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Abstract

This study provides an overview of the diffusion of small household wind generators and development of wind farms in Inner Mongolia, China with the emphasis on policy and institutional perspectives. It analyzes the patterns of wind technology diffusion within social, economic, and environmental contexts. It relates the diffusion of wind technology to institutional framework building, and to international investment and technology transfer. By examining the economics of windfarm development and analyzing the role of alternative policy instruments, it identifies the major constraints of wind technology development and gives relevant policy recommendations.

Keywords: wind energy; technology diffusion; institution barriers; Inner Mongolia; China

Contents

1 Introduction

In recent years, there is a growing interest in renewable energy technology development as a perceived solution for energy and environmental problems in developing countries. Considerable amounts of study have been done in this field. Most of the studies have focused on technical and/or techno-economic issues, and few deal with the process of technology diffusion. Renewable energy studies about China have a policy and institutional orientation, but most of them concentrate on improved cookstove and biogas technology (Smith et al., 1993; Gu et al., 1995; Qiu et al., 1996). Although there is a general consensus on the significance of wind technology in building a sustainable energy system in China, less attention has been paid to the diffusion of wind energy technology at the regional level. Our study is, therefor, an effort to fill up this gap.

We approach the objective through a case study about the diffusion of wind generation technology in the Inner Mongolia Autonomous Region, China. We select Inner Mongolia as a case study based on the following considerations:

1. It is an important energy production base in China, and has exceptional wind resources;
2. It has already led China in the field of small-sized wind generator installations;
3. It currently ranks the second behind the Xinjiang Autonomous Region in terms of windfarm development, but will replace Xinjiang's position by the end of this century.

Analyzing Inner Mongolia's wind technology diffusion process could help us better understand the discourse on wind energy development, and enable us to draw lessons for other parts of China as well as for other developing countries. The rest of the paper is organized as follows. Section 1 summarizes the characteristics of Inner Mongolia's wind energy resource situation. Section 2 presents Inner Mongolia's wind generation technology diffusion pattern. Section 3 examines the social, economic, and environmental motives for wind generation technology development and dissemination in Inner Mongolia. Section 4 overviews the policy and institutional framework. Section 5 examines the role of international investment and technology transfer. Section 6 identifies the barriers to wind generation technology diffusion in the future. Section 7 shows the economics of windfarm development and analyzes the role of alternative policy instruments. Section 8 gives some policy recommendations. Finally, conclusions highlight the issues for policy change and adjustment.

2 Wind energy resource

Inner Mongolia lies in 38-53 degrees north latitude and 95-126 degrees east longitude, covering an area of 1.183 million square kilometers (km^2). Because of its geographical location, Inner Mongolia boasts abundant wind energy resource. It has an annual average wind speed of 3.7 m/s.

Table 1: Wind energy resource available for commercial exploitation.

Categories	**Areas** ($10^3 km^2$)	**Annual effective wind power density** (W/m^2)	**Annual effective wind energy** (kWh/m^2a)	**Annual exploitable hours**
Rich	83	240-320	1,500-2,480	6,100-7,800
Good	200	180-220	1,000-1,500	5,300-6,780
Marginal	660	100-200	400-1,000	4,400-6,000

Source: Zang and Feng, (1998).

The annual effective wind power density[2] in Inner Mongolia ranges 100-300 W/m^2 while the annual effective wind power 400-2480 kWh/m^2a. 80% of Inner Mongolia has the wind energy resource that can be economically exploited while the economically exploitable wind hour is 4400-7800 each year. In terms of energy, the total wind reserve in Inner Mongolia reaches 1.01 billion kW, of which 0.101 billion kW can be exploited economically or approximately 40% of China’s total economically exploitable wind reserve. Table 1 summarizes the three categories of wind energy resources in Inner Mongolia: rich, good, and marginal, which are available for commercial exploitation. Another characteristic of Inner Mongolia’s wind energy resource is that the wind speed distribution is in line with electricity use pattern: the weed speed is higher in daytime than at night with 10 a.m.- 5 p.m. being the highest and 11 p.m. – 5 a.m. the lowest.

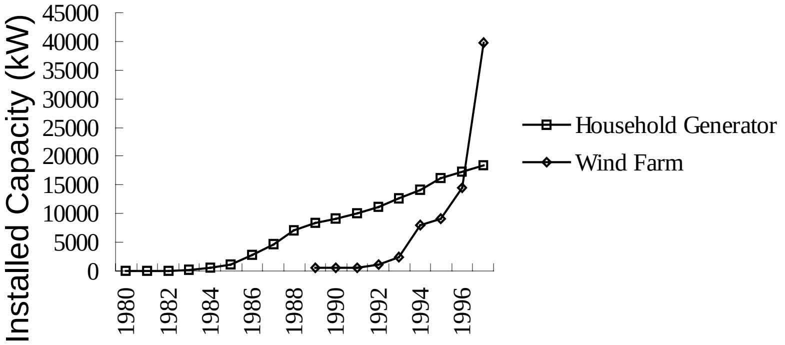

Figure 1: Diffusion curves of household wind generators and wind farms.

[2] The wind speed is called *effective wind speed* if its falls in 3-20 m/s. The *effective wind power density* is calculated on *effective wind speed.*

3 History, current situation and future development

Inner Mongolia is one of the pioneers in terms of wind generation technology development and dissemination in China. It started its wind generation efforts as early as in the late 1950s.

Table 2 lists the installations of the three major wind generation technologies in Inner Mongolia since 1980: small-sized household wind generators with capacity ranging from 50 W to 5 kW, independent small wind generation stations, and grid-connected wind farms. As the capacity of small wind generation stations is rather limited, our study focuses on the development and dissemination of small-sized household wind generators and grid-connected wind farms.

Table 2: Wind generation development in Inner Mongolia since 1980.

Year	Household generator		Small generation station		Wind farm	
	Units	Capacity (kW)	Units	Capacity (kW)	Units	Capacity (kW)
1980	300	22.5				
1981	600	45				
1982	1,000	75				
1983	3,200	220				
1984	8,600	640				
1985	12,845	1,100				
1986	33,638	2,850				
1987	50,178	4,700				
1988	76,000	7,100				
1989	83,700	8,420			5	500
1990	86,000	9,100			5	500
1991	9,500	10,100			5	500
1992	102,000	11,200			11	1,100
1993	110,000	127,00	2	10	20	2,375
1994	118,000	14,200	8	40	45	8,075
1995	125,000	16,100	16	80	49	9,075
1996	130,000	17,300	24	120	58	14,475
1997	137,000	18,500	32	160	101	39,775

Source: Chen, (1998).

Figure 1 depicts the historical path of the development of the household generators and wind farms in Inner Mongolia. As demonstrated in Table 1 and Figure 1, Inner Mongolia's wind generation technology diffusion could be roughly divided into three stages: Household Wind

Generator (HWG) stage (1958-1988), HWG domination stage (1989-1996), and Wind Farm (WF) domination stage (1997 to date).

Before 1988, Inner Mongolia concentrated its wind generation technology development and dissemination efforts on HWG. Up to 1988, HWG installation reached 76,000 units with a total installed capacity of 7,100 kW, which supplied more than 300,000 people with electricity in the remote rural and pastoral areas where the power grid could not reach them. Since 1989, WF began to be installed in Inner Mongolia, and witnessed a rather high diffusion rate after 1993 as shown in Figure 1. HWG also maintained its momentum, and kept its lead in terms of accumulated installed capacity until 1996. In 1997, however, the accumulated installed capacity of WF (39,775 kW) firstly surpassed that of HWG (18,500 kW). The former is approximately two times of the later. This is a milestone, which marks that Inner Mongolia's wind generation technology diffusion has entered a new era.

Inner Mongolia currently ranks the first in China in terms of HWG installation as well as HWG industrial development. It ranks the second in terms of WD development in China, just behind Xinjiang Autonomous Region where exists a total installed capacity of 64,650 kW. Inner Mongolia's HWG diffusion target is to reach 160,000 units with a total installed capacity of 23,200 kW by the end of 2000. Its WF development plan is very ambitious with estimated installed capacity reaching 150,000 kW and 750,000 kW by 2000 and 2010, respectively (Chen, 1998; Zhao et al. 1998). By then it will exceed Xinjiang's 100,000 kW and 300,000 kW, respectively (Zhao et al. 1998). It is hoped that Inner Mongolia becomes a leading region in China in wind technology development in the future.

4 Social, economic and environmental motivations

It is important to understand the process and pattern of wind technology diffusion in Inner Mongolia. It is also important to understand why such a pattern appears and through what means. There must be some fundamental elements that govern the wind technology diffusion process. In this section, we examine the driving forces, or fundamental motives, of HWG and WF diffusion within social, economic, and environmental contexts.

4.1 Household wind generators

Inner Mongolia is an agricultural and livestock province of China. Approximately 70% of its 23 million population scatters in the vast rural and pastoral areas. A large number of villages consist of only two to three households. The economic condition of the scattered rural and pastoral households is often very poor.[3] Due to huge investment requirements for power grid development, these scattered rural and pastoral villages are usually beyond the reach of power supply. It has left a large number of rural and pastoral households without access to electricity supply, which poses a critical problem for social and economic development of the region. It also creates a large potential market for decentralized wind generation technologies and their applications.

The unavailability of electricity to rural people poses the greatest constraint to the social and economic development of the remote rural and pastoral communities, as it creates a barrier to improve the quality of life of farmers and herdsmen. Without access to electricity, farmers and herdsmen are unfairly denied the opportunity to enjoy energy services provided by electric light, television, refrigerator, and other electric appliances. More importantly, without electricity, they have difficulties to be informed about the outside world, including science and technology matters, through mass communication and the media. Therefore, the immediate motive of the HWG diffusion is to enable the poor and the disadvantaged rural population having access to electricity services. As we discussed above, diffusion of HWG is closely related to achieving social development objectives of the rural areas, thus, has important implications for regional development.

In addition to improve quality of life for rural people, and to increase their capability to adapt to social development objectives, another important social motive associated with disseminating HWG is to consolidate national unity. There are a variety of ethnic groups living in the rural and pastoral areas of Inner Mongolia. National unity is often regarded as one of the fundamental elements of social stability in the country. Providing minority groups with a better energy service is considered to be a positive element for national unity and social stability.

[3] GDP per capita in Inner Mongolia was at 3,013 Yuan in 1994, which accounted for No.16 among 30 provinces/regions in China. See: State Statistics Bureau, 1996, p.11.

4.2 Wind farms

In addition to abundant wind resource, Inner Mongolia has rich coal resource. It is estimated that coal reserves account for 210 billion tons. Its neighbors, Beijing, Tianjin, and other parts of the North China, have a huge demand for energy, particularly for electricity supply, because of fast economic growth in these cities/regions. So Inner Mongolia enjoys exceptional advantages from electricity production. Electricity generation and export are regarded as one of Inner Mongolia's basic economic development strategies. In 1997, Inner Mongolia transmitted 1,000 MW of electricity to Beijing with a total electrical quantity about 6.5 billion kWh, which was approximately 23.3% of Beijing's total electricity consumption of 4,300 MW in that year. According to a contract, Inner Mongolia's electricity export to Beijing will reach 2,000 MW, approximately 12 billion kWh, in 2000, which constitutes 28.6% of Beijing's total electricity demand (Chen, 1998).

Before 1989, all electricity was produced by coal in Inner Mongolia. On the one hand, coal-fired electricity production and export contributed to Inner Mongolia's economic growth; on the other hand, the fast development of coal-based electricity caused serious local (particulate), regional (SO_x), and global (CO_2) environmental problems. Taking the most widely used 300 MW steam turbine generation system for example, it consumes about 4 tce (tons of coal equivalent) of coal for generating 10,000 kWh electricity, emitting approximately 0.5 ton of particulate, 0.08 ton of SO_x, 0.05 ton of NO_x, and 10 tons of CO_2 (Wu, 1998). In the 1980s, the increasing global, national, and local environmental concerns resulted in the re-examination of Inner Mongolia's electrical development strategy. Power source optimization, particularly with the concern for power source diversification, became a new element of the Inner Mongolia's electricity development strategy. It is aimed to reduce dependence on fossil fuel based energy systems, and deal with increasingly serious environmental pollution problems. Therefore, windfarm provides an emission free option for the energy systems development in the region. Furthermore, the areas covered by the main lines of the Western Inner Mongolia Grid have exceptional advantages for the construction of wind farms. In these contexts, wind farms development became integrated into Inner Mongolia's electricity plan from the mid-1980s.

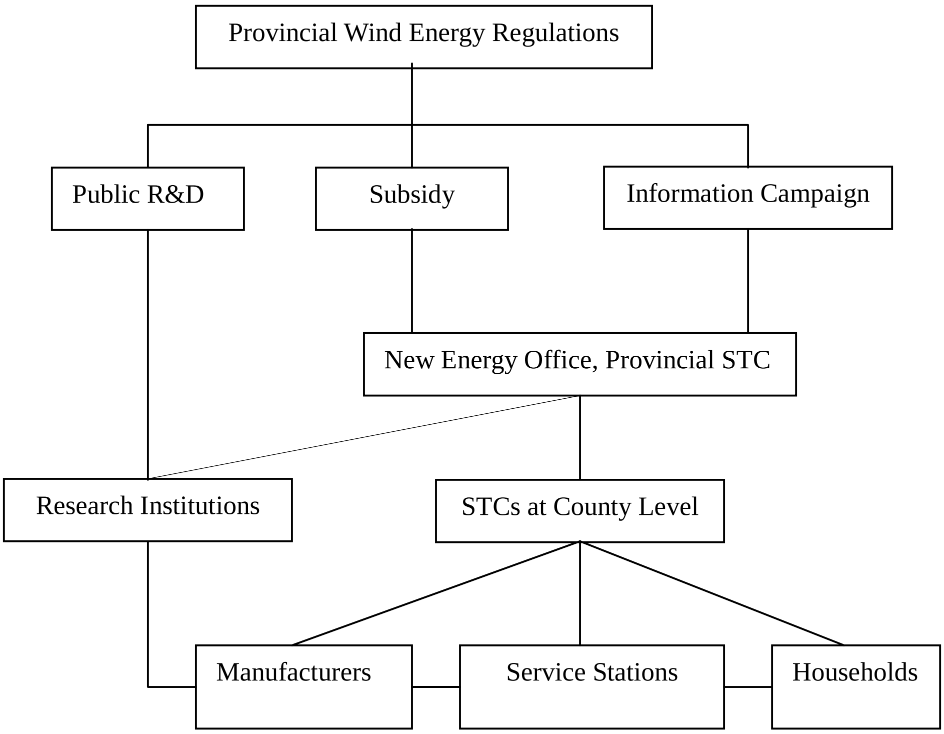

Figure 2. The institutional framework for HWG diffusion in Inner Mongolia.

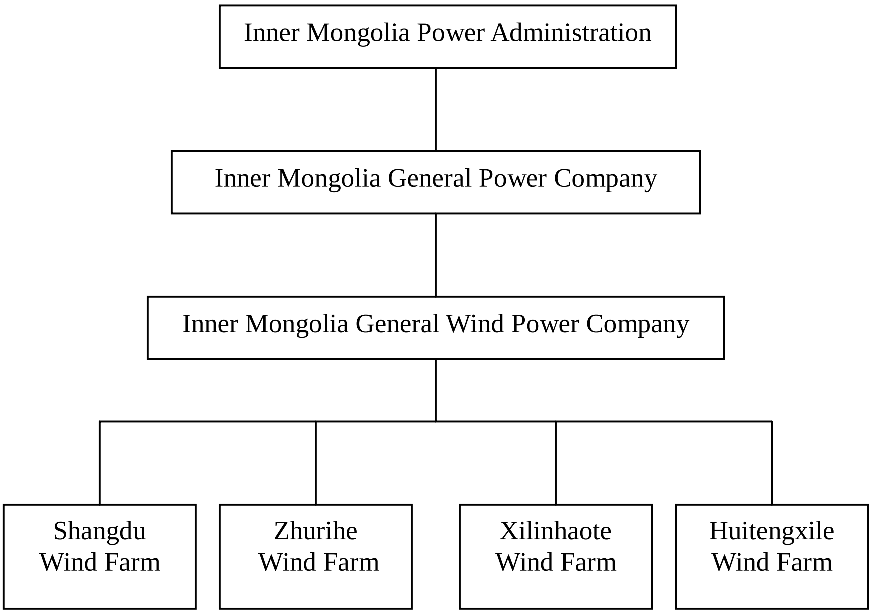

Figure 3. The Institutional Infrastructure of WF Development in Inner Mongolia.

5 Policy and institutional arrangement

In this section, we examine the governmental policies and institutions, which are intended to facilitate HWG dissemination and WF development.

5.1 Household wind generators

Inner Mongolia government's intervention in wind resource development started with supporting research and development of household wind generators and small-sized wind pumps. Regarded as a key project, wind resource development first became a component of Inner Mongolia's science and technology development plan in 1980. The plan specified the objective of wind resource development as solving the electricity supply problem for households in remote rural areas. According to the plan, research priorities were given to the research and development of small wind turbines and small wind pumps. The Inner Mongolia government subsidized 0.3 million yuan to research and development each year. Due to such a policy, more than 20 models of small-sized wind turbines have been developed by research institutes and universities in Inner Mongolia with their capacities covering 50W, 100W, 200W, 300W, 500W, 1 kW, 2 kW and 5 kW.

In 1981 Inner Mongolia's Science and Technology Commission (STC) initiated a three-year demonstration project for small-sized wind turbines and wind pumps in Xilinguole pastoral areas. Within the project, 141 HWGs were installed with a total installed capacity of 18.2 kW. The project had 234 households having access to electricity.

After the successful demonstration, a large-scale HWG dissemination started in 1984. Since then, diffusion of HWG has entered into a new stage. During this stage, a set of preferential policies has been formulated for HWG development and dissemination. In 1986 the government of Inner Mongolia promulgated two important regulations related to wind resource development: *Regulations on New Energy Exploitation and Utilization* and *Economic Support Method for Wind Generator and Silicon Solar Cell Installations*. Under the two regulations, a subsidy and an institutional infrastructure were established for HWG diffusion. According to the *economic support method*, HGW manufacturers receive 200 yuan of subsidy from the government for every 100 W of wind turbine sales, which is approximately 15-20% of the cost for HWG. The Government totally subsidized 16 million yuan for HWG diffusion during 1986-1990, and 9 million yuan during 1991-1996, respectively[4].

The New Energy Office of the Inner Mongolia Science and Technology Commission (STC) and the STCs at the county level are in charge of HWG diffusion and subsidy management. The new energy service stations at the county and town levels are also involved in HWG diffusion. In Inner Mongolia, 100% of the counties and 90% of towns have established new energy stations. They are responsible for sales of HWG and technical service. Figure 2 depicts the institutional framework for HWG diffusion in Inner Mongolia. Inner Mongolia's HWG development and dissemination is largely attributed to the establishment of the framework.

[4] The subsidy decline after 1990 is largely attributed to the budget constraint of the government, and the fact that farmers know more about the benefits of using wind technology, thus, are willing to pay a higher price. See Ministry of Agriculture, 1997.

Table 3: Wind turbine installations in wind farms in Inner Mongolia.

Wind turbine type	**Capa-city per set** (kW)	**Instal-lation num-ber**	**Time of export electricity to the grid**	**Manufacture country**	**Installed capacity** (kW)
Shangdu Wind Farm					
Huafeng	55	5	June, 1993	China	275
NTK300	300	12	December, 1994	Denmark	3,600
Subtotal					3,875
Zhurihe Wind Farm					
Windpower	100	5	December, 1989	United States	500
Windpower	100	6	April, 1992	United States	600
HSM	250	4	September, 1993	Germany	1,000
Hangfa	120	10	December, 1994	China-Denmark Joint Venture	1,200
NTK300	300	3	November, 1994	Denmark	900
Subtotal					4,200
Xilinhaote Wind Farm					
HSM-Luotuo	250	4	November, 1995	China-Germany Joint Venture	1,000
Subtotal					1,000
Huitengxile Wind Farm					
M1500-600	600	9	October, 1996	Denmark	5,400
M1500-600	600	33	October, 1997	Denmark	19,800
Zond-40	550	10	December, 997	United States	5,500
Subtotal					30,700
TOTAL					39,775

5.2 Wind farms

The policies for wind farm development in Inner Mongolia consists of central government and regional government policies, covering price of wind electricity, taxation, and government credit.

5.2.1 Wind electricity price

In 1994, the former Ministry of Power Industry issued the *Regulation on Grid-Connection Management of Wind Farms*. According to the regulation, all utilities have obligation to purchase the electricity produced by wind farms. The regulation stipulates that wind farms can sale electricity to power grids at a price based on electricity production cost plus reasonable profit, and the difference between the wind electricity price and the grid's average electricity price should be shared by the whole grid. In 1995, the Inner Mongolia Price Administration approved that the wind farms could sell electricity to power grids at 0.71 yuan/kWh while the coal-fired power plants at 0.35 yuan/kWh. The Inner Mongolia Price Administration approved that the Inner Mongolia Utility could increase its electricity price by 0.2 yuan/kWh to all its consumers in order to subsidize its loss in wind electricity purchase.

5.2.2 Taxation

The Inner Mongolia Government has reduced the Surtax of the Value Added Tax (VAT) of wind farms from 8% to 3% since 1995. The land royalties are calculated according to the land actually used or the land occupied by the wind farm's buildings, facilities, and roads. Foreign investors can enjoy two years of complete income tax exemption and another two years of half income tax exemption from the year of profit making. If the investment ranges from 3.01 million US dollars to 5 million US dollars, foreign investors can also enjoy 5 years of land royalty exemption if the land occupied is cultivated land or 10 years of land royalty exemption if the land has not been used.

5.2.3 Government credit

In 1995, the Energy Conservation Investment Company of the State Planning Commission provided 16 million yuan of energy conservation loan for the purchase of the four 250 kW wind turbines installed in Inner Mongolia's Xilinhaote wind farm. In 1996 the State Economic and Trade Commission (SETC) chose the construction of the Huitengxile wind farm as the demonstration project of its *Shuangjia* Program, and poured 200 million yuan of loan in the project. The interest rate of the loan is 13% and the payback period is 7 years.

In line with the governmental policies, an institutional infrastructure has also been established for the development of wind farms in Inner Mongolia. As shown in Figure 2, the Inner Mongolia Wind Power General Company (IMWPGC) is the core of the infrastructure. As a branch of the Inner Mongolia General Power Company, IMWPGC was set up in 1995. IMWPGC is an independent legal entity, and currently operates four wind farms, i.e., Shangdu Wind Farm, Zhurihe Wind Farm, Xilinhaote Wind Farm, and Tenghuixile Wind Farm, with more than 100 employees.

6 The role of international investment and technology transfer

Inner Mongolia's HWG development completely depends on local resources. Inner Mongolia leads China not only in HWG installations, but also in HWG manufacture. It has currently more than 10 manufacturers of small-sized wind turbines, and could produce a variety of models, ranging from 100W to 25 kW with a total annual production capacity over 30,000 units.

However, most of the wind turbines installed are imported from abroad. So far, neither Inner Mongolia nor China has the capability to manufacture the wind turbines with capacity over 600 kW. Table 3 summarizes the wind turbine installations of four wind farms in Inner Mongolia. As shown in Table 3, completely domestically made wind turbines only account for 0.7% of the total installed capacity of the four wind farms, and wind turbines made by joint venture companies account for 5.5%. Denmark is the largest wind turbine supplier to Inner Mongolia, and its wind turbines account for 74.7% of the total installed capacity of the four wind farms. Wind turbines made by the US and Germany account for 16.6% and 2.5%, respectively.

Table 4: International investment in wind farms in Inner Mongolia.

Year	**Amount** (10^3USD)	**Type**	**Country**
1993	1,765	Government grant	Germany
1996a	4,000	Mixture of soft loan and commercial loan	Denmark
1996b	3,650	Government soft loan	The United States
1997	4,500	Mixture of soft loan and commercial loan	The Netherlands
TOTAL	13,915		

Table 4 lists the international investments in the four wind farms since 1993. The total investment for the accumulated 39,775 kW of installed capacity is approximately 377.9 million yuan (45.9 million US dollars). The accumulated international investments have already reached 13.9 million US dollars (114.4 million yuan), or 30% of the total investment. International investments from bilateral and multilateral sources are usually provided with favorable conditions. They are either foreign government grants or low-interest soft loans. For example, of the 4 million US dollars loans from the Danish government, 85% is interest-free loan and the rest is commercial loan. The interest rate for the 3.7 million US dollars of US government soft loan is only 0.75% with a payback period of 9 years.

From the above discussion, we can see that international development assistance and technology transfer have played an important role in Inner Mongolia's wind farm development and dissemination.

7 Barriers for future development

7.1 Household wind generators

Despite the past achievements in the diffusion of HWG, there were still 1,600 villages that were unable to access electricity by 1996, covering 0.3 million households. These households are often more scattered and located in even remote areas than those who have already adopted HWGs. At the same time these households often suffer from serious financial and technical constraints. As a result, HWG diffusion will face greater challenges in the future. As we have discussed in Section 5 that governmental subsidies played an important role in the past HWG diffusion. Since the condition for wind technology diffusion becomes even severe, we suggest that a heavier subsidy is needed to maintain the current HWG momentum. However, due to budget constraints, the Inner Mongolia Government cannot increase its subsidy level again, which will negatively affect the rate of HWG diffusion in the future.

7.2 Wind farms

Although wind farms have recently witnessed a rapid development in Inner Mongolia, there are still important barriers to future development, which are discussed below.

7.2.1 High costs for imported wind turbines

Manufacture of wind turbines requires high technology inputs. Due to the limitation of technical and human resources, China is not able to produce large wind turbines so far. As shown in Table 3, almost all the installed wind turbines in the wind farms of Inner Mongolia are imported from abroad. The cost for imported wind turbines is as high as 8,000–9,000 yuan/kW. Since the cost of wind turbines normally constitutes about 75% of the total wind farm investment, this becomes a major contributor to the high wind electricity production cost, which makes wind farms not competitive, compared with conventional coal-fired power plants. The sale price for wind electricity is 0.71 yuan/kWh, while the electricity from coal-fired power plants is sold for 0.35 yuan/kWh. It is estimated that the cost of wind turbines could be reduced by 30%, if they are produced domestically (Zhao et al., 1998).

7.2.2 Lack of clear and authoritative wind electricity price guidelines

The former Ministry of Power Industry issued an important regulation regarding wind electricity price in 1994. According to this regulation, wind electricity price should be based on full production cost plus *reasonable* profit, and the price difference between wind electricity price and the average electricity price of the power grid should be shared by the whole grid. Although the Regulation has played an important role in China's wind farm's development, it has deficiencies in implementation. First, the wind electricity price principle is rather ambiguous, on which wind farms and utilities have difficulties to achieve a price that could be accepted by the two sides, because they are now two different economic bodies and both seek profit-maximization. Second, since the power grid is operated by different regional utilities, there are difficulties in sharing the price difference among different regional utilities. Third, any pricing principles and price changes have to be approved by the local price administration authorities. Now the price difference is shared within the Inner Mongolia Power Grid, thus bore by the consumers in Inner Mongolia. This means that under the current price mechanism, the more wind electricity Inner Mongolia produces, the more its consumers have to bear. Because a large proportion of the electricity produced in Inner Mongolia enters the North China Power Grid, and consumed by Beijing, Tianjin, and other cities/regions, the fairness issue has generated concerns within power producers, policymakers, and consumers.

7.2.3 Inadequate economic incentives

As China is now incapable of producing large wind turbines, these wind turbines have to be imported from abroad. Wind farms, therefore, have to pay duty, import VAT, and surtax. The duty rate for wind turbines is 6%, the import VAT rate 17%, and the VAT surtax rate 8% - 11%, respectively. Wind farms also need to pay income tax of 33%, and production VAT of 17%. The Inner Mongolia Government has given wind farms some special treatment in terms of income tax and VAT surtax. But only the central government has the authority to adjust the VAT rate and the import duty rate. So far the central government has not given wind farms special VAT treatment. Furthermore, as wind electricity production does not need fuels like coal electricity production, wind farms often pay more VAT than coal-fired power plants for a unit of electricity sale. For example, in 1995 wind farms paid 0.71 yuan of VAT per kWh of electricity sale in Inner Mongolia, while coal-fired power plants paid 0.35 yuan (Zhao et al., 1998). As a result, heavy taxation increases the production costs of wind electricity, and makes wind farms less competitive in the energy market.

7.2.4 Lack of standard wind electricity purchase contract

The regulation issued by the former Ministry of Power Industry in 1994 requires utilities to purchase the electricity produced by wind farms, but it does not provide a standard wind electricity purchase contract for wind farms and utilities. Since there are often conflict of interest between wind farms and utilities, they have difficulties to reach a self-enforced agreement without clear rules. Lack of regulation that guarantees wind farms' right to access power grid is an important barrier to attract more investment in wind farms, thus impedes large-scale development of wind farms in the future.

7.2.5 Lack of finance

Neither Inner Mongolia nor China as a whole has special financial institutions that support wind power development. Of the accumulated investment in Inner Mongolia's wind farms, approximately 57% or 216 million yuan came from the central government, 30% or 114 million yuan from foreign aid, and only 13% or 44 million yuan was locally financed. The investments from the central government and from foreign aid were mainly for setting up demonstration projects. In a long-term perspective, it would be unrealistic to expect that huge needs of investment for future wind farm development should still depend on the central governmental support and international aid. In this context, financial constraint would become a major barrier to Inner Mongolia's wind farm's development.

8 A case study: Economics of Huitengxile wind farm

Located in the middle of Inner Mongolia, Huitengxile boasts almost all the favorable conditions for building a world-class wind farm: rich wind endowment, good quality of wind resource, low land cost, near to the main power grid, and convenient transportation. Huitengxile has such a bright wind development prospect that it is often called “China’s California”. Table 5 shows the main indicators of wind resource in Huitengxile.

Table 5: Indicators of wind resource in Huitengxile.

Annual average wind speed at 10 meter height (m/s)	7.12
Annual average wind speed at 40 meter height (m/s)	8.8
Effective wind power density at 10 meter height (W/m^2)	597
Effective wind power density at 40 meter height (W/m^2)	747
Annual effective wind energy at 10 meter height (kWh/m^2a)	3,109
Annual effective wind energy at 10 meter height (kWh/m^2a)	5,448
Annual hours of effective winds at 10 meter height (hours/year)	6,255
Annual hours of effective winds at 40 meter height (hours/year)	7,293
Wind capacity coefficient	0.4

Note: Effective wind means the winds ranging from 5-25 m/s.
Source: Inner Mongolia Wind Power Company (1996).

As shown in Table 7 and Table 9, the wind farm’s electricity production cost is 0.62 yuan/kWh while the local utility’s purchase price is 0.71 yuan/kWh, according to Inner Mongolia’s wind electricity price regulation. As a consequence, under the current policy for wind electricity price, the wind farm enjoys a gross profit rate of 14.9%. However, the wind farm is not competitive, compared with local coal-fired power plants as the purchasing price for coal electricity by the local utility is only 0.32 yuan/kWh (see Table 9).

Table 6: Technical and economic parameters of the project.

Wind turbine capacity (kW)	600
Installation numbers	33
Total installed capacity (MW)	19.8
Annual electricity production (MWh/year)	59,400
Wind electricity price purchased by local utility (yuan/MWh)	713
Wind turbine purchase before import taxes (10^3 yuan)	113,170
Cost of transmission system and other equipment (10^3yuan)	25,360
Loan's share of the total initial investment (%)	65
Loan's interest rate (%)	13%
Loan's payback period (year)	10
Total import taxation rate (duty, VAT, and surtax) (%)	24
Total Value Added Tax rate (VAT & surtax) (%)	18.36
Income tax rate (%)	33

This case study is based on a project supported by the *Shuangjia* Program of the State Economic and Trade Commission (SETC) in 1996. Within the project, 33 of 600 kW wind turbines were imported from the Mocon Company of Denmark, and SETC provided 65% of the total initial investment by loan. Now the wind farm is under operation, and often cited as a success story of wind farm development in China. Table 5 lists the major technical and economic parameters of the project. Table 6 shows the costs of electricity production in the farm and its composition.

Table 7: Wind electricity production cost (yuan/kWh).

Capital Cost	
Depreciation*	0.2892
Interest payment	0.0244
Operation Cost	
Labor	0.0015
Maintenance	0.0644
VAT & Surtax Payment	0.1309
Income Tax Payment	0.1100
TOTAL	0.6204

*Life: 10 years

Table 8 indicates the effects of alternative policy options on the electricity production cost in the farm. Among the five instruments, subsidizing loan interest is the least effective measure, while VAT exemption is the most effective measure. Subsidizing loan interest rate can reduce the production cost only by 1.3%, while VAT/surtax exemption by 21.1%. The production cost is not very sensitive to import tax and duty exemption by decreasing only 5.4%. Income tax exemption could be the second cost-effective instrument while reducing the production cost by 13.8%. Public sector R&D could increase the rate of localization of wind turbine production, thus lead to the reduction in wind turbine prices. If the cost of wind turbines is reduced by 50%, the electricity production cost will drop by 13.8%.

Table 8: Effects of alternative policies on production cost.

Policy instruments	**Production cost** (yuan/kWh)	**Production cost reduction** (%)
a) Base case or business as usual	0.6182	0
b) Subsidizing interest rate by 50%	0.6123	1.32
c) Exemption of import duty and taxes	0.5873	5.35
d) Exemption of VAT and surtax	0.4896	21.10
e) Exemption of income tax	0.5105	17.73
f) Wind turbine cost reduction by 50% through public R&D	0.5347	13.83
g) d)+e)	0.3796	38.83
h) b)+d)+e)	0.3674	40.80
i) c)+d)+e)	0.3300	46.82
j) b)+c)+d)+e)	0.3197	48.48

It should be noted that none of the five instruments alone enables the wind farm to compete with coal-fired power plants. However, as shown in Table 8 and Table 9, VAT exemption might enable the wind farm to compete with the coal-fired power plants in the coastal Zhejiang, Fujian, and Guangdong provinces. Furthermore, exemption of both VAT and income tax would enable the wind farm to compete with the coal-fired power plants in Liaoning and Shandong provinces as well. If the wind farm would simultaneously enjoy VAT exemption, income tax exemption, and subsidizing loan interest, its operation would be both profitable and competitive, even if it sells electricity to the utility at the coal electricity price.

Table 9: Utility purchasing prices in selected provinces of China (yuan/kWh).

Provinces	**Coal-fired electricity**	**Wind electricity**
Xinjiang	0.32	0.698
Inner Mongolia	0.35	0.713
Liaoning	0.45	0.9-1.00
Shandong	0.45	0.80
Zhejiang	0.50	0.79
Fujian	0.55	0.79
Guangdong	0.60	0.77

Source: Zhao et al. (1998).

9 Conclusions and policy recommendations

Inner Mongolia has achieved marked success not only in HWG diffusion, but also in wind farm development. Despite the precondition of its abundant wind energy resource, important social, economic, and environmental motives have contributed to the diffusion of wind energy technologies. The success in HWG diffusion is largely attributed to the local government's stimulation efforts, including direct subsidies, public R&D, information campaign, and infrastructure development, i.e., service networks.

The wind farm's development, however, has benefited mainly from the joint efforts of the local government, the central government, and the international community. Despite marked success, a number of technological, economic, and institutional constraints need to be removed in order to promote further wind energy development in Inner Mongolia. Improved public policy instruments are needed to help Inner Mongolia overcome these barriers, such as public R&D, tax reduction, policy credits, and wind electricity price mechanism and legislation.

As we have discussed in previous sectionse, on the one hand, Inner Mongolia's wind generation technology diffusion has made marked progress; on the other hand, it has important technological, economic, and institutional barriers. We have made the following policy recommendations that we consider relevant for the improvement of wind technology operation.

1) Increasing public R&D expenditure
R&D are considered as an essential approach not only to performance improvement and cost reduction of small wind turbines, but also to production localization of large wind turbines. It is a potent option to improve the economics of wind turbines. However, because of the free-rider problem, R&D is often less provided by the private sector than the social optimal amount (Jaffe and Stavins, 1994). As a consequence, public R&D is often regarded as an important technology policy instrument.

2) Optimizing wind electricity price
The most important is to specify the rules, standards, and methods of the wind electricity price mechanism, including determining the profit ratio of wind farms and how the price difference is shared by the consumers in different regions covered by the same power grid.

3) Formulating standard wind electricity purchase contract
An important option is to specify the rules that would guarantee wind farms' right to access power grids for a long period of time.

4) Reducing taxes
The local government can further reduce the income tax level. However, as shown in Table 8, reducing VAT would be more effective for wind farm development. In this context, the central government could play a bigger role.

5) Providing more policy credits
Finance is an important bottleneck for both HWG diffusion and WF development in Inner Mongolia in the future, which needs both the local and the central government to provide more policy credits, or venture capital, through policy banks and financial institutions.

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