of electric power generated using conventional energy resources is relatively low, because environmental damage is not taken into account when calculating costs. Electric power generated from renewable resources has both environmental and social benefits but, in the electric power market, the financial value of these two benefits is not measured. Electric power generated using new energy technologies does not provide customers with inherently better service than the electricity generated using conventional energy resources, so it is impossible in the current financial environment for renewable energy to compete with conventional energy at a relatively higher price. Moreover, since the environmental benefits of renewable energy affect the whole population, it is appropriate that the public sector should pay for the price difference. Governmental organizations could pay for buy-down, or the government could set up a system to allow the public to pay for the extra expense directly. In addition, since it is assumed that new energy technologies are beneficial not only to the local environment, but also to the global environment, international organizations such as the International Environment Fund (IEF) have a responsibility to contribute something towards the buy-down costs.

8.1.4. Deployment stage

When a new energy technology has successfully gone through the R&D, demonstration, and buy-down stages, it is ready to be deployed. Even though the technology is now considered viable and competitive from an economic point of view, for deployment to be successful, various important problems must be dealt with, which include:

1) Assuring potential purchasers that a new technology or new product is viable, profitable, and low-risk.
2) Carrying out a sufficient number of feasibility studies.
3) Setting up a series of supply and marketing systems.
4) Supplying investment and finance assistance to prospective customers, especially when the technology is competitive in the operation stage, but requires large capital investment in the construction stage.
5) Reducing transaction costs for new small-scale technologies. These costs are comparatively high because most producers have not yet set up supply, marketing, and service networks.

Over the past couple of decades, in countries recognized as centers of excellence for new generation technology, wind power has passed through the R&D and demonstration stages, and most of the work in the buy-down stage has also been completed. At present, wind power in these countries is reaching the end of the buy-down stage and is in transition to the deployment stage. Wind power technology in these countries is nearing commercialization. If a few more obstacles related to investment, development systems, and gaining access to relevant markets can be overcome, then wind power and conventional energy will be able to compete on equal terms in the same market.

In the course of the development of wind power technology, other countries have discovered from experience that the government should design integrated policies to harness market drivers and research into new technology for the industry's development. Creating a 'research push' means that the government needs to make more effort to finance new technology and attract the participation of relevant enterprises in order to accelerate its transition from the research and development stage to the demonstration stage, as well as to accelerate the pace of the demonstration stage itself. In this way, a 'research push' can speed up reductions in the cost of a new technology. Market drive is also an important factor, as growth in market demand enables producers of new technologies and new products to reduce costs through experience. However, if no large- or medium-scale enterprises become involved, then it will be impossible to fully apply any new technology, and thus difficult to learn from new advances.

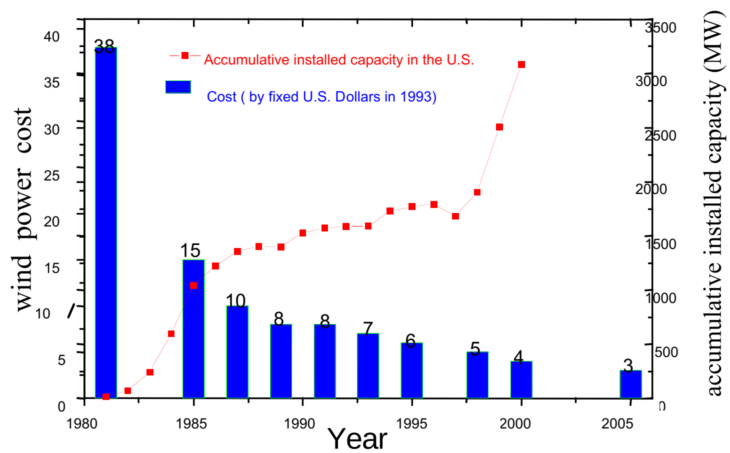
The buy-down stage is the most difficult stage that a new technology must go through. During this period, the scale of production should grow steadily but the scale of capital investment, public expenditure, and financial allowances will probably increase as well, which may lead to some uncertainty about the whether wind costs can ultimately be decreased. Also, the benefits of the incentive policies may be offset if a heavy social burden has been imposed to support them. This can adversely affect efforts to reduce costs by enlarging the market share. For example, serious fluctuations in progress during the buy-down stage were observed during the development of the wind power technology industry in the United States. It is important that China designs measures to control the scale and pace of development, and chooses long-term, durable incentive policies. This way, the reduction of costs will be accelerated, and the commercialization of new technology will be achieved in the shortest time and at the lowest possible cost.

8.2. The relationship between the scale of the wind power industry and production costs

The history of wind power development both in China and abroad has shown that there is a close relationship between the scale of wind power generation and the cost of the power produced. In order to explore this relationship further, this section will take the U.S. as an example and analyze how the reduction in wind power cost and price corresponded to increases in the scale of the wind power industry.

In the 1980s, the U.S. wind power industry went through a period of rapid growth. Total installed capacity soared from 10 MW in 1980 to 1500 MW by 1990, while the generation cost dropped from 38 ¢/kWh to 8 ¢/kWh. During the 1990s, the pace of installation of new wind power generator sets slowed dramatically, and the rate at which costs decreased slowed down correspondingly, reaching 5 ¢/kWh by 1998. Between 1994 and 1997, the total installed capacity remained more or less constant at around 1700 MW, but rapid growth began again in 1998, increasing the total installed capacity to 2500 MW by the end of 1999. The generation cost had correspondingly fallen to 4 ¢/kWh.

\Figure 8-2 The trends for the accumulative installed capacity and economic cost reduction in the U.S. (1981-2000)



Source: The American wind energy association (AWEA)

At present, the costs of wind power and of conventionally-generated power lie within the same range at least at some wind sites with robust wind energy resources, as shown in Table 8-1. The data in the table are taken from *The Report on the Status of Energy Technology*, issued by the California Energy Commission (CEC, ETSR 1996). The cost of electric power generated using natural gas has risen, so the mean price over its operation period is a little higher than the figures show in Table 7-1. In January 2001, the cost of natural gas reached a high range of 15–25 ¢/kWh.

Table 8-1 A comparison of the generation costs for various different power generation methods (drawn up by the California Energy Commission, 1996)

Energy Resource	Average Cost (¢/kWh)
Coal	4.8–5.5
Natural gas	3.9–4.4
Water	5.1–11.3
Organic materials	5.8–11.6
Nuclear	11.1–14.5
Wind power (excluding production tax credit)	4.0–6.0
Wind power (including production tax credit)	3.3–5.3

Notes: 1) The federal production tax credit (PTC) is a policy adopted by the U.S. government to give preferential tax rates to wind power. The PTC is one of the provisions of the *Energy Policy Act* implemented in 1992. Under its provisions, newly-built wind farms enjoy allowances of 1.5 ¢/kWh for their first 10 years of operation. The PTC was originally due to expire on June 30, 1999, but in 1999 the U.S. government decided to prolong the deadline to December 31, 2001. Then in 2002, the PTC was extended for another two years, so it is currently slated to expire on January 1, 2003.

2) The power generation costs in the table are given from the invariable dollar value in 1993.

8.3. Requirements for reducing the cost of wind power

China has been very successful in the manufacture and use of small-scale domestic wind power generators, but the development of large-scale, on-grid wind power capacity has not yet reached the commercial stage. If the technology continues to develop at a sufficient pace and scale over the next few years, the price of wind power will decrease steadily, subject to three requirements.

1) Increase the scale of the market. To a large extent, increased market demand is a result of increased exposure to wind power technology because of rising numbers of installed generator sets. The economies of scale are a result of increases in the scale of individual projects as well as increases in the scale of the manufacturing of wind turbine sets.
2) Introduce a competition mechanism. Open competition should be introduced into the manufacture of equipment and the construction and operation of wind-farms, so that those involved are motivated to reduce the costs of their products and services independently.
3) Manufacture equipment domestically. The domestic manufacture of wind power generator sets could help reduce costs by taking advantage of the skill China has developed in the manufacture of electricity generation equipment.

Two basic requirements exist to reduce the price of wind power. One is market drive, which helps to maintain appropriate levels of demand; the other is the relevant technological and competitive factors that help to speed up cost reductions. When the cost of wind power is higher than conventionally generated power, market demand may be encouraged by government policies. Incentive policies encourage the public to use renewable energy and thereby ensure market demand. Technological advances, domestically and internationally, enable generation costs to be reduced. In China, such advances depend on research and development of key technologies. Competition encourages the participants in this industry to reduce their costs and maximize their profits through the improvement of their management and technology.

To date, China has accumulated considerable experience in the areas of wind-farm construction and the manufacture of large-scale wind power generator sets. The next steps in the industry's development should include the scaling up of individual projects and of the whole industry, an increase in the construction of wind farms and the manufacture of wind-energy equipment in order to reach economies of scale. At present, China is preparing to adopt a competition mechanism known as 'chartered bidding rights'—or a "concession" approach—in order to diversify and commercialize capital investment in wind farms. Many wind farms have already installed domestically manufactured wind power generator sets, and it is estimated that after about 3 years of demonstration and assessment, mass-production of domestic wind power generator sets will begin.

So the requirements for a significant reduction in both the costs and price of wind power can be met only if the government is willing to draw up effective policies and implement and administer them properly. The price of wind power should decrease substantially after several years of development, and its competitive ability will be greatly enhanced.

8.4. Cost reduction expectations for wind power in China

Chinese wind power needs to go through a buy-down process to accelerate the reduction of its cost to a level acceptable for commercialization. The buy-down process follows a learning curve, as discussed above. This section will present a calculation of the expected learning curve for the development of Chinese wind power, based on general trends in the industry both in China and abroad. The learning curve will then be used to predict future trends in the cost of wind power.

The basic assumption underlying the following calculation is that the cost (price) of wind power in China will decrease when cumulative installed capacity increases. This trend can be described by the following mathematical formula:

$$L = A + BN^{-\beta} \qquad (1)$$

where

L is the long-term marginal cost (or price)

A is the lowest possible cost (or price)

B is the difference between the initial cost and the final cost

N is the cumulative installed wind power capacity.

_ is an offset factor.

8.4.1. Determining initial scale and initial cost

By the end of 2000, the total installed on-grid capacity of wind power in China was 344 MW. As of 2001, 98 percent of wind power generator sets are imported, since domestically manufactured generator sets are still in the technological demonstration stage. Two or three more years will be needed for domestically manufactured equipment to enter the market on a significant scale, so it is not likely that the cost of wind power can be reduced by a large margin within a short period. As a consequence, 344 MW (rounded up to 350 MW for convenience) will be chosen as the value for the initial scale.

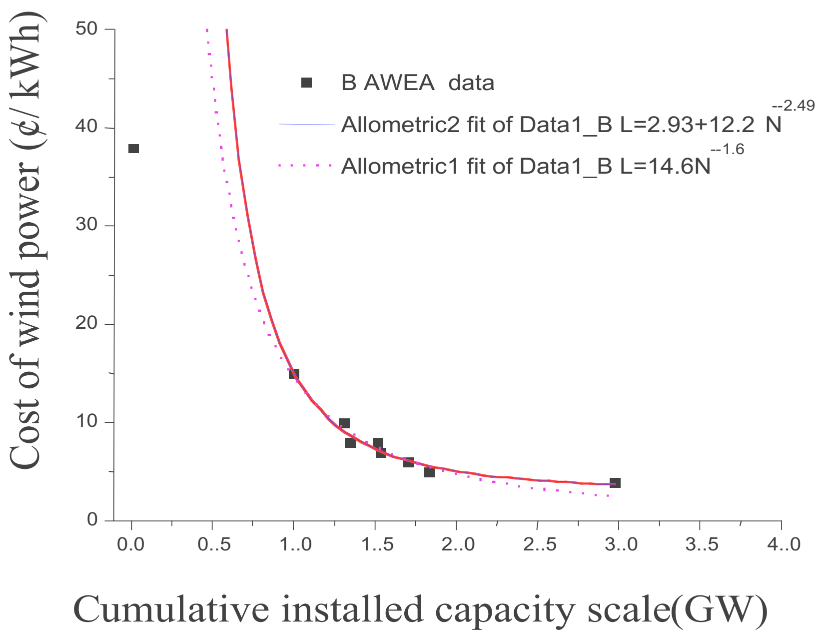
The real costs of an enterprise are usually invisible, but are reflected in the price, which changes in response to variations in cost. In the learning curve, the coordinates representing variations in cost can be calculated by combining a reasonable profit and the rate of tax. According to recently issued regulations governing the power industry, the on-grid power price should be based on the average power price over the whole operating cycle of a generating set. In accordance with these regulations, for a wind farm with a domestically manufactured 100 MW capacity of generation set, the mean power price would be 0.64 Yuan/kWh (0.55 Yuan/kWh excluding taxes) over its 20 years of operation. We have determined the starting point for the learning curve at 350MW, 0.55Yuan/kWh.

8.4.2. Predicting the lowest possible cost of wind power

As Table 8-1 showed, in the U.S., the cost of wind power has declined to almost the same level as the cost of power generated using conventional energy resources, such as natural gas and coal. According to the latest data issued by *Wind Energy Week* (2001—6–9), the contract price for power generated by a newly-built wind farm located on the border between Washington State and Oregon is 2.5 ¢/kWh (which includes 1.5 ¢/kWh of PTC allowances. Otherwise, the price would be 4 cents/kwh). Thus, it is likely that the buy-down stage in the U.S. is drawing to an end, although subsidy policies may be maintained for a long time, not only to attract more investment, but also to ensure greater use of new wind power technologies, ultimately reducing costs and enhancing the competitive strength of wind power. If the environmental and social benefits of wind power technologies are taken into account, wind power will soon be economically preferable to conventional generation, especially in areas with abundant wind resources.

To predict the lowest possible cost of wind power in China, we should study the cost profiles of various wind power technologies in the U.S. Figure 7-2 showed that, as the cumulative installed capacity in the U.S. increased, the cost of wind power generation declined steadily. Despite the slow rate of the reduction in costs between 1990 and 1997, the corresponding increases in scale were still governed by the relationship in the learning curve. If cumulative installed capacity were assumed to have reached around 1000 MW by 1985, a cost of 15 ¢/kWh could be taken as the starting point of the learning curve for the development of the U.S. wind power industry. The curve, shown below in Figure 8-3, is plotted according to formula (1) above ($L = A + BN^{-\beta}$). The preliminary results are as follows:

Figure 8-3 The learning curve for the reduction of the cost of wind power in the U.S.



The learning rate for U.S. wind power is 33 percent, which means that when the cumulative installed capacity doubles, the cost is reduced to 67 percent. In reality, when the cost reaches a certain level, the learning rate decreases too, yet it won't decrease steadily. Once wind power reaches a certain cost, it is unlikely that the cost can be reduced any further (this figure is calculated using formula (1)); when the scale of wind power generation increases, the cost will gradually approach the lowest limit, and the learning rate will decrease accordingly.

$$L = 2.93 + 12.2N^{-2.49} \qquad (2)$$

Formula (2) above can be used to calculate the value of the lowest potential wind power cost, which for the U.S. wind power industry is about 2.9 ¢/kWh. This is about 73 percent of the current cost of wind power and the cost of power generated from conventional sources, both of which lie at around 4¢ per kWh.

In China, at present, the marginal on-grid power price for electric power generated using conventional energy resources (mainly coal) is around 0.35–0.45 Yuan/kWh. So the on-grid power price can be taken to be roughly 0.35 Yuan/kWh, or 0.30 Yuan/kWh if taxes are not included. To continue with the necessary calculations, several assumptions must be made. The first of these is that the marginal on-grid power price will remain constant at around 0.30 Yuan/kWh over the duration of the period of analysis (20 years, for example). The second assumption is that if the price of wind power is reduced to 0.30 Yuan/kWh, which is about the same as the current wind power price in the U.S., then it will be assumed that the target price for commercialization has been reached. The third assumption is that the ratio between the lowest possible cost for wind power and the commercial power price of wind power will be the same in China as in the U.S., which is the 73 percent estimated above. Given these assumptions, the final price of wind power in China is estimated at around 0.22 Yuan/kWh.

8.4.3. Determining the offset factor

The value of the learning rate for most manufacturing industries is 20 percent (Argote & Epple, 1990) so, when the cumulative scale of the industry doubles, costs are reduced by 20 percent. The statistical average of the learning rates for all kinds of energy technology industries is 17 percent, according to analysis carried out by Alan McDonald (2001). However, according to research carried out by Bernd Kummel (1999) the learning rate for wind power technology in the U.S. is 33 percent, while in Denmark it is 28 percent. Statistical data relating to the development of wind power in China is lacking, so the value of the learning rate for China's wind power technology industry will have to be calculated in a different way. This will involve first defining an initial value for the learning rate (assumed here to be 35 percent), and then testing the validity of the assumption by comparing the value to the learning rates for other industries.

Once the learning rate has been determined, the offset factor can be calculated using the following formula:

(3)

$$\text{The Learning Rate} = 1 - \frac{L_2 - A}{L_1 - A} = 1 - 2^{(-\beta)} \qquad (3)$$

If the learning rate is 30%, then _= 0.515.

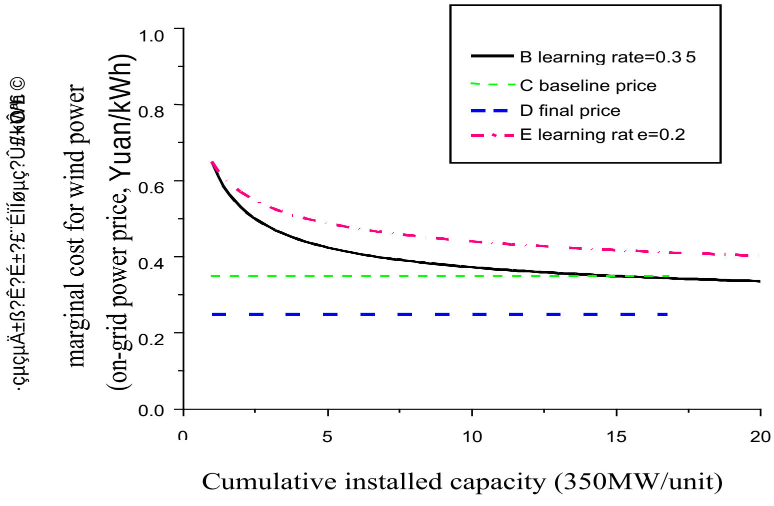
8.4.4. The learning curve for Chinese wind power

According to the previous section, the learning curve for wind power in China can be calculated according to the following formula:

$$L = 0.22 + 0.33_{N}^{-0.515} \qquad (4)$$

The curve is plotted in Figure 8-4.

Figure 8-4 The predicted learning curve of the wind power industry in China



If formula (4), above, is used to calculate various values for the price of wind power relative to the growing scale of the industry, then the learning rate for the industry would be as follows in Table 8-2.

Table 8-2 The rate of reduction in the cost of wind power

(assuming a learning rate of 35 percent)

Cumulative scale (scale unit)	Cost (Yuan)	The rate of reduction of cost (%)
1	0.55	
2	0.44	20
4	0.36	18
8	0.31	14
16	0.28	10
32	0.26	7

Table 8-2 shows that the rate of reduction in the price of wind power conforms with the rate of reduction for other energy technologies and other manufacturing industries. This not only shows that the learning curve for wind power coincides with the learning curves of other industries, but that the learning rate chosen above obeys the rules of development governing other technologies in China.

8.5. The growth in industry scale and investment needed to achieve the commercialization of wind power technology

To accelerate the reduction of the cost of wind power and to give wind power a competitive edge against conventional power, the total installed wind power capacity must be increased. The balance between the cost of wind power generation and conventional power generation is currently covered by government subsidies. So how large must the scale of the industry be, and how much public funds must be invested before wind power can compete with the conventional power generation industry? This section will attempt to answer these questions.

8.5.1. Scale of growth necessary for the commercialization of wind power in China

The figure for cumulative installed capacity when the price of wind power on the learning curve reaches 0.30 Yuan/kWh (0.35 Yuan/kWh if taxes are included) is the capacity needed for the commercialization of wind power in China. The cumulative installed capacity turns out to be 10 scale units, with each unit equivalent to 350MW. In other words, the commercialization capacity is around 3500 MW in total.

8.5.2. Additional social input required for the commercialization of wind power in China

To analyze the total social input needed during the buy-down stage, the following assumptions are made:

1) The operating period for each wind power project is 20 years (excluding one year of construction).
2) The price for each wind power project is the average price over its whole operating period, and this price remains constant over those 20 years.
3) The price of wind power is assumed to be 0.30 Yuan/kWh.
4) The social expenditure per kWh is the difference between the power price given by the learning curve (actual cost) and the price of electricity in the power market. The time span for the calculation of social costs is the whole operating period.
5) It is assumed that wind generators will be in operation for an average of 2,300 hours per year.
6) The market price of wind power is assumed to be 0.55 Yuan/kWh, at the point where the industry has an initial capacity of 350 MW.

It is also necessary to define several parameters before a formula to calculate the total social cost of commercializing wind power can be derived.

When the scale is x, the social expenditure per year can be calculated using the formula below:

$$\begin{aligned} T_y(x) &= hx_1\left[\int_1^x \left(L(x)-P_g\right)dx + (P_1-P_g)\right] \\ &= hx_1\left\{\frac{B}{1-b}\left(x^{1-b}-1\right)+B-(P_g-A)x\right\} \end{aligned} \qquad (5)$$

Where:

$T_y(x)$ = the annual social cost. As the cumulative installed capacity increases, the annual social cost also increases, as shown in Figure 8-5

h = Hours of operation with full power per year

x_1 = Unit of installed capacity scale, here 350MW

_ = Offset factor

P_g = The reference cost or price

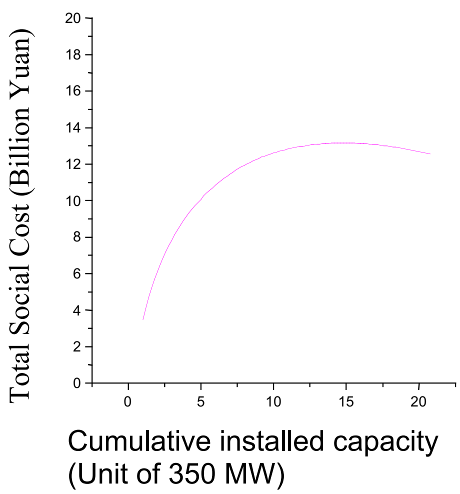
P_1 = The cost at the starting point of the learning curve

A = The lowest limit for the wind power price or cost

B = Difference between initial cost and final floor cost.

Figure 8-5 (below) shows that the annual social cost reaches a maximum level of about 626 million Yuan when the cumulative installed capacity reaches 10 scale units, which is the capacity required for commercialization. Therefore, the social costs reach a maximum only when the target wind power price is reached. As installed capacity rises above the commercialization threshold, social costs theoretically will decline and, eventually, become economic benefits.

Figure 8.5



8.6. Conclusions

1) Chinese wind power can compete with the electricity generated using conventional energy resources when supported by effective incentive policies.
2) To achieve the aim of the incentive policies, the scale of the industry must be increased so that cumulative installed capacity is greater than 3,500 MW.
3) To achieve the aim of reducing wind power prices to a commercialization target, social

investment of about 12.5 billion Yuan in total will be needed. If it is assumed that the buy-down process will continue for another 10 years, and the operating period for each project is 20 years, then the accumulative costs will be spread over 30 years, with an annual outlay of around 0.417 billion Yuan.

9. Comprehensive Comparison and Discussion of Policies

The analysis above demonstrates that although stronger incentive policies promote the commercialization of the wind power industry, the effectiveness of incentive policies is closely related to their cost. However, before reaching any decisions about the suitability of different policies, it is important to take into consideration any problems that might arise during the process of their implementation. The following table lists the potential problems of the various policies discussed in this paper.

Table 9-1 Comprehensive comparison of different policies

Policy Type and Content	Comparison of Benefits and Costs	Function to Promote Commercialization	Potential Barriers
1. Full subsidy of the difference between wind power costs and conventional power costs (S4) Costs shared by the whole of society in the form of an increase in the price of electricity (S4.1)	Negative benefits, and a benefit-to-cost ratio of 0.26	The policy is effective, and would help decrease wind power prices significantly.	The increase in the price of power over the commercialization period would be an average of 0.5 Yuan/MWh per year, which would be affordable. In addition few government departments would be involved, which would facilitate implementation.
1.1 Government subsidies (Prolonging the repayment period to 15 years, exemption from import duties and VAT, 3-year deduction and 2-year exemption from income tax, and a subsidy funded by the pollution charge) (S4.2)	Negative benefits, and a benefit-to-cost ratio of 0.26	The policy is effective, and would help decrease wind power prices significantly.	The policy would be implemented by the government, and would mean that annual tax revenue would be reduced by 0.49 billion Yuan. A variety of departments would be affected, making it difficult to collect the necessary funds, and the policy is likely to meet with resistance from local governments.
2 Combination Policies 2.1 Three-year interest allowance loan and	Negative benefit, and a benefit-to-cost ratio of 0.64	The effect of this policy would be limited, as a large difference would remain between actual	It would involve few government departments, but still require a significant

Policy Type and Content	Comparison of Benefits and Costs	Function to Promote Commercialization	Potential Barriers
prolonging of the repayment period to 15 years (S3.1)		power price and the price needed for commercialization.	amount of public money, which could lead to difficulties in obtaining the necessary capital.
2.2 Exemption from import duties and income tax, and a reduction in VAT (S3.5)	Negative benefit, and a benefit-to-cost ratio of 0.60	The effect of this policy would be limited, as a large difference would still remain between actual power price, and the price needed for commercialization.	It would involve a lot of government departments, and would be likely to meet resistance from local governments.
2.3 Three-year interest allowance loan, prolonging of the repayment period to 15 years, exemption from import duties and VAT, 2-year deduction and 3-year exemption from income tax (S3.14)	Negative benefits, and a benefit-to-cost ratio of 0.15	The effect of this policy would be limited, as a large difference would remain between actual power price and the price needed for commercialization. A subsidy would be needed to cover the price difference.	It would involve a variety of banking and revenue departments, but still require the allocation of special government capital. It would probably meet with resistance from local governments.
2.4 Prolonging of the repayment period to 15 years, exemption from import duties and VAT, 2-year deduction and 3-year exemption from income tax, keeping investment levels below 7,500 Yuan/kW, increasing annual power generation time to 2,600 hours (S3.16)	Negative benefits, and a benefit-to-cost ratio of 0.26	The policy is likely to be effective, and would help decrease wind power prices significantly.	This policy has a limited scope as the restraint on levels of investment is too strict to be accepted by most investors, and the amount of wind resources required are so high that most wind farms would not be able to provide them.
3. Preferential taxation policy (VAT reduction)	Positive benefits, and a benefit-to-cost ratio of 0.81	The effect of this policy would be limited, as a large difference would still remain between the actual power price and the price needed for commercialization.	This policy will probably meet with resistance from local governments and, in practice, the reduction in VAT would be difficult to implement.
4. Preferential investment policy (3-year interest allowance loan)	Positive benefits, and a benefit-to-cost ratio of 1.02	The effect of this policy would be limited, as a large difference would still remain between actual power price and the price needed for commercialization	A limited amount of capital would probably be available.

The policies are ranked in the table below according to their comparative usefulness in achieving their goals, taking into consideration costs, implementation potential, social benefits, and the potential of moving wind power towards commercialization.

Policy	Usefulness
Costs shared by the whole of society in the form of an increase in the price of electricity (S4.1)	1
Government subsidies (Prolonging of the repayment period to 15 years, exemption from import duties and VAT, 3-year deduction and 2-year exemption from income tax, and a subsidy funded by a pollution charge) (S4.2)	2
Prolonging of the repayment period to 15 years, exemption from import duties and VAT, 2-year deduction and 3-year exemption from income tax, keeping investment levels below 7,500 Yuan/kW, increasing annual power generation time to 2,600 hours (S3.16)	3
Three-year interest allowance loan, prolonging of the repayment period to 15 years, exemption from import duties and VAT, 2-year deduction and 3-year exemption from income tax (S3.14)	4
Exemption from import duties and income tax, and a reduction in VAT (S3.5)	5
Three-year interest allowance loan and prolonging of the repayment period to 15 years (S3.1)	6
Preferential taxation policy (VAT reduction)	7
Preferential investment policy (3-year interest allowance loan)	8

10. The Implementation of a Preferential Pricing Policy and Some Further Comments

10.1. Basic rules

Foreign and domestic experiences have shown that the successful implementation of government policies requires basic rules, step-by-step plans, and well-defined aims. The rules governing the implementation of a preferential pricing policy should be as follows:

First, wind power generators should be able to connect locally to the power grid for a flat rate. However, to ensure the smooth functioning and stability of the grid, the amount of wind power should be less than 5–10 percent of the total on-grid power.

Second, as a source of clean energy, wind power should be able to connect directly to the power grid, avoiding competition with power generated using conventional resources.

Finally, an effective mechanism is required to ensure fair and open competition for on-grid power prices and project development.

10.2. Making decisions about power prices and price differences

China has previously set power prices by combining the costs of a specific power plant with a reasonable profit. However, as it does not involve any competitive mechanism to encourage power plant managers to economize, this method could cause costs and power prices to spiral upwards, and is not therefore a useful tool for reducing power project costs. In 2001, the Chinese State Development Planning Commission issued a *Notice about Standardizing Power Price Management* in issue 701 of the *Pricing Periodical*. This article suggests setting average power prices not by the traditional method of calculating the costs of repaying capital and interest, but based on the operating life of a power project. The operating period for a thermal power plant is 20 years, and that for a hydroelectric plant 30 years. The loan repayment period for a thermal power plant is 13-18 years, and that for a hydroelectric plant is 18-25 years. The on-grid power price for newly built plants is decided on the basis of the average costs of technologically advanced generating units of the same kind, built in the same period, and connected to the provincial power grids.

The *Notice* does not specifically mention wind power but, as the wind power industry shares similar characteristics with most power industries, it seems reasonable that the price of wind power be determined in a similar way as hydroelectric and thermal power prices.

Bids should be invited and entered openly, so that the process of determining the final on-grid price can be used to help encourage the development of technology and gradually reduce power prices.

So, the general principle behind establishing wind power prices is the use of competition mechanisms.

One of the basic aims of developing the wind power industry is to gradually replace conventional power plants with wind farms, so as to decrease pollution caused by conventional power generation methods (especially coal combustion). The appraisal of the gap in the on-grid wind power price should be based on an evaluation of the difference between the on-grid prices of wind and coal-fired power.

10.3. Dealing with the price gap

In general, the price of wind power in China is about 0.3 Yuan/kWh more than that of coal-fired power (0.65 Yuan/kWh and 0.35 Yuan/kWh respectively). So, for a 100,000 kW-capacity wind farm, which would generate around 200 million kWh annually, the total price difference would be approximately 60 million Yuan if all the power generated were put onto the grid. The central problem is how to pay for this price gap so as to allow wind power to compete with coal power. Three main options exist:

1) The cost of closing the price gap can be shared by the whole of society.

The extra cost of wind power can be added onto the total cost of all power on the grid, and the per kWh price of all types of power on the provincial grids calculated again after the additional price of wind power has been distributed amongst them. (As an independent accounting unit, the provincial power grid has the ability to regulate the price of power.) Taking Inner Mongolia and Guangzhou Province as examples, if the extra cost of 100,000 kW of wind power were distributed among the total amount of power on sale, then the average price per kWh would rise by 0.002 Yuan and 0.0004 Yuan in Inner Mongolia and Guangzhou respectively. If this method is chosen, then the burden on small-scale consumers will not become noticeably heavier.

2) Public subsidies.

The extra cost of wind power can be subsidized directly by state funds, or compensated through a combination of tax exemptions and investment subsidies. These methods are not as easy as they sound, and the latter is especially complex.

3) Setting up a wind power fund, which would be used to cover the price gap.

This fund could be distributed by competition; the enterprise that requires the lowest subsidies for a set amount of power would win a contract for subsidies from the fund. There are a variety of possible sources of financing for the fund, which are detailed below:

- Allocation of state funds.

The government could provide a specified amount of funding each year; for example 120 million Yuan to support the construction of a 200,000 kW wind farm.

- Financing from societies and individuals.

Possible supporters of the fund include domestic and international banking institutions, environmental protection organizations, farsighted investment consortiums and enterprises, and individual investors.

- Funding from a lottery and/or bond system.

As this requires public participation, it would probably only be feasible if the public were aware of, and convinced of, the importance of the development of wind power.

- Using a certain proportion of pollution charges (which come mainly from coal-fired plants) to create a wind-power fund.
- Funding from an extra per-kWh charge on consumers.

Collection of an extra power charge is the easiest and most attractive way that a wind-power fund could acquire financial resources. A small per-kWh tariff would be added to the price of electricity, so that consumers would pay a subsidy related to their consumption levels.

Of the three methods detailed above, the first—sharing the additional cost of wind power among the whole of society—is the most feasible. However, it is important to introduce policies to keep this shared charge as low as possible. Some potential measures are outlined below:

- Extend repayment periods to a minimum of 15 years.
- Exempt imported wind technology parts from VAT (but not whole units)
- Exemption from VAT on power
- A 2 year deduction and a 3 year exemption from income tax.

10.4. Establishing rational and scientific competition mechanisms

To reduce the cost of wind power and the shared charge to cover the price gap, a competition mechanism should be introduced into the construction process for wind farms, which should include the following stages:

- Bids from investors should be openly invited for wind projects.
- Bidding should be based on the on-grid price of power produced after the wind farm has been completed.
- The bidding should be won by whichever investor offers the lowest reasonable price (quality and safety should not be sacrificed), and an agreement on the construction of the wind farm drawn up.
- All parties should agree on the on-grid price gap, the distribution of the extra cost of wind power, and the extra price difference per kWh.

10.5. Management of wind power policies

A responsible and efficient organization should be established to manage and promote the policy of distributing the extra initial cost of wind power across society. (The provincial power grid corporation should not be allowed to assume this role). Such an institution would undertake the following responsibilities.

- Drawing up and implementing local wind power plans in accordance with the *National Wind Power Plan*.
- Compiling data needed to make annual adjustments to the market price, calculating a new price, obtaining approval from the State Power Corporation, and putting it into effect.
- Supervising and measuring the development of wind farms and their connection to the grid.
- Supervising and measuring the purchase of wind power generated by local power corporations.
- Organizing the bidding for wind farm projects.

11. Conclusions

1) Wind power is one of the most promising of the new and renewable energy sources available. Wind energy resources are plentiful and renewable, and their use does not cause environmental pollution or resource depletion, so wind power is of crucial importance in a sustainable energy development strategy. In China, the development of wind power capacity will not only reduce air pollution and improve the power-generation structure, which at present is dominated by coal-fired power, but also it has the potential to make great contributions to the development of local economies and to efforts to provide universal access to electricity.

2) During the 1990s, global wind power capacity increased rapidly as a result of the development of the global economy and the recognition of a need to protect the natural environment. By 2000, installed capacity exceeded 17,500 MW worldwide, and the amount of wind power generated annually exceeded 35 billion kWh. The average annual rate of increase is higher than 30 percent, which is equal to or even higher than the rate of growth of the information technology industry since the 1960s. Wind power has become a significant part of the international power system.

3) Although wind farm construction in China lags behind wind farm construction internationally, great advances in wind power technology and the wind power industry have taken place over the last few years. By 2000, installed wind power capacity in China exceeded 340 MW, and the scale of wind farm construction is constantly increasing. Chinese scientists and engineers are now familiar with the relevant technology, and the majority of wind turbine parts can be manufactured domestically. A number of specialist manufacturers have emerged, creating a new industry. In short, wind power is becoming an important part of the national economy, and its value is widely recognized.

However many problems and misapprehensions concerning policy and technology still hinder the development of the wind power industry. The most important of these is that the on-grid price of wind power remains too high to be competitive with conventional power. Nowadays, the on-grid wind power price is normally between 0.6 and 0.7 Yuan/kWh, but it has been as high as 1.20 Yuan/kWh in a special local grid. Because this is far higher than the on-grid price of power from a conventional coal-fired power plant, and higher than the average on-grid power price across all generation sources, it has proven an obstacle to the development of the wind power industry. To promote the development of wind power, the factors contributing to wind power’s high on-grid price should be analyzed and policies should be developed to help reduce it.

4) The experiences of other countries have shown that strong incentive policies are crucial to

overcoming the difficulties that arise during the development of the wind power industry. In Germany, large investment subsidies and a policy of setting relatively high power prices across the grid were introduced to promote the development of wind power technology. They led to a growth in the national installed capacity, making Germany the country with the highest installed wind capacity in the world. In Britain, the dual policies of the Non-Fossil Fuel Obligation and a price difference subsidy meant that between 1991 [and when?] and 1997 installed capacity grew fivefold, and the price of wind power dropped by more than 50 percent to the equivalent of € 0.079/kWh. In India, the introduction of a variety of preferential policies has contributed greatly to rapid advances in wind power technology that have made India one of the most advanced countries in this field.

5) For improving efficiency, reducing costs, and promoting the commercialization of the industry, the most effective incentive policies are (1) the preferential pricing policy (total subsidy) and (2) mixtures of several policies. These two approaches should help to generate significant investment in the wind power industry, thereby narrowing the price gap between wind power and conventionally generated power, and reducing investment risks in the industry.

6) All policies require funding if they are to produce any results, but sometimes a policy becomes infeasible when the cost of implementing it outweighs the benefits it provides. Whether a policy is economically feasible or not can be determined by a cost-benefit analysis. As far as preferential pricing and multiple-incentive policies are concerned, the cost (which refers to additional costs) is made up of any incentive or tax costs balanced by the pollution, resource, and social benefits—such as the conservation of water and coal, and increased employment opportunities. The cost-benefit ratios of the two approaches mentioned above are not positive, and within their life-cycle the net present value of the benefits provided by the policies is negative.

7) Policies are not objectives in themselves. Their purpose is to promote the development of wind power, reduce the cost and price of power, and facilitate the commercialization of the wind power technology industry. Commercialization requires that wind power technology matures and that the industry becomes economically well developed. Policies that seem unfavorable from the perspective of a cost-benefit analysis can be considered feasible in the long term because they offer strong incentives to promote industry development and long-term economic benefits. The preferential pricing and multiple-incentive policies conform to the standards outlined above and are therefore strongly recommended as potential options.

8) The preferential pricing policy would be effective, and relatively few government departments would be involved, which makes the policy easier to implement. In combination with increased competition, this policy can have enormous impacts on industry development and, although the amount of money needed to finance the subsidies is large (around 500 million Yuan annually), there are ways to raise these funds and these subsidies are affordable.

9) Calculations show that effective incentive policies will accelerate the commercialization of wind power technology enormously. Commercialization of the wind power industry can be expected when the cumulative installed capacity reaches 3–5 million kW.

10) Some basic conditions are required in order to ensure that the preferential pricing policy operates successfully. These conditions are clear aims for wind power development, plans for each stage of development, rational and scientific operating mechanisms, and the purchasing of all wind power produced.

References

Another Suggestion to Accelerate the Development of Wind Power, *China Energy*, Issue 1, 2001

BTM Consultancy for APS, 1999, updated 2000. *International Wind Energy Development*, Denmark.

CHEN Qingyun, 1996. *An Analysis of Public Policies*, Chinese Economic Publishing House.

Chinese Development Commission, Chinese National Science Commission, and Chinese State Economic and Trade Commission, 1995. *A Plan for the Development of the New and Renewable Energy Industries in China*.

Chinese National Scientific Commission and the European Energy Resources Company, 1997. *The Conference on Renewable Energy Resource Technology held by the Sino-European Friendship Association*, Beijing.

Chinese State Economic and Trade Commission, 2000. *Some Thoughts about Further Promotion of the Development of Wind Power Generation*, Proceedings of the Conference on the Development of Wind Power in China in the 21st Century, 2000, Beijing.

Chinese State Scientific Commission Blue Book, 1985. *Chinese Technical Policies (for Energy Resources*), Beijing.

Chinese Sustainable Energy Program, David and Lucy Packard Foundation, and Energy Resources Fund, 2001. *The Development of Renewable Energy [in China]*, Beijing.

CORY Karolyn S. *et al.*, 1999. *An Analysis of Wind Turbine Cost Reductions: The Role of Research and Development and Cumulative Production*, AWEA Windpower '99 Conference, Burlington, Vermont, USA.

Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Coal and Electricity Analysis Branch, U.S. Department of Energy, 1995. *Electricity Generation and Environmental Externalities: Case Studies*, Washington, DC.

European Community Commission, 1999. *Future Energy Resources: The White Book on European Union Strategies for Renewable Energy Development, and their Implementation*.

Government support is a powerful force for accelerating the development of renewable energy, *China Energy*, 1997

GU Shuhua, LIU Hongpeng, 2001. *Development Plans for the New and Renewable Energy Industry*, Chinese Economic Publishing House.

HUANG Yicheng, 2000. *A discussion of the problems involved in trying to accelerate the development of wind power until it accounts for 10 percent of all power generated in China*, China Energy Resources, Issue 11.

Investment Institute of the Chinese State Development and Planning Commission, The Social Evaluation Group at the Standards and Quotas Institute of the Construction Department, 1997. *Guide to Social Evaluations of Investment Projects*, Economic Management Publishing House.

Japan Energy, No.11, 1993

KOOMEY Jonathan and KRAUSE Florentine. *Introduction to Environmental Externality Costs*, Energy

Analysis Program, Applied Science Division, Lawrence Berkeley National Laboratory, California, USA.

LI Baoshan, 2000. *An Assessment of the Lack of Domestic Manufacturers of Large-scale Wind Turbines*, Proceedings of the Conference on the Development of Wind Power in China in the 21st Century, 2000, Beijing.

LI Junfeng, WANG Zhongying, SONG Yanqin, 2001. *We Need New Ideas to Help Develop the Wind Power Generation Industry*, Chinese Energy Resources, Issue 1.

LI Junfeng, ZHU Li, 2000. *An analysis of the Obstacles to the Development of Large-scale and Medium-scale Wind Power Generation*, Proceedings of the Conference on the Development of Wind Power in China in the 21st Century, 2000, Beijing.

LIU Wenqiang *et al.*, 2000. *The Commercialization of Chinese Wind Power*, Proceedings of the Conference on the Development of Wind Power in China in the 21st Century, 2000, Beijing.

New Renewable Energy, 1998

Organization for Economic Cooperation and Development, 1996. *Guide to the Economic Evaluation of Environmental Projects and Policies*", China Environmental Science Publishing House.

SARIGIANNIS Denis A., TRIACCHIN Giuseppe, 2000. *Meso-scale Life-cycle Impact Assessment of Novel Technology Policies: The Case of Renewable Energy*, Journal of Hazardous Materials No. 78, pp145–171.

SHI Pengfei, 2000. *Chinese Wind Power Resources and the Plans for Wind Farm Construction*, Proceedings of the Conference on the Development of Wind Power in China in the 21st Century, 2000, Beijing.

TAILSPIN Anthony B. *et al.*, 1996. *Public Economics*, People's Publishing House, Shanghai.

Technology and Industrialization Department, Chinese Science and Technology Ministry, 2000. *Collated Regulations and Policies Concerned with Cleanliness in Production 1995-2000,* The Coal Industrial Publishing House, China.

TODD Joel Ann and CURRAN Mary Ann, 1999. *Streamlined Life-Cycle Assessment: A Final Report from the SETAC North America Streamlined LCA Workgroup*.

Wind Turbine Department, Chinese Agricultural Machinery Association. *Information of Wind Turbines*, Issue 5, 2001

WISER Ryan, 2001. *Future Cost Trends for Coal-Fired Plants in the United States*.

WISER Ryan and KAHN Edward, 1996. *Alternative Wind power Ownership Structures: Financing Terms and Project Casts*, Energy & Environment Division, Lawrence Berkeley National Laboratory, California, USA.

World Energy Resources Council, 1998. *New and Renewable Energy – A Guide for Future Development*, Ocean Publishing House.

YANG Xiaosheng, *et al.*, 2000. *Discussion and Suggestions on Policies to promote the Development of Wind Power*, Proceedings of the Conference on the Development of Wind Power in China in the 21st

Century, 2000, Beijing.

ZHANG Zhengmin, LI Jingjing, 2000. *Comparative Research into Chinese and Foreign Policies to promote Wind Power Generation*, Proceedings of the Conference on the Development of Wind Power in China in the 21st Century, 2000, Beijing.

ZHANG Zhengmin, WANG Qingyi, ZHUANG Xing, HAMRIN Jan & BARUCH Seth, 2001. *Renewable Energy Development in China: The Potential and the Challenges*, Center for Resource Solutions, San Francisco, California, USA.

ZHANG Zhengmin, XIE Hongwen, WANG Baiyu, 2001. *Analysis of Wind Power Prices and Suggestions on Policies*, Chinese Power, Issue 9.

ZHANG Zhengmin, ZHU Junsheng, 2000. *The Development and Industrialization of Renewable Energy Technology*, Teaching Materials of Commerce Cultivation for Enterpriser of Renewable Energy, 2000, Beijing.

ZHAO Jiarong *et al.*, 1998. *Research into the Effect of Incentive Policies on the Development of Renewable Energy in China*, Chinese Environmental Science Publishing House.

ZHUANG Yuan, 2000. *Current Conditions and Future Developments in the Construction of Wind Farms in China*, Proceedings of the Conference on the Development of Wind Power in China in the 21st Century, 2000, Beijing.

ZHOU Huang, CHEN Heping, 2000. *Some Suggestions for Accelerating the Development of Wind Power Generation*, Proceedings of the Conference on the Development of Wind Power in China in the 21st Century, 2000, Beijing.