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Cost-competitive incentives for wind energy development in China: institutional dynamics and policy changes

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Abstract

This paper presents an overview of the development of wind power in China. The factors that affect the directions of wind power development are analyzed. It examines the economics of windfarm development and compares it with conventional energy sources. The major constraints in wind technology development, and defects of the current policies, are discussed. It points out that wind power development should be subject to rational policy change and institutional adjustment. It discusses the incentive mechanisms and institutional frameworks for future development. Particular importance is attributed to market incentives for wind power to reach the objectives of industrialization and commercialization. A number of cost-competitive incentive measures and policies are recommended: (i) introducing market based mechanisms through standard power purchase agreement; (ii) establishing effective investment policies and regulations to attract private investment; (iii) promoting localization of wind turbine production; (iv) adjusting tax and subsidy policies; and (v) reforming governmental institutions to make clear rules and responsibilities for policymaking, and enhancing communication/coordination between relevant government agencies in order to formulate uniform and effective policies. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Wind power; Institutions; Incentives; Policy measures; China

1. Introduction

China is endowed with rich wind resource. The amount of exploitable wind energy reserve is at 253 GW (He, 1996). This figure is comparable with the exploitable hydropower reserve of 378 GW. The rich reserve of wind energy in China provides a basis for large-scale development of windfarms. Wind power, among renewable sources of energy, has reached its technical maturity, and is expected to become a major alternative for coal-fired power generation (Cavallo et al., 1993; Chen, 1998; Wu, 1998; Debra et al., 1998; Debra, 2000). As it is well known, China is the largest coal-dependent country in the world with 1.23 billion tons of coal consumption in 1998, or 71.6% of the total primary energy consumption (State Bureau of Statistics of China, 1999).

China's coal-dominated energy structure has brought a great pressure to the environment. In 1999, emissions of smoke and dust, and SO_2 were 11.6 and 18.5 Mt, respectively, among which 70% and 85% came from coal burning (Communiqué for China's Environmental Situation, 1999). Thus, China is eager to develop cleaner energy technologies, including renewable energies. Wind power has been prioritized to substitute for fossil fuels. Wind power development is also considered a major option to alleviate CO_2 emissions, which reached 840 Mt in 1999, ranking China the second in the world, just behind USA. China has been criticized for not taking proper responsibilities for its greenhouse gas emissions (Zhang, 2000). As China's power industry is facing the challenge from quantitative to qualitative growth in the next 10 years (Hirschhausen and Andres, 2000), industrialization and commercialization of wind power is expected to be a driving force for sustainable energy development.

This paper provides an overview of the wind energy development in China. Economic analysis is carried out to estimate the generating cost and utility purchasing

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price of wind power. Generating costs are compared between wind power and conventional power generation, i.e. coal-fired and hydroelectric power. Particular emphasis is given to analyze the causes of high generating cost and price of wind power. After exploring the existing incentive policies of the Government, the study analyzes the means to reduce wind generating costs, and to propose relevant measures, policies and institutional changes to promote industrialization and commercialization of wind power generation, especially on how to shift from the current non-market based support to market-based incentives.

2. Wind energy development in China: past, present and future

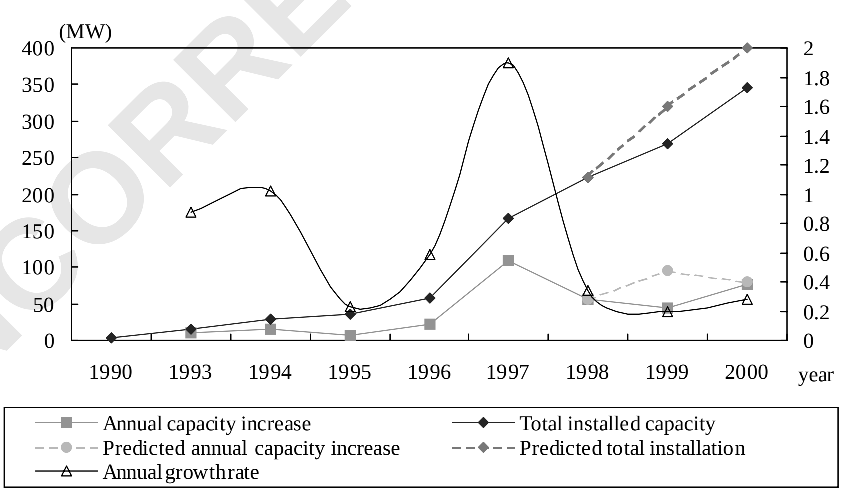
2.1. Past development

In the early 1970s, China began to develop wind energy with a primary purpose of supplying electricity to people living in the remote areas without electricity grid connection, such as herdsmen and residents in remote pastoral areas or isolated islands (Shen, 1996; Debra, 2000). After 30 years of efforts, small-scale wind generation technologies have become mature, and over 10 types of wind generation units with a capacity range between 100 W to 10 kW can be manufactured in China (He, 1996). Over 170,000 sets of small-sized wind turbine generators with a capacity of 100 W have been installed in the whole country, around 80% of which, 140,000 sets, were installed in the Inner Mongolia Autonomous Region (Lew et al., 1997; Zhang et al., 2000). In addition, some off-grid hybrid generation systems with the capacity range of 1–10 kW were installed in remote villages or islands.

The development of grid-connected wind power started from the late 1980s, along with the build-up of the first windfarm in Rongcheng County in Shandong Province in 1986, which used imported equipment from Denmark. In the same year, another pilot windfarm was built in Pingtan County of Fujian Province in south-eastern China, supported by a grant from Belgium. After these two pilot projects, windfarms began to be built throughout the country, mainly using imported wind turbines. After these two projects, the installed capacity of wind power increased very fast (Chen et al., 1991; Dai et al., 1992; He and Shi, 1995; He, 1996; Debra, 2000). In 1990, the total installed capacity of wind turbines was only 4 MW with a maximum unit capacity of 200 kW. From then, windfarm development achieved an impressive progress with an annual growth rate, as indicated in Fig. 1.

2.2. Current slow-down of annual capacity increase

By 2000, the total installed capacity of wind turbines in China reached 344.8 MW with the total installed units of 727. Though the annual power generation of about 700 million kW is not impressive in China's total commercial energy output, wind power has become the fastest growing power generation technology. At present, there are 26 windfarms, among which some have a total installed capacity over 10 MW, for example, Dabancheng in Xinjiang, Nan'ao in Guangdong, Huitengxile in Inner Mongolia, Donggang in Liaoning, Kuochangshan in Zhejiang, etc. However, it can be seen clearly from Fig. 1 that obvious slow-down of annual capacity increase has occurred since 1997, which is far lower than that of some countries, such as Germany, Spain and India (Morthorst, 1999; Rajsekhar et al., 1999). Moreover, China has currently a much smaller



Source: see table 1. Author collected related information

Fig. 1. Wind power development in China.

total installed wind energy capacity than other industrialized countries. In the early estimates made by the Hydropower & New Energy Development Bureau of the State Power Corporation, and the State Development Planning Commission (SDPC), their targets at the end of 2000 were 400 and 1000 MW, respectively. Unfortunately, the actual figure was only 344.8 MW, far below the expected targets. The annual growth rate of installed capacity during 1998–2000 slowed down to 20% (see Fig. 1). Table 1 illustrates details of the total installed capacity in all windfarms in 1998–2000.

2.3. Future development

In China, wind power development became a high priority of the Government in the early 1990s when a guideline for large-scale development was put forward by the central government. In 1994, the former Ministry of Electric Power (MOEP) (currently the State Power Corporation) planned to install wind turbines with a total capacity of 1000 MW by 2000. The targets were revised in 1998 to become 500–600 MW by 2000, 1000–1500 MW by 2005 and 3000 MW by 2010. In the beginning of the Ninth Five-Year Plan (1995–2000), the SDPC set up a target to install 400 MW of wind turbines by 2000, and windfarm construction was also identified as key field for investment during 1995–2000. Meanwhile, at the regional level, targets for wind power development are formulated by regional governments, electricity administrative authorities or utilities.

Though the recent decline in annual growth reflects the difficulties to meet the targets of wind power development, wind power is still being set as a high priority for future development. In the Tenth Five-Year Plan (2001–2005), the SDPC sets up a new plan of 1500 MW of wind turbine installation by 2005. In the *Industrial Development Plan for Renewable Energy* (2000–2015) enacted by the State Economic and Trade Commission (SETC), a long-term target is that 7000 MW of wind turbine is to be installed by 2015. Industrialization and commercialization of wind power will be the focus of future development and a large-scale expansion. In the industrial development plan, wind power is considered a major energy technology being used to reach the target of 2% (3.6% if including small hydropower) of the total commercial energy consumption through renewable energy sources by 2015. Though it is far lower than the objective of 12% of energy consumption by 2010 with renewable supplies, as put forward in the white paper of the European Commis-

Table 1
Total installed capacity of windfarms in China (1998–2000)

No.	Province/wind farm	Unit capacity sets (kW)	Total capacity in 1998 (kW)	Total capacity in 1999 (kW)	Total capacity in 2000 (kW)
1	Xinjiang/Dabancheng no. 1	100–600	8500	11,500	12,100
2	Xinjiang/Dabancheng no. 2	300–600	57,500	59,800	59,800
3	Xinjiang/Buerjin	150	1050	1050	1050
4	Gansu/Yumen	300	1200	1200	1200
5	Inner Mongolia/Huitengxile	550,600	36,100	36,100	36,100
6	Inner Mongolia/Zurihe	100–330	4200	4200	7500
7	Inner Mongolia/Shangdu	55,300	3875	3875	3875
8	Inner Mongolia/Xilinhaote	250,330	1000	1000	2980
9	Inner Mongolia/Cifeng	600,750	—	6450	6450
10	Hebei/Zhangbei	275–600	9850	9850	9850
11	Liaoning/Donggang	55–550	12,205	12,205	12,205
12	Liaoning/Hengshan	250	5000	5000	5000
13	Liaoning/Jinzhou	600	—	600	600
14	Liaoning/Yingkou	660,660	—	5940	7200
15	Liaoning/Dandong	750	—	—	21,000
16	Shandong/Changdao	55,600	110	5510	5510
17	Shandong/Rongcen	55	165	165	165
18	Zhejiang /Sijiao	30	300	300	300
19	Zhejiang/Kuochangshan	600	19,800	19,800	19,800
20	Zhejiang/Cangnan	55–600	10,255	10,255	10,255
21	Fujian/Pingtan	55–600	1055	1055	7055
22	Fujian /Dongshan	600	—	—	6000
23	Guangdong/Nan'ao	150–750	42,880	43,380	56,780
24	Guangdong/Huilai	600	—	13200	13,200
25	Hainan/Dongfang	55–600	8755	8755	8755
26	Jilin/Tongyu	600,660	—	7260	30,060
Total			223,800	268,450	344,790

Source: Statistics from the New Energy development Division, Hydropower & New Energy Development Bureau, State Power Corporation of China.

Table 2
Average static costs for wind power generation without considering VAT and self-raised funds' profits (yuan/kW)

Item	Repayment period of loan	After repayment of loan and interest	Average cost in the whole lifetime
Depreciation	0.27	0.11	
Operating costs[a]	0.166	0.166	
Interest[b]	0.115	0	
Total	0.551	0.276	0.372

[a] Including expenses for labor, maintenance.
[b] Referring to financial expenses. kW = Cunderscore;D + Cunderscore;OM + Cunderscore;I Nunderscore; kW .
The static costs are calculated using the following formula:
C_{kW} = static costs of wind power generation in a certain period (for example repayment period of loan); C_D = depreciation expenses for fixed assets; C_{OM} = annual operating and maintenance expenses; C_I = annual financial expenses; N_{kW} = annual generation.

sion, the planned target of wind power development is still a big blueprint for China. The Government and the power industry will meet a great challenge to realize this target.

3. Economic analysis of wind generation

There are many factors that influence the development of wind power, among which generation cost and utility purchase price of wind power are considered as two key points. It is important to carry out an economic analysis for wind generation system so that we can better understand these influential factors and find the means to remove perceived barriers. Some basic assumptions can be made to measure wind generation cost.

- Total initial investment of a windfarm is estimated by US$1000 (8300 yuan)/kW.[1] Among the total investment, 20% comes from self-raised funds while the other 80% is provided through domestic commercial loans with an interest rate of 7.56% and a repayment period of 7 years.[2]
- The lifetime of a wind turbine is 20 years, and the construction time for a windfarm is one year, the depreciation period of a wind turbine is 12.5 years, and annual operating costs of a windfarm is accounted for 5% of the total initial investment.[3]
- The annual operation time of a wind turbine is 2500 h.
- Income tax of windfarm is 33% and value added tax (VAT) of wind power production is 17%.

Based on the above assumptions, the general financial evaluation method is used to calculate static average cost of wind power generation (see Table 2). The table shows that the average cost of wind generation during the repayment period of loan (years 1–7) is 0.551 yuan/kW (US$ 0.066/kWh), while it falls to 0.276 yuan/kWh (US$ 0.033/kWh) after repayment of loan and interest, if taxes and profits are not taken into consideration. The static average cost of wind generation during the whole lifetime is only 0.372 yuan/kWh (US$ 0.045/kW).

The above calculation does not take the cost of self-raised funds into consideration. The depreciation of windfarm construction is not enough to repay the loan. In order to guarantee the profit for investors, the MOEP issued a *Regulation on the Management of Grid-Connected Windfarms* in 1994, which regulated that purchasing price for wind power should be based on a pricing principle of generation cost plus repayment of loan and interest, and reasonable profit. Table 3 shows wind power generation costs calculated in terms of the above assumptions and the pricing principle. After considering the repayment of loan and interest and reasonable profit, the static average cost of wind generation during the repayment period of loan increases to 0.813 yuan/kW (US$ 0.098/kW), while it falls to 0.266–0.319 yuan/kW (US$ 0.027–0.038/kW) after repayment of loan and interest. However, these figures do not include VAT. Once VAT was taken into consideration, the costs during the two periods would reach 0.951 yuan/kW (US$ 0.115/kW) and 0.311–0.373 yuan/kW (US$ 0.037–0.045/kW), respectively. The static average cost in the whole operation period reaches 0.472 yuan/kW (US$ 0.057/kW).

The results of the above calculation shows that although wind power generation cost in the loan repayment period is very high, it is considerably lower after it, and moderate in the whole lifetime of wind power operation. Therefore, it is meaningful to calculate dynamic average cost of wind power in its 'lifetime' using the dynamic cash flow assessment method. The calculation result indicates that average dynamic cost of

[1] Figures expressed in Chinese currency have been converted into US dollars. The exchange rate is at 8.3 yuan RMB per US dollar.
[2] It is much difficult to obtain a long-term loan with a repayment period over 10 years in China.
[3] Actual annual operating costs of a windfarm should be much lower, possibly accounting for only about 2% of the total initial investment. However, a share of 5% is used to calculate the generation cost and price in most windfarms of China.

Table 3
Average static costs for wind power generation calculated according to the pricing regulation[a] (yuan/kW)

Item	Payback period of loan	After payback of loan and interest
Capital costs		
Payback of loan	0.379	0
Interest of loan	0.115	0
Payback of self-raised funds	0.053	0–0.053
Profit for self-raised funds[b]	0.100	0.100
Subtotal	0.647	0.100–0.153
Operating costs	0.166	0.166
VAT (17%)[c]	0.138	0.045–0.054
Total pre-tax cost	0.813	0.266–0.319
Total cost including VAT	0.951	0.311–0.373

[a] The pricing regulation requires both interest of loan and profit of self-raised funds must be considered in the calculation of wind generating cost.
[b] Profit for self-raised funds is calculated at 15% of investment.
[c] Including VAT surtax of 8%. kWˆ 1 = Cunderscore;c + Cunderscore;OM Nunderscore; kW .
The static costs are calculated using the following formula:
C^1_{kW} = static pre-tax costs of wind power generation in a certain period in terms of the pricing regulation; C_c = capital cost including payback of loan and self-raised funds and their interests; C_{OM} = annual operating and maintenance expenses; C_I = annual financial expenses; N_{kW} = annual generation.underscore; kW ˆ2 = (1 + Runderscore; VAT) Cunderscore;underscore; kW ˆ1 , C^2_{kW} = total static costs including VAT; R_{VAT} = ratio of VAT.

Table 4
Comparison of generating costs between wind power and other generating methods

Generating methods	Unit generating cost	
	Yuan/kW	US$/kW
Coal	0.30	0.036
Nuclear	0.51	0.061
Hydro	0.28	0.034
Wind[a]	0.56	0.067

[a] If operation cost of windfarms is estimated at 2% of the initial investment (5% is assumed in the current cost), wind power generating cost will be reduced to 0.46 yuan/kW (USdollar; 0.055/kW).
Source: Calculated by authors according to related information.

wind power in the whole lifetime is only 0.56 yuan/kW (US$ 0.067/kW).[4] Compared with conventional generating technologies, currently wind power is still not able to compete with them (see Table 4). If operating cost of wind power is estimated at 2% of the initial investment (5% is assumed in the above calculation), the dynamic average cost of wind power generation will be reduced to 0.46 yuan/kW (US$ 0.055/kW), which will basically be able to compete with nuclear power, but still higher than hydropower and coal-fired power.

[4] The generating cost of wind power in the table is calculated in terms of dynamic cost assessment methods (see to the following formula) in the whole lifetime period.

$$C_{\mathrm{kW}} = \frac{(C_F \times CRF + C_{OM} + C_R \times PVF \times CRF)}{N_{\mathrm{kW}}}$$

where, C_{kW} is the dynamic cost of wind power generation in the whole lifetime period, C_F the initial capital cost, C_{OM} the annual operating and maintenance expenses, PVF the present worth factor (based on discount rate $i = 10\%$), CRF the capital recovery factor (also based on discount rate $i = 10\%$), and N_{kW} the annual generation.

4. Institutional support and barriers

Institutional arrangements have been set up to support wind power development, considering that wind power lacks competitiveness to conventional power generation. In the following section, description about current institutional arrangements to push wind power development is made, and the barriers that impede further development of wind power are analyzed.

4.1. Institutional arrangements

The earliest initiative can be traced back to a preferential policy about customs duty exemption for imported wind turbines. A regulation about customs duty exemption was put forward and finally approved by the government in the early 1990s. The policy has had direct effect in almost all wind turbines installed, which were imported from aboard during 1990–1995. With strong expectations to establish the domestic wind turbine industry, China changed the regulation about customs duty diminution of wind turbines in 1996. The tariff ratios were adjusted as 12% for wind turbine units and 3% for major components. However, the actual duty level for turbine units was kept at 6%, so that total import tax reached 25.5% of wind turbine unit cost after adding up VAT (17%) and VAT surtax (8%).[5] The latest amendment to the regulation was made in 1998, restoring the policy to exempt import of grid-connected wind turbines from customs duty and to keep a tariff ratio of 3% for major components.

The *Regulation about Management of Grid-connected Windfarms* issued by the MOEP in 1994 is another powerful institutional instrument. According to the regulation, grid administrative authority should allow windfarms to connect with power grid at the nearest points and local utilities purchase all electricity generated by windfarms. The purchasing price for wind power should be based on the pricing principle of generating cost plus repayment of loan and interest and reasonable profit. If the price is higher than the average price in the grid, the difference should be shared in the grid.

Preferential loan and subsidy were also regarded by the government as important policy instruments to support the building of windfarms and promote wind generation technology development. For example, the "*Shuangjia*" programme, aiming at accelerating both windfarm construction and localization of wind turbine manufacture, was put into practice in 1997 by the SETC. A preferential loan of 900 million yuan (108 million US$) was invested to install wind turbines with a total capacity of 81.6 MW in four windfarms in Xinjiang and Inner Mongolia autonomous regions, and in Zhejiang and Hebei Provinces. After the Program concluded in 1997, the total installed capacity of wind turbines doubled. Furthermore, the government also provided a large amount of subsidies or appropriation expenditures to wind energy R&D organizations. For example, the State Science and Technology Commission (current the Ministry of Science and Technology) made budget allocations for tackling national or regional key technical projects. In some regions such as Inner Mongolia, Gansu, Xinjiang, etc., local governments have also used subsidies to promote the diffusion of wind power technology (Zhang et al., 2000).

4.2. Institutional barriers

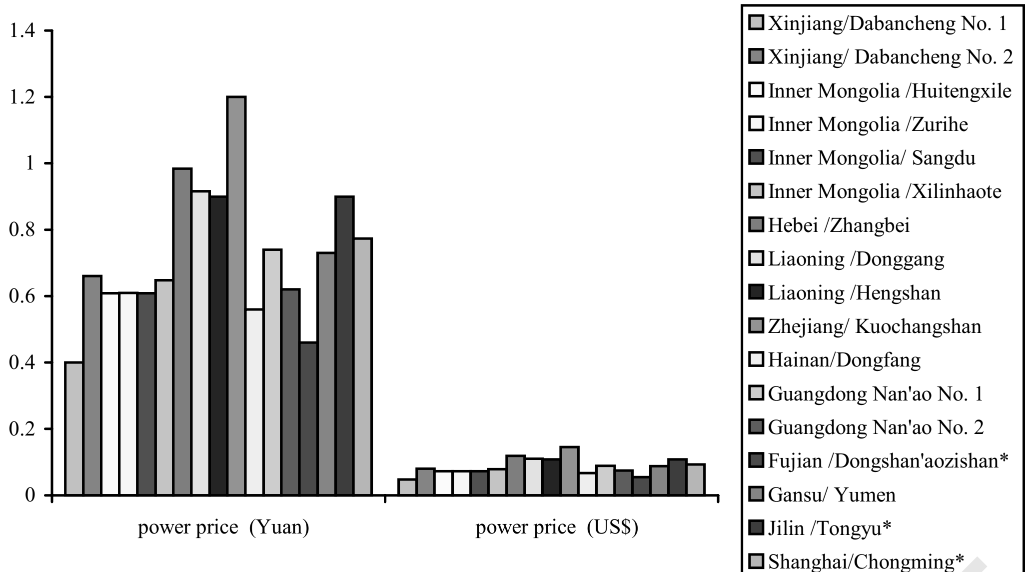
4.2.1. Pricing regulation leads to exorbitant utility purchasing price of wind power, and it has little incentive for local utilities to support wind power development, and negates the efforts of windfarm owners to reduce generation cost

The current pricing regulation assures windfarm developers to price wind power at a high tariff, so that their sale's income of wind power will cover not only all costs of windfarm construction but also the repayment of loan and interest. A certain amount of profits could even be acquired from the beginning of windfarm operation. The above assumed calculation shows that wind power should be priced, in terms of the pricing regulation, at 0.951 yuan/kW in the first period, of which payback of loans and interest account for 52%, operating costs 17%, and VAT 17% (see Table 3). This point can be seen clearly from Fig. 2, which compares wind power prices with coal-fired electricity prices in some provinces in 1997.

High price of wind power can be effective to guarantee the payback of investment, but it will inevitably lead to unwillingness of local utilities to purchase more power from clean but costly sources. In the early stage of windfarm development, the pricing regulation, which would directly bring windfarm developers profits even at the beginning of project operation, greatly stimulated investors' enthusiasm to invest in wind energy projects, and was the most powerful driving force for wind power development. However, the profit of windfarm developers, based on higher price than conventional power generation, places more and more burdens on local utilities along with the increase of installed capacity and therewith power generation. They have to depend on improving average power price paid by end-users to compensate their losses for purchasing wind power, so that the burden will finally be transferred to power consumers, because there is no other way to subsidize the price difference through such system as green power market or fixed subsidy. With the increase in wind power generation, local utilities find it difficult to compensate their losses for purchasing wind power, if they cannot increase electricity price to end-users. However, power price increase has to be approved by local government. Once it is not possible to put the burden of high wind power price onto end-users, utilities will not be willing to support large-scale development of windfarms. Lacking support from utilities, it is very hard for the wind energy industry to achieve a fast development. From this viewpoint, the pricing regulation thus distorts the original intention to promote wind energy development.

Furthermore, the current pricing principle regulates that if the purchasing price for wind power is higher than the average price of the grid, the difference should be shared among the grids concerned. This principle seems okay in theory, but cannot work in practice, because grids are administrated by different utilities or corporations, and they have conflicts in interest. For example, a World Bank/GEF "China Renewable Energy Development Project" prepared from 1998 originally planned to build a 100 MW windfarm in Inner Mongolia, but failed to have it started. Because the higher wind power price, Northern China Electricity

[5] Total import taxes ratio = (1 + tariff ratio) × (1 + VAT ratio × (1 + VAT surtax ratio))–1.



∗ under construction.
Source: Wang Y.T. (1999).

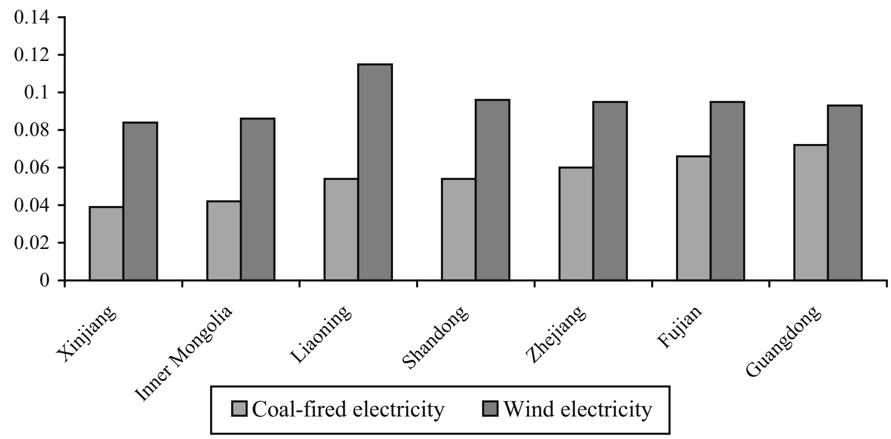
Fig. 2. Price comparison between wind power and coal-fired power in selected provinces of China in 1997.

Utility Corp. refused to share the price difference with the Inner Mongolia Utility Corp. If the price difference cannot be shared between the grids, equity issue concerning fairness arises among consumers. For example, consumers in Inner Mongolia where windfarms are built and connected to the grids might shoulder higher burden than those consumers in Beijing. Some remedies need to be done to make the principle operational, or new institutions set up to replace the principle. Perhaps, the later will be much preferable.

On the other hand, the pricing regulation theoretically makes a promise about high feed-in price of wind power to windfarm owners. However, the owners have to submit a report about generation cost and feed-in price for approval from both local price regulation authority and local utility, which are considerably subjective to approve a specific price. This point can be manifested from Fig. 3, which also shows a great diversity for practical utility purchasing prices of wind power in some windfarms in 1999. The highest price was obtained by the Cangnan windfarm in Zhejiang Province (US$ 0.145/kW), while the lowest was at the Dabancheng No. 1 windfarm in Xinjiang Autonomous Region (US$ 0.048/kW). Even in the same location, for example, Xinjiang Dabancheng No. 1 and No. 2 windfarms, have different prices.[6] The pricing regulation and the actual pricing procedure therefore cause windfarm developer to pay more attentions to strive for approval of a higher price, but care much less about efforts for cost reduction. There is no strong incentive for windfarm developers to improve management of windfarms and to reduce costs. This argument can be proved by the steady price of wind power during the course of the 1990s.[7] Comparatively, the price of wind power in UK has fallen down to an average of 3.0 p/kW of the NFFO-5 contracts in 1998 from 8.0 p/kWh of the NFFO-1 contacts when the NFFO system was first introduced into wind power industry in 1990 (Kettle, 2000). UKs experience provides a good example. However, current pricing regulation in China seems to negate most of the efforts to reduce investment and operation costs. Meanwhile, how much wind power should be priced in the second period of investment, and when the price should be put into practice, are much neglected. In fact, the real wind power prices in the repayment period of loans are considerably high (Fig. 3), generally falling into the range of US$ 0.07–0.11/kW, so that wind power has little competitive advantage compared with conventional power generation.

[6]The two windfarms are neighbors, but No. 1 windfarm is subordinate to the Department of Water Conservancy of Xinjiang and No. 2 windfarm is subordinate to the Xinjiang Electricity Utility.

[7]Custom tariffs on imported wind turbines should also have a great impact on price change, because imported turbines' cost almost accounts for as high as three-quarters of the total windfarm investment. However, custom tariffs were almost exempted in the whole 10 years' period, except 6% in the period of 1996–1998. Even so, because most of imported wind turbines were imported using foreign government grants, custom tariffs on these turbines were exempted, too. Therefore, custom tariffs should have little effects to costs and prices in a specific windfarm project. Generally, both wind power generation cost and price should have some extent of reduction because of decrease of wind turbine costs. The fact is that they were almost unchanged in the whole 1990s. According to a field investigation about windfarm in China, it is a common thought for windfarm developers to pursue a much higher feed-in price.



Source: Zhao et al. (1998).

Fig. 3. Utility purchasing prices of wind power in some windfarms of China in 1999.

4.2.2. Swinging custom tariff policy discourages the enthusiasm of domestic wind turbine producer

The most important reason directly linked to the high generating cost and poor economics of wind power is high initial investment costs. Most wind turbines (about 97%) that installed in China's windfarms were imported. The initial investment of installed capacity in 1998 was as high as US$ 1000/kW. Compared with some advanced countries such as Denmark, Germany, etc., the installation cost in windfarms of China is comparatively higher.

Exemption of custom tariff can greatly cut down windfarm construction investment, and it is an effective option to lower wind turbine cost as well as initial investment of windfarm. It is estimated that investment of windfarm construction will be reduced by 15% if wind turbine import tax is completely exempted. Therefore, the latest amendment of custom duty regulation in 1998 exempted tariff for wind turbine import, but kept 3% for major components. Obviously, the custom duty regulation does not form a protection umbrella, or create a fair competition environment for domestic wind turbine manufacturers. Inversely, it seems to be more favorable to block the progress of localization of wind turbine production.

4.2.3. Government subsidy policy has yet solved the problems in investment incentive mechanism

Because of high initial investment and poor economics, wind power cannot attract sufficient capital resources. Up to now, capital investment for wind power development mainly comes from several limited sources:

- *Government finance or policy loans*. The "Shuangjia Program" supported by the SETC is a typical example. The SDPC has also sponsored programs to provide funds for windfarm construction, and small wind turbine dissemination such as the "guangming" or the Lightness Program.
- *Grants or preferential loans from foreign governments or international organizations*. Most of these funds are soft loans with a lower interest rate or with a small amount of grant, and they are often intended to facilitate sales of wind generating equipment produced in donor countries. The annual amount of grants from bilateral sources, such as Denmark, Germany, Netherlands, Spain, USA, etc., average US$ 30–40 million. Similarly, some international organizations, such as the World Bank, also begin to provide loans to promote wind energy development in China.
- *Direct investment or financing from foreign investors*. Though some foreign companies or domestic private investors have shown great interest in windfarm projects in China, and actually some have begun their investment activities, the difficulties to get guaranty for wind power price and support from local utilities impede their further efforts.

From the above, capital investment for windfarm construction is mainly from government preferential loans with some subsidies or from foreign loans with a small part of grants or a preferential interest rate. Unfortunately, in terms of wind energy development potential in China, there is a big gap between demand and actual investment. Fundraising and financing are crucial elements to speed up wind energy development. The past trend indicates that the growth rate of wind power development is on average about 50% per year up till 1998. Current financial channels, such as government loans and subsidies, foreign grants or preferential loans, accounting for over 90% of the total investment in wind power market in China,[8] cannot keep the similar growth rate. For example, after the "Shuangjia Program" was completed in 1997, investment activities on windfarm construction shrank rapidly, and it led to a consequent slow-down of wind power capacity increase.

By contrast, private investment has become the predominant force in windfarm construction in other countries. For example, around 95% of investment in windfarms was contributed by the private sector in India (Rajsekhar et al., 1999); In Denmark, individuals established ~80% of annual capacity increase in 1998 and individually owned turbines account for the bulk of capacity expansion (Morthorst, 1999). However, unless a new investment mechanism with incentive policies and regulations is established, and more financial channels are opened up, it would be difficult to realize the target of wind energy development.

5. Turning towards cost-competitive incentives

In general, wind energy has much poorer economics compared with other conventional energy. If capacity factors of equipment were not included, wind power would require similar initial investment as hydropower, but it would be much higher than coal-fired power plants.[9] As is well known, wind turbine's capacity factor (about 0.30) is far less than those of other generating ways, so actual initial investment for per kW effective generation capacity of wind power is far more than others, such as hydropower and coal-fired power. In order to promote the development and diffusion of wind energy with a high cost and price, the government has issued a series of measures or policies, which are mostly non-market based, or administrative, measures, but not on economic incentives. Some of the policies are gradually impeding wind power development. From the viewpoint of long-term sustainable development, wind power has to depend on the improvement of its economic performance in order to be independent from government support in the future. Thus, it would be much better to establish a cost-competitive incentive mechanism to push for cost reduction in utility purchasing price of wind power. Some remedies to current institutional framework need to be done to support wind power market and to make wind power much cost-competitive in the energy market.

5.1. Eliminating monopoly and introducing a market competition mechanism so as to reduce wind generation cost

In China, local utilities usually perform three functions in the market simultaneously: power producer, power distributor, and grid manager.[10] Practically, wind energy producers are hostages to their distributors, except in circumstances where they serve isolated markets,[11] because they have to depend on grid connections to supply as well as to take power. Consequently, there is no incentive for the distributor to recognize the externalities from wind energy production and to pay a price higher than the avoided cost[12] of power of equal value to its system from the least cost alternative source (Debra, 1998; Wei et al., 1999). Thus, local utility does not enter into negotiations in good faith. Two ways can solve the problem. One is to force local utility/distributor to take wind power through the formulation of law, for example, to introduce the system of Renewable Portfolio Standard through amending electricity law (Righter, 1996; Loiter and Norberg-Bohm, 1999). Another is to directly appoint a related government agency on replace of the grid the authority to make contracts with wind power companies to take wind power (Kettle, 2000). Meanwhile, wind power sector should introduce competition force just like UK's NFFO so as to drive wind power producer to reduce its generation cost (Shao et al., 1997; Hirschhausen and Andres, 2000; Andrews-Speed and Dow, 2000).

5.2. Creating a specific and effective investment policy to attract private investment

To drive large-scale development and diffusion of wind power, it needs not only to introduce competition

[8] Because wind power development has been conducted for over 10 years, and unit cost of wind power has a great change, it becomes difficult to make a breakdown of the total investment by government finance, grants and private investment. Another reason is that relevant government agencies have no statistics about investment in windfarm. This figure is approximately estimated based on the windfarms' affiliations.

[9] Initial investment of coal-fired power plants in 1996 was only US$ 651/kW (5404 yuan/kW) and that of hydropower in 1995 was about US$ 999.5/kW (8296 yuan/kW) (China Energy Review, 1997).

[10] China is preparing to reform its electricity system, so it is possible to change the situation along with the deregulation of electricity market, which is expected to be in force several years later.

[11] Stand-alone systems includes hybrid generation systems and household-based small wind generators, which can supply most of the annual electricity needs of the site or a household. The annualized costs of these power systems work out to be several times of the present price of grid-connected electricity supply (Liu et al., 1998).

[12] Avoided cost refers to the cost saved by electric power company for using wind power substitute for conventional power generation. It consists of two parts: avoided fuel cost and capacity cost. Avoided cost of electric power companies is far less than the current feed-in price. A case study in Xinjiang Dabancheng No. 1 and No. 2 windfarms (Wei et al., 1998) shows the avoided cost resulting from large wind farm is about 0.20 yuan/kW (2.40 US cents/kW). Another case study conducted by Chen et al. (1999) indicates a result of US 2.04 cents/kW.

into wind power industry to force wind generation cost to drop, but also to set up a specific and effective investment policy to attract private investment.

Since wind power industry is more like a monopoly market under control of electricity utilities in China, it blocks the entry of private investors, though there is a regulation about management of grid-connected windfarms. Unless a clear and effective investment policy or regulation was established to reduce the risk of investment, windfarm projects will not be able to attract enough investment.

Therefore, there is no arrangement more important than a specific power purchase agreement (PPA),[13] through which the responsibility and rights of the grid and windfarm owners can be made clear, and windfarm developer and financer can estimate their profits and risks. There are two institutional barriers in establishing PPAs. First, the negotiation over terms is exceedingly complex and expensive, and the expense itself is a barrier to even initiate an effort to establish a wind energy project. Second, the major difficulty in developing such a model agreement is to determine the price at which power is to be transferred. The former may be diminished with a uniform national policy for the transfer of power in the form of a required model PPA, subject to specific adjustments under specific conditions. The simplest way to avoid the difficulty in determining the feed-in price is to make a clear regulation about a nationwide unified price for wind power according to the difference in wind energy resources. The standard payment system[14] adopted by such countries as Germany, Denmark, and The Netherlands is a good example (Meyer, 1995; Morthorst, 1999; Wolsink, 1996; Steinbuch, 2000; Wagner, 2000). Of course, it is also effective to formulate the Renewable Law like Germany. (Wagner, 2000).

5.3. *Promoting localization of wind turbine production to lower windfarm investment cost*

As mentioned above, the current method for reducing initial investment costs of windfarm constructions is to exempt import duty for wind turbines. There is another effective way, i.e. to localize wind turbine production so as to reduce initial investment costs. It is estimated that production cost of wind turbines could decrease by 30% if they were produced domestically (Wu and Ge, 1999).

China's government began to introduce advanced foreign technologies of large-scale wind turbines several years ago, aiming to improve and accelerate the development of wind generating technology. Specially, a few joint ventures between local and foreign companies have been set up to produce wind turbines. Xinjiang Wind Energy Corporation (XWEC) is an example, which has realized the local production of 600 kW wind turbines (Wu et al., 1999). However, production capacity is a prerequisite of localization of wind turbine production. Another key is to create a wind turbine market for domestic made wind turbines (Wang, 1999). Thus, market incentive should be more effective to realize the objective of domestic production of wind turbines.

From the outset, domestically produced wind turbines seem to confront an unfair environment for competition. There are two points concerning the unfairness. First, the current policy exempts imported wind turbine units from duty, and keeps that for imported components. This policy has a considerable impact on the domestic wind turbine industry. The government should urgently adjust the duty ratios to create a protective umbrella for the domestic industry (the adjustment of import tariff will be discussed in the following section). Second, current foreign government grants or preferential loans are often connected to sales of wind generation equipment of the donor country, which prevents domestic suppliers of wind generation equipment from bidding in the construction of windfarms. This will block the progress of domestic manufacture of wind turbines.

Two measures can be adopted to overcome these barriers. One is to increase domestic funds for windfarm construction and meanwhile to set up incentives to increase adoption of domestic made wind generation equipment. Another is to establish a whole set of quality measuring standards, auditing and certification systems for wind generation equipment and national criteria, through which quality of both domestic wind turbines and imported ones can be ensured. Domestic producer will have more opportunities to bid in the construction of windfarms, if their wind turbines pass quality examination and get a certificate so as to increase windfarms' confidence for adopting domestic wind turbines (Parthan, 1998; Rajsekhar et al., 1999; Jagadeesh, 2000).

5.4. *Amending or enhancing taxation policies*

Tax deduction and exemption provide an important option for government to cut the price of wind power to support its development. There are three types of taxes that have direct and powerful influence on wind power price: custom tariff, VAT and income tax. Among them, only a preferential custom tariff policy has been adopted

[13] The PPA sets the terms by which power is marketed and/or exchanged. It sets the delivery location, power characteristics, price, quality, schedule, and penalties for the failure to meet contracted terms.

[14] The buy-back rate is equal to a certain proportion, 85% in Denmark and 90% in Germany, of the consumer price of electricity in the distribution area where the turbine is located. On average, it is about 0.33 DKK/kW (4.4 c Euro) and 0.16 DM/kW in these two countries.

by the government up to now. Any favorable rules or regulations in the field of VAT and income tax are not introduced to wind energy industry.

5.4.1. Custom tariff

The defects and advantages of current tariff policy have been described in previous sections. The government should make some remedies to current regulations. At the least, a much higher rate of tariff should be kept for imported wind turbine units, while a lower rate should be imposed for components that cannot be manufactured domestically.[15]

5.4.2. VAT on power production

Though China made a great effort to set up a tax system for wind turbines, and reformed it in 1994. It is still unfair for the wind power industry. At present, windfarms have to hand in VAT at a rate of 17% to tax authorities. Unlike other conventional power production (such as coal-fired power generation), wind power generation has minimal fuel consumption. Wind power producers have no fuel costs to deduct from their profits, so that they have to hand in a large amplitude of VAT. However, current VAT ratio for small hydropower, which has similar characteristics as wind power, is only 6%. Thus, it seems to be unfair for wind power industry. Many experts recommend reducing the current VAT rate of wind power production to the same level as small hydropower.

5.4.3. Income tax on windfarms

Income tax privileges for wind energy enterprises are still not adopted as an incentive policy in China. At present, windfarms are charged with an income tax of 33%. However, there are enormous privileges for other types of enterprises, such as foreign companies, joint ventures, high and new technology firms, etc. To establish a better and fair environment for wind energy, and renewable energy as a whole, the government should, at least, grant wind power production enterprises privileges for partially deducting income tax burden, for example, levying half of the current income tax rate.

5.5. Providing subsidies for wind power generation, but not for windfarm investment

Just as the proposals made by many experts in India about the shift from capital-based incentives to production-based incentives, which need to be urgently undertaken (Rajsekhar et al., 1999), China also needs to change its subsidy policy for wind power development. As a major incentive, it will be more cost-effective to provide subsidies for wind power output than for initial investment. Under the current pricing regulations, subsidies for investment are less effective to improve the management of windfarms, while subsidies for output will stimulate wind energy developers to increase wind power generation and cut down production costs. To keep the subsidy policy effective, there must have enough funds. The best solution is to set up a special fund for wind energy development (perhaps renewables as a whole) through some measures such as green tax, carbon tax or incomes from green electricity so as to alleviate the pressure for government finance (Speck, 1999; Vahmas et al., 1999).

6. Conclusions

As a source of clean energy, wind power has a great development potential in China. Under the current situation, wind power has difficulties to compete with other conventional power generation technologies. Like in many other countries, China has attempted to provide favorable policies to advance the development and dissemination of wind energy. Tax deduction and exemption are used as important instruments for the government to support the development of wind power. It is evident that solo government support to wind power development will be effective in market operation unless private sector participation is actively promoted and implemented. Wind power producers, faced with uncertainty of deregulation, have found investment in wind energy a risky business. It is also clear that various institutional barriers need to be removed in order to realize the ambitious target for wind energy development. To set up a more rational policy environment for wind power becomes a necessity. Such efforts are in progress, though they are insufficient, especially the government lacks a single coherent and internally consistent policy and institutions. It is partly because the current institutional frameworks for policies and regulations are complex and ineffective.

Two points can be made concerning this issue. First, unlike UK's solution to authorize the Department of Trade and Industry to coordinate other related government agencies to formulate wind power regulation or policy, the responsibilities for policy formulation in China appear to be shared by several government agencies: SDPC, SETC, MOST, the Ministry of Agriculture (MoA), and even the powerful grid administrator: the State Power Corporation. The current governance structure in China suffers from the fact the responsibility for wind energy policy formulation is not clearly assigned to a single government institution. Because China had already reformed its central

[15] Along with the progress of China's entry into the World Trade Organization (WTO), the custom tariffs were revised again at the end of 2000. The new amendment regulated custom tariff for imported wind turbine units to be at 12%, and for components at 3%.

governmental organization framework in 1998, it seems not to be feasible to set up a new agency, e.g. like India's Ministry of Non-conventional Energy Sources (MNES), through another governance reform. One more feasible solution, therefore, is to make clear functions and authorities of all related agencies, especially on their authority and obligation in policy formulation. Through improved coordination and cooperation, relevant government agencies should make joint efforts to:

- Work out rational preferential policies or regulations, including tax, investment, subsidy and pricing, etc.;
- establish a fair, competitive market environment, especially for domestic wind turbine production; make clear rules for utilities not to abuse their market monopoly power;
- support public R&D of wind generation technology, and localization of wind turbine production;
- set up wind energy development funds to provide support to wind power generation; and
- establish a national quality control, monitoring, and supervisory center for domestic wind turbine production and industry development.

7. Uncited references

European Commission, 1997; Hydropower & New Energy Development Bureau of the State Power Corporation, 1998; Mathur and Shah, 2000; Mays, 2000; State Economic and Trade Commission (SETC) of China, 2000; Zhao et al., 1998.

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