CACETC

CHINA WIND POWER

Study Report

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China Wind Power

1. Current situation of wind power technologies

1.1. International development of wind power technologies

In the near term, wind energy is one of the renewable energy sources that has very good prospects for large scale expansion. During the past 20 years wind power has rapidly developed from the research and development phase to become a mature technology, with generating costs reduced from 20 US cents/kWh to 5 US cents/kWh, close to the cost of conventional energy. As with other renewable energies, such as solar, biomass and ocean energy, wind power is a newly established industry, and is currently the fastest growing power source in the electric power sector. Compared to other power sources, wind power is clean, without harmful emissions and problems of resettlement. In addition, wind power is an effective method of mitigating greenhouse gas (GHG) emissions, especially CO_2. Wind power can also help protect the local ecological and environment situation and improve the structure of electric power industry.

Many countries have formulated development plans and incentive policies in the last 20 years, and have facilitated technology improvement and market exploration. The unit capacity of commercial wind turbines has increased from 55kW to 1650 kW, and the cost of wind power has reduced continuously. About 10,000MW of wind turbines were installed worldwide by the end of 1998; energy production was on the order of 20 TWh. Wind has been increasing by more than 2000 MW of new installations each year, at an annual growth rate of 27%.

Denmark was the first country to generate electricity by wind, and is currently in the leading position of wind turbine technology and production. Currently, 1480MW is installed, equaling more than 5% of total installed capacity in the country. By the end of 1998, 2870MW of wind power had been installed in Germany, which leads the world in wind power capacity. Other countries with more than 100MW of wind power are the USA with 1870MW, India with 970MW, Spain with 830MW, the Netherlands with 360MW, the UK with 330MW, China with 224MW, Italy with 180MW and Sweden with 170MW. Global wind power installed capacity and cost per kWh are listed in Table 1.

Table 1 Global wind power installed capacity and cost

	1983	1985	1987	1989	1991	1993	1995	1997	1998
Total MW	140	940	1440	1710	2160	2980	4830	7600	1000
kW/unit of major type	30	55	100	150	200	300	500	600	750
cost(US cent/kWh)	15.3	10.9	7.2	6.6	6.1	5.6	5.3	5.0	

1.1.1. Wind power development in Europe

Germany

A comprehensive policy system for supporting renewable energy has been established, including:

- Measures provided by the "Electricity Feed Law" went into effect in 1991: utilities must purchase all of the electricity generated by renewable energy sources, and the standard power purchase price should be 90% of the average selling price, i.e. DM 0.16/kWh (US$ 0.102) compared to the power purchase price for conventional power plants of DM 0.10/kWh. The price difference is be shared by all end users.

- Via the 250 MW wind power program of the Ministry of Research and Technology, the government offered a DM 0.06/kWh production subsidy to the owner of wind farms until 1996.

- Wind farm developers may apply for a subsidy from local government, ranging from 20 to 45% of the total investment.

- The German policy bank under the Ministry of Economy may provide financing for up to 80% of the total investment, for medium or small wind farms of sales volumes less than DM 500 million.

- An improved wind power investment system has been established for individuals to become shareholders in wind facilities.

The improved environment for wind power in Germany resulted in rapid development, with installed capacity increasing from 100MW in 1991 to 2870MW in 1998. Germany became the world leader in wind, overtaking the USA.

Denmark

In 1979, an investment subsidy of 30% was provided to wind turbine owners. This subsidy ended in 1989. A power purchase agreement was signed between the government and the Danish Electric Power Federation in 1985, stating that state owned power companies must purchase all electricity generated by renewable energy, at a price guaranteed to equal to 85% of the average selling price. In addition, non-utility owners of wind were eligible for a refund of the CO_2 tax and energy tax (including VAT of energy tax). In this way, the purchase price of wind power increased from DKK 0.38/kWh to DKK 0.60/kWh.

The installed capacity in Denmark increased from 400MW in 1991 to 1480MW in 1998, equaling 10% of total electricity consumption. A strong wind turbine industry has been established: Danish companies have about half of the world wind market.

UK

The “Non Fossil Fuel Obligation (NFFO)” law was implemented by the British government, which states that all electricity consumers will be taxed to pay for nuclear power and wind power. Projects will be selected by tendered bids, and the developer with the lowest bid price wins the contract. Compared to other countries, wind power growth was slow in UK, increasing from 40MW in 1992 to 340MW in 1998.

In summary, the main measures used in Europe to stimulate wind power markets are:

- Laws requiring utilities to purchase all electricity generated from renewables
- Laws requiring renewables to be a certain percentage of all power generation
- Subsidies for wind power investments
- Exemptions or reductions in taxes
- Preferential tariffs for electricity from renewables

Current policy trends are to keep preferential tariffs and stop direct subsidies. Major incentive policies in Germany, Netherlands and UK are listed in Table 2.

Table 2 Major incentive policies in Germany, Netherlands and UK

	Purchasing wind power	Percentage of wind in power mix	Preferential tariff	Exemption or reduction from taxation	Subsidy for investment
Germany	Electricity Feed Law(1991): Utility required to purchase all electricity from renewables		Tariff of electricity from renewables sales to utility should be 90% of average retail price		local governments provide subsidies of 20% to 45% of total investment
Denmark	State owned utilities required to purchase all electricity from renewables		Tariff of electricity from wind sales to utility should be 85% of average retail price	Refund of CO_2 tax and energy tax available for non-utility owners	Subsidies of 30% of total investment were given to investors in 1979
UK	Tendering for wind power projects according to NFFO by government	NFFO in power law	Preferential tariff paid for wind power; all power consumers obligated to share incremental cost of wind		

1.1.3. Wind power development in the USA and India

USA

In 1978, a federal law was passed that required utilities to purchase renewable energy at their avoided cost.

Before the end of 1985 investors in wind farms could obtain tax credits of 25% from the Federal Government and 25% from the California State Government. By the end of 1985, this policy had stimulated installation of 1000MW of wind capacity. After 1985 followed very slow growth in USA - it took 13 years for the US to surpass 2000MW.

At present, a Federal Government regulation allows a 1.5 US cent/kWh production tax credit. Some states now require a minimum percentage of renewable power generation in the power mix, and property tax and sales tax may be exempted.

India

As a part of the Eighth Five-Year Plan (1993 - 1997), the Indian Government put forth a comprehensive engineering program to expedite the construction of 2500 MW renewable energy, including 600 MW of wind power. This program included fundraising, site selection, application of electric power, import tax and wind resource measurement. This program was organized and implemented by the Ministry of Non-Conventional Energy, with the Indian Renewable Energy Development Agency responsible for raising funds. So far the target has been realized. During the year 1995, 300MW was installed and the total capacity in 1998 reached 970MW.

The rates of import tariffs can help to introduce technology and domestic manufacturing, i.e. tax-free for those components not manufactured locally, but high rates for those already made domestically. For example, the import tariff for the tower is 65%, compared to 25% for the complete machine.

The government allowed 100% depreciation within the first year for wind farm, and allowed revenues to be tax-free for the first five years.

Due to electricity shortages, power supply is rationed for enterprises in India. This encourages enterprises to invest in wind power. Wind electricity can be “banked” at the utility, and if the power supply is cut or reduced, those enterprises have priority to get power supply. Also, the power from wind farms can be "wheeled" through utility grid to the enterprises for a modest charge, typically 2% of the value.

The Indian Renewable Development Agency is able to offer "soft" loans for wind farm developers with interest rates that are lower compared to commercial banks.

1.1.2. Experiences and lessons

Wind power is an effective way of mitigating CO_2 emissions. In European countries wind power development is seen as one of the measures to realize their promise of reducing GHG emissions. They passed laws to promote wind power and laws requiring preferential tariffs for wind power that were kept stable for many years. The tariff difference between wind and conventional coal fired thermal power was subsidized through CO_2 and energy taxes, which were collected from all consumers of electricity. These measures enabled continuous rapid development of wind power and created a strong wind turbine industry.

The USA and India have issued many incentive policies to stimulate the development of wind power, however, the instability of these measures led to a boom-and-bust market: wind power boomed for a few years and then slowed down for many years. In the process, several wind turbine manufactures went bankrupt.

1.2. Current wind power development in China

1.2.1. Evaluation of wind resources and assessment of GHG emissions mitigation

1.2.1.1. Potential and distribution of wind energy resource in China

The value of total wind energy potential at 10m height in China has been estimated to be 3226GW, in terms of “theoretical wind potential”. However, the “practical wind potential” at 10m height in China has been estimated to be 253GW.

This estimated value of wind energy potential is larger than the total installed capacity of electric power in China in 1996. It gives an impression that China is rich in wind energy resources; however, more a detailed survey is urgently need to reach the potential capacity which could be real utilized economically. In addition, along the coast line of east China, offshore areas with a water depth between 2m and 15m are extensive. In these regions the wind speed is higher than onshore and the air flow is less turbulent. Also these offshore wind farm sites are closer to the main electricity load centers in eastern China. With such great potential for the development of offshore wind farms, a wind resource survey should be started.

In China, areas rich in wind energy resource are mainly in the grassland or gobi of northwest, north and northeast China, as well as coastal area and islands in east and southeast China, where there is usually a lack of coal and other conventional energy resources. Strong winds occur in the winter and spring. During the summer, the wind is not so strong but there is heavy rain fall, making wind and hydropower seasonally complementary. The provinces rich in wind energy potential are listed in Table 3.

Table 3 Provinces rich in wind energy potential

Province (region)	Wind potential (MW)		Province (region)	Wind potential (MW)
Inner Mongolia	61780		Shandong	3940
Xinjiang	34330		Jiangxi	2930
Heilongjiang	17230		Jiangsu	2380
Gansu	11430		Guangdong	1950
Jilin	6380		Zhejiang	1640
Hebei	6120		Fujian	1370
Liaoning	6060		Hainan	640

Source: China Academy of Meteorological Sciences

1.2.1.2. Assessment of GHG emissions mitigation

Assuming that the average wind farm has 2500annual full load operation hours, (i.e., 1kW installed capacity of wind power will produce 2500kWh of electricity), the potential annual energy production by 253GW of wind power is estimated to be 632.5TWh. This would result in the mitigation of 750 million tons of CO_2 each year.

1.2.2. Development of wind farm

Grid-connected wind power is the most effective way of utilizing wind energy on a large scale. A wind farm, or wind power plant, is created by installing many grid-connected wind turbines at a site with good wind energy potential, forming an array according to geographic terrain and prevailing wind direction, to generate electricity that is fed into the power grid.

1.2.2.1. Demonstration phase of scientific research

In 1985 a 55kW commercial wind turbine was imported from Denmark by the Ministry of No.1 Machine Building Industry and installed in Dongfang of Hainan. In April 1986 three of these turbines were imported jointly by the Ministry of Aeronautic Industry and the Shandong Provincial Planning Commission, and installed in Rongcheng of Shandong. This is the earliest wind farm composed of commercial turbines in China. Successful grid-connection was of great significance, because this was the first demonstration in China that wind power could be a new source in the power grid. In October 1986 a 100kW turbine was imported by the Water Resources Bureau of Xinjiang and installed at Dabancheng; in 1989 the Nan'ao wind farm of Guangdong and Zhurihe wind farm of Inner Mongolia were established, with turbines imported from Sweden and the USA, respectively. Additional turbines were installed through international science & technology cooperation or soft loans provided by foreign governments: four 200kW turbines, the largest turbines in China at that time, were donated by the Belgian Government and installed on Pingtan Island of Fujian in 1986; another thirteen 150kW turbines provided by the Danish government were installed at the Dabancheng wind farm of Xinjiang. The demonstration phase of wind farm construction ensued from 1985 to 1990: five wind farms were built, with more than 30 units, averaging 130kW each, and totaling 4MW.

1.2.2.2. Initiation of industrialization phase

The size of wind farms expanded gradually during 1991 to 1995, mainly through soft loans from foreign governments. The first wind farm with more than 10MW was Dabancheng No.2; other wind farms included Shangdu of Inner Mongolia, Donggang and Hengshan of Liaoning and Hedingshan of Zhejiang. By the end of 1995, there were 14 wind farms nationwide, with 180 units, averaging 200kW each, and totaling 37MW.

After 10 years of experience from demonstration projects and international wind power development trends, along with improvements of technology and increased scale of projects, costs are decreasing continuously. At the same time, due to exhausted resources and increased environmental standards, the cost of fossil fuel fired conventional power plants is increasing. In order to improve the structure of electric power sector, the Ministry of Electric Power decided to accelerate the commercialization of wind power. They formulated a regulation on connection of wind power to the power grid, issued standards on wind power engineering, and officially included wind power in the national electric power development plan, thus starting a new phase of large scale development of wind power.

1.2.2.3. Development phase of scope economy

In May 1995 the Ministry of Electric Power held the Beijing International Conference on Wind Energy (BICWE'95) and announced their goal of 1000MW of installed wind power by the end of the year 2000, thus attracting attention both domestically and internationally. Wind power projects of 80MW had been involved in the national technology innovation program, called "Shuang Jia" Engineering, in which the State Economic & Trade Commission (SETC) would subsidize bank loan interest. A great deal of soft loans were continually provided by foreign governments for wind power development. Financing organizations worldwide, such as the World Bank (WB) and Asian Development Bank (ADB), etc., gave wind power a high priority for investment, associated with grants from the Global Environment Foundation (GEF).

During 1996-1998, wind power had more rapid development: new installations of 346 units, averaging 540kW each, and totaling 187MW new installations were installed in those three years. Wind power projects in the "Shuang Jia" Engineering program were completed, including 40MW in Dabancheng of Xinjiang and 20MW each in Huitengxile of Inner Mongolia and Kuocangshan of Zhejiang, with more economical, larger-scale development. By the end of 1998 total installed capacity in China reached 224MW in 19 wind farms. The biggest one is Dabancheng of Xinjiang (66MW); other wind farms surpassing 30MW were Nan'ao of Guangdong and Huitengxile of Inner Mongolia (see Table 4).

By the end of 2000, there was available funding sources through various projects for an estimated 960MW of installations, e.g., 190MW through the World Bank-funded project. In general, the power supply in China shifted from a shortage to a surplus and the electric power industry began restructuring, e.g., separation of generation from transmission and distribution, competition between generators based on price, and establishment of a normative power market. Currently, since the cost of wind power is still higher than that of conventional coal fired power, support by national incentive policies is necessary. These could include bank loans, taxation and tariffs of electricity, etc.

Table 4 Installed capacity of wind farms in China by end of 1998

No.	Province /Wind farm	kW/unit	Total kW
01	Xinjiang /Dabancheng No.1	100-600	8500
02	Xinjiang /Dabancheng No.2	300-600	57500
03	Xinjiang /Buerjin	150	1050
04	Gansu /Yumen	300	1200
05	Inner Mongolia /Huitengxile	600	36100
06	Inner Mongolia /Zhurihe	100-300	4200
07	Inner Mongolia /Shangdu	55-300	3875
08	Inner Mongolia /Xilinhot	250	1000
09	Heibei /Zhangbei	275-600	9850
10	Liaoning /Donggang	55-550	12005
11	Liaoning /Hengshan	250	5000
12	Shandong /Changdao	55	110
13	Shandong /Rongcheng	55	165
14	Zhejiang /Sijiao	30	300
15	Zhejiang /Kuocangshan	600	19800
16	Zhejiang /Hedingshan	55-500	10255
17	Fujian /Pingtan	55-200	1055
18	Guangdong /Nan’ao	150-550	42880
19	Hainan /Dongfang	55-600	8755
	Total		223600

Source: Dept. of Hydropower & New Energy Development
State Power Corporation of China

1.2.3. Case studies of technology transfer in China

1.2.3.1. Xinjiang Wind Energy Company – licensing of Jacobs turbines

In the Dabancheng wind farm No.1, which was developed by Xinjiang Wind Energy Company (XJWEC), there are six types of wind turbines: BONUS 150kW, AN BONUS 450kW, Jacobs 500kW, TACKE 600kW, WINCON 100kW and MICON 55kW. After comprehensive comparisons in availability, economic, erection, operation and system design, the operation record showed that the advanced technology of the Jacobs 500kW turbine had the highest availability

among similar types of turbines, and good economic performance.

As a result, a 600kW fixed-pitch three-bladed machine designed by Jacobs of Germany was selected for local manufacturing. The product had obtained certification from GERMANISCHER LLOYD in Germany. Jacobs agreed to transfer their technology by licensing production: Jacobs provided the manufacturing technology and license; components produced in China were to be procured by XJWEC; the rest of the turbine was offered by Jacobs; and the percentage of locally made components was to increase gradually.

The strategy of localization of technology carried out by XJWEC was as follows: Import the design and manufacturing technology of the model 43/600kW wind turbine; understand the philosophy of turbine design; partial local manufacturing; full local manufacturing; and finally, innovation.

Chinese experts, including engineers from component manufacturers, visited Jacobs and other component supplier facilities in Germany; then the training of Chinese technicians was implemented. Jacobs experts also visited China for supervision and training. The first prototype machine with 38% of Chinese components was erected in June 1998, and the ninth, with 70% of locally manufactured parts was installed in November 1999. The operating record of these turbines shows good performance, equivalent to imported turbines.

1.2.3.2. State Development Planning Commission “Ride the Wind” program

In order to obtain technology by providing a market, and to establish a high-quality Chinese wind turbine manufacture industry, the “Ride the Wind” program was issued by State Development Planning Commission (SDPC) in March 1996. The goals of this program were:

- To establish joint ventures for imported technologies by providing orders of a certain quantity of wind turbines;
- To produce large machines with 60% of locally manufactured components;
- To organize R & D projects for large wind turbine technologies.

The program tasks were:

- Analyzing the status and future development of large wind turbine technology, and identifying the type and series of turbine for local manufacture;
- Tender for and selection of two factories as final assembly and related firms for supply of key components, forming a “state team”;
- Organize research forces in different industries, through key R & D projects, to help the enterprise master the key technologies of wind turbines;
- The final assembly factory is responsible for finding a foreign partner for the joint venture and transferring the manufacturing technology and part of design technology, starting with assembly and then increasing the percentage of local made components; finally the key components should be made in China.

The foreign partner of the joint venture is requested to transfer all technology including turbine design, in return for orders of equipment for wind farm projects, including those financed by the World Bank or other international organizations. The "state team" should understand the imported technology and have their own R & D ability. Key components such as generators, gear boxes, blades and controllers should be made available in China.

1.3. Localization of wind power facilities manufacture

1.3.1. Key scientific research

- Grid connected wind turbines of 30kW, 40kW and 55kW were developed in the 1980's in China. Prototype machines of 200kW were also developed in the 1990's, but due to the market situation or lack of current market demand for this size, most of them are not commercialized.
- As a key R & D project of State Science & Technology Commission (SSTC), the 200kW wind turbine developed by the Zhejiang Academy of Mechanical & Electrical Engineering passed appraisal. Five of these units were made and installed on Nan'ao to verify long-term operational performance. A batch production has now been prepared.

1.3.2. Technology import

- As mentioned above, a licensing production agreement has been signed between XJWEC and Jacobs of Germany. The first ten 600kW prototype machines were produced with 40% to 78% of Chinese components.
- Supported by the "Ride the Wind" program of SDPC, two joint ventures were established: the Yituo Group and MADE of Spain, and the Xi'an Aero-Engine Group and Nordex of Germany. Wind turbines of 660kW or 600kW capacity will be produced locally soon.
- A 600kW turbine imported from Austria by the Beijing Wandian Company, with Chinese-made blades, will be installed in Inner Mongolia.
- Many Chinese component suppliers, such as gear box and generator suppliers, are active not only in the domestic wind turbine market, but are also interested in supplying to the international market.

1.4. Stimulating policies for wind power development

(1) Regulation on the issues of wind power connecting to grid

A regulation was formulated by the former Ministry of Electric Power in 1994, with the following stipulations:

- The grid administrations must allow wind power to be connected to the nearest grid and must purchase all electricity generated by wind.
- The tariff setting principle in the loan repayment period is "recovery of principal & interest plus reasonable profit". The difference of the actual tariff and average tariff will be amortized by the whole grid and purchased by the utility.

This policy was confirmed by the SDPC and the Ministry of Science & Technology in 1999. Problems of wind power connecting to the grid were solved, but the issues on tariff have still not

been completely settled. Since the tariff of electricity is controlled by the provincial government, the scope of grid and who pays the incremental cost have not been clearly identified. Environmental benefits are a social issue; the price difference between wind and coal should be shared by all consumers of the power grid, beginning with the scope of the provincial power grid, and later extending to the whole society.

(2) Import Duty

The import duty for a complete wind turbine is 12% and for wind turbine components is 3%. The rate of Value Added Tax (VAT) associated with the import duty is 17%. The real value of import tax paid should be 31%, since the cost of equipment is about 70% of the total investment of the wind farm project. In case domestically manufactured wind turbines are not available, the cost of electricity generated by wind will be increased by 20% when paying the full import tax. Since January 1, 1998, wind turbines larger than 300kW are duty free, to promote the development of wind farms. In order to encourage local manufacturing, the import duty should be levied on complete turbines and components which are manufactured in China. For those components that are not yet made in China, tax exemption is necessary; the list of specific parts should be checked once a year.

(3) VAT of sale electricity

The rate of VAT is 17%. For coal fired power plants the real value of the VAT is less because coal is purchased. Wind power plants do not purchase fuel and must pay the full rate of the VAT. Suggestions have been made to set the rate for wind to 6%, same as for small hydro.

(4) Income tax

Policies which encourage the use of foreign investment or for high technology can have tax exemptions and reductions in a certain period.

(5) Bank loan with subsidized interest

Wind power projects using bank loans for basic construction can apply for subsidies of 2% of the bank interest rate from the government.

(6) Payback period of bank loan

At present the payback period for domestic bank loans is 7 years. Because a limited amount of energy can be produced by wind farms in such a short time, the tariff of electricity must be high enough to recover the capital and interest. Increasing the payback period to 15 years has been proposed: it would make the tariff of wind electricity competitive with newly built thermal power.

(7) Land acquisition

The area of land acquisition should be based on land actually occupied by wind farm facilities, with some discount rate for the compensation of using the land.

All of the aforementioned incentive policies propose to bring down the investment of wind farm projects, in order to reduce the price difference between wind and conventional power thus making wind power more attractive.

China's abundant wind energy resources, growing economy and stricter environmental protection requirements all indicate that clean wind energy must be an important part of China's sustainable energy development in the 21st century.

2. Difficulties in the development of wind power and technologies needed to be transferred

The main difficulties in the development of wind power in China are:

- Lack of funding for resource assessment – the economic wind potential is still unknown; advanced wind measurement equipment and resource assessment technologies are urgently needed.
- The high cost of wind turbine generators requires a high initial investment and high tariff for purchase of wind-generated electricity.
- The cost for transferring the technology of manufacturing wind turbines is expensive. The ability to develop domestically made wind turbines needs to be strengthened and the quality of new products needs to be improved. The market for wind power is difficult to expand.
- Lack of wind turbine performance test technology and equipment. Certification for grid-connected wind turbines has not been established in China.
- Standard power purchase agreements between independent power producer and utility have not formulated. The rights and benefits of investors should be protected by law.

2.1. Resource assessment

2.1.1. Lack of sophisticated resource assessment technology

The area of mainland and offshore shallow seas are huge in China. A great deal of funds and manpower are needed for a detailed wind energy resource assessment. Since China lacks a sophisticated macro wind energy resource assessment technology, the progress of wind assessment has been very slow, and none of the provinces or regions has prepared local wind maps.

A computer model for macro wind energy resource assessment has been developed by the National Wind Technology Center (NWTC) in the US National Renewable Energy Laboratory (NREL). The US Environmental Protection Agency (EPA) supported a wind mapping project for a region along the southeast China coast and NREL generated preliminary results by using existing databases. EPA also provided several automatic wind loggers which were installed in 6 wind sites of Jiangxi, Fujian and Guangdong provinces. This data is collected and transmitted to NREL. At least a year's worth of onsite measurement data will be used to verify the preliminary results to refine the accuracy of the wind map. This kind of technology urgently needed for the remaining provinces and regions, as well as offshore shallow sea areas in China.

A wind energy resource database has been established in the NWTC of NREL, including global digital maps, surface and balloon wind data from meteorological stations, and satellite and

ship data. Use of these databases and computer models for China would facilitate the process of detailed wind energy resource assessment.

2.1.2. Chinese wind loggers are not suitable for gathering data on wind power

Wind data from detailed onsite measurements are crucial for development of wind power on a large scale. However, the existing wind loggers made in China are not suitable for wind power but for meteorological stations. Imported wind loggers are more expensive, resulting in fewer measurement stations and thus less accurate assessments.

There are several US firms of wind measurement equipment that lead this market. US/Chinese business partnerships in this sector could result in equipment cost reductions through local manufacturing and increased installations.

2.2. Technology of wind farm design

Currently in China the wind farm design tools are imported from Europe, which are not suitable for complex terrain and result in large errors in the estimation of the energy production of the wind farm. Optimal design tools for wind farm in complex terrain are needed.

2.3. Local manufacture and design of wind turbine generator
2.3.1. Technology for large-scale wind turbine design is needed

In order to develop wind turbine technologies suitable for Chinese wind regime, performance and load design software packages are very useful tools. The NWTC at NREL has engaged in extensive research on wind turbine design and has helped to develop software models for turbine design. In China, assistance and training in use of design tools to develop Chinese wind turbines are needed.

2.3.2. Lack of advanced testing technology for wind turbine product certification

Manufacturing of large-scale wind turbine generator has been initiated in China. Testing and certification are crucial to guarantee the safety of the new product, however. China lacks the advanced technology and equipment for the testing. China would like to have the capabilities to implement onsite safety and performance testing on large wind turbine installations. Transfer of testing technologies is important for further development of a local manufacturing base.

3. Draft action proposal

(1) Resource assessment
There are three main activities to be implemented in wind resource assessment:

- Wind mapping based on the wind data and macro resource assessment model at NREL - high priority areas include the east China coast, onshore and offshore islands, as well as shallow sea areas with water depth between 2m to 15m; the north part of Hebei province; the east part of Inner Mongolia and Heilongjiang province; and the west part of Liaoning and Jilin province.

- Onsite measurement at potential wind sites - install wind loggers and collect data for a full year so that wind maps can be verified by NREL. The goal is to identify good wind sites for installation of 5000MW of wind capacity by the year 2005.

- Training: standards of wind measurement equipment installation, data processing programs, guidelines for site selection, etc. The goal is to determine an appropriate methodology and to standardize the wind resource assessment for all provinces or regions.

(2) Local manufacture of wind measurement equipment

Create US/Chinese business partnerships in this sector to facilitate local manufacturing of automatic wind data loggers and wind measurement equipment that are suitable for wind energy resource assessment in China.

(3) Optimal design tools for wind farm in complex terrain

Select optimal design tools for wind farms, with an emphasis on tools that can applied to complex terrain, and which will result in more accurate estimation of energy production. Identify or assist in development of suitable design tools for China and train Chinese engineers in their use.

(4) Technology of wind turbine design

Research on the theory of large-scale wind turbine design has been performed at the NWTC for many years. Develop cooperation with Chinese organizations on identification of or development of wind turbine design software packages and train Chinese engineers in the application of the wind turbine design software package.

(5) Advanced testing technology for wind turbine product certification

NWTC has extensive experience in wind turbine testing. Provide assistance in establishing a Chinese wind turbine test center and provide training on testing protocols.

(6) Workshop on financing pathways and/or to present wind farm opportunities to private investors and developers

After identification of good wind sites and renewable energy policy implementation by the government, a workshop can be held to discuss various financing pathways, to present wind farm opportunities to private investors and developers, and/or to exchange experiences and solicit input from investors on wind farm development in China.