Support for Wind Resource Assessment and Wind Farm Development in China

W.L. Wallace, Z.Y. Wang, and S.J. Liu
NDRC/UNDP/GEF Project Management Office

Abstract: *China has an enormous potential for wind power development estimated at as much as 250 GW inland and another 750 GW offshore. Installed wind capacity in China in 2005 reached 1.26 GW with the addition of 498 MW, a 252% increase in new installations over 2004. Interest in the commercial development of wind power is also increasing with passage of the Renewable Energy Law in February 2005 and the establishment of strategic planning targets by the National Development and Reform Commission (NDRC) of 5,000 MW in 2010 and 30,000 MW in 2020 for wind development. Since the year 2000, the United Nations Development Programme and the Global Environment Facility have cooperated with the NDRC to pursue a site characterization program to expand the wind resource information base for commercial development and increase the capacity in China for wind resource assessment and analysis. This paper will review support for resource assessment and trends for wind energy development in China, and update information on the National Wind Concession Program, national planning targets, and policy support for commercial development from the Renewable Energy Law.*

Key words: *Wind power development, resource assessment, wind farms, project development*

1. Introduction

Worldwide wind development has been accelerating with an average annual growth rate of 20% over the last five years, due to the favorable implementation of government policies in Europe and the US and the increasing recognition of the investment potential for wind by corporate, institutional, and private investors. Installed cumulative global wind capacity grew to 60,000 MW at the end of 2005, an increase of 11,407 MW from 2004, representing a 40% growth in new installations. While most of this growth took place in the US and Europe, strong development also occurred in Asia with India installing 1,253 MW to become the fourth largest market and China installing 498 MW to become the sixth largest market in 2005 [1].

1.1. Potential and Current Scale of Development of Wind in China

China has an enormous potential for wind power development estimated at as much as 250 GW inland and another 750 GW offshore for a total of more than 1000 GW. Cumulative installed wind capacity in China in 2005 reached 1,264 MW with the addition of 498 MW, a 252% increase in new installations over 2004, and China is now ranked eighth in the world in terms of cumulative capacity. This development has been accelerating in recent years, for example, during the last seven years the average cumulative installed capacity has been increasing at an average rate of 25% per year. During this period the development of wind power in China has made a transition from a heavy reliance on bilateral grants and soft loans to commercial development supported by domestic and international sources of investment.

The Chinese Government has also been providing support for an increasing scale of wind development through a wind concession program initiated in 2002. In the wind concession program, contracts are awarded on the basis of competitive bidding to establish the lowest price offer, after which power purchase agreements guarantee the electricity tariff for 15 years (30,000 full load hours), combined with other concessions in the form of providing site access roads, transmission lines to substations, and others. By the end of October 2006 there were nine concession projects awarded totalling 2,350 MW with tariffs of up to 6.4 US cents per kWh [2]. Through the concession program that require domestic content for wind turbines of at least 70% and other incentives, the Chinese Government has encouraged the development of a domestic base of manufacturers for wind turbines and components. China now has four domestic turbine manufacturers, of which Goldwind in Xinjiang province is the largest, as well as manufacturing plants opened by international companies such as General Electric, Nordex, Gamesa, and Acciona [3]. Wind turbines installed in new wind farms in China now range from 650 kW to 1.5 MW.

1.2. Future Prospects and Challenges for Wind Development

Interest in the commercial development of wind power in China has increased with passage of the Renewable Energy Law in February 2005 and with publication of implementing regulations for the law in early 2006. The National Development and Reform Commission will continue to support the national wind concession program, and electricity tariffs for large projects above 50 MW will continue to be set by competitve bidding procedures, resulting in power purchase agreements with guaranteed prices. Most new wind concession projects are now in the range of 100-300 MW. Local governments at the provincial level will also have flexibility for approving smaller projects (less than 50 MW) and can establish tariffs directly for projects having one developer or through competitive bidding for projects with interest from multiple developers. Provincial tariffs will be referenced to other wind farm projects within a given region. Future large scale concession projects will also link project development with the manufacturing of advanced wind turbine generators to support domestic manufacturing. In addition the Renewable Energy Law encourages capacity building in several areas, including initiating a national wind resource assessment program, providing support for domestic wind turbine manufacturing, establishing testing and certificaiton for turbines and wind farms, and exploring the potential for off-shore wind development. The National Development and Reform Commission has also established aggressive targets in its strategic national wind development plans, including increasing the cumutive installed capacity of wind power in China to 5,000 MW in 2010 and to 30,000 MW in 2020. In order to support these targets, the NDRC is also increasing China's capacity for regional planning for large-scale wind development in cooperation with the utility sector for aggregation of 1000 to 3000 MW of additional wind capacity in selected provinces. The NDRC is also currently preparing a National Wind Industry Development Roadmap in further support of these targets.

The near-term and longer term targets for 2010 and 2020, while aggressive, are achievable given the wind potential in China and the existance of a rapidly evolving infrastructure for wind resource assessment, manufacturing, project development and project construction, wind farm management, and investment. This existing infrastructure will require ongoing improvements and will need to be expanded to meet the demands of the increasing development scales needed to achieve targets. One key area that represents a barrier to accelerated wind development is China's current capacity for wind resource assessment and site characterization, for which improvements are needed for wind measurement and data acquisition, wind flow analysis and modeling, GIS mapping, off-shore wind measurements, and feasibility study preparation.

▪ 2. Support for Resource Assessment and Site Characterization

Since the year 2000, the United Nations Development Programme and the Global Environment Facility have cooperated with the National Development and Reform Commission in the Project "Capacity Building for Rapid Commercialization of Renewable Energy in China" to assist in meeting China's national objectives for wind development. One of the Project's major contributions has been focused on capacity building to overcome one barrier to project development associated with the lack of high quality wind data. In 2002 the Project initiated a resource assessment and site characterization program to expand the wind resource information base for commercial development of wind in China.

Objectives for the wind support activities include: i) increase the general capacity of Chinese organizations to perform wind resource assessment and wind energy measurement projects at international best practice levels; ii) establish field installation and data acquisition protocols for the measurement of wind data, iii) develop advanced modelling and analysis capabilities for wind site characterization and feasibility study preparation, and iv) assist in developing technically and financially viable wind farm projects to promote wind commercialization in China.

The major components of the resource assessment and site characterization project include: i) site selection, initially identifying 10 sites located in 8 provinces in northern, eastern and southern China, ii) procurement and installation of equipment for wind measurements, including training for the installation and use of equipment, iii) data collection and field monitoring by field organizations at each project site, iv) data validation and wind flow analysis, and v) preparation of site characterization reports.

2.1. Site Selection

During late 2001 and early 2002, the State Power Corporation (now reorganized into the National Grid Corporation) and the Long Yuan Electric Power Group Corporation investigated and identified ten wind farm development sites for inclusion in the project. Major criteria for site selection included potential for at least 100 MW of commercial development at each site, good potential wind resource based on nearby weather station data (if available), access to site, proximity to a local transmission grid, and others. For each site a field organization was identified with a potential commercial interest in the site to be responsible for installing equipment and collecting data, representing a source of cost sharing in the project. For each site, the preparation of project feasibility studies and commercial project development are the sole responsibility of the Chinese Government.

Table 1. Identification of Sites and Field Organizations

Number	Site Name	Province	Field Organization
1	Yumen	Gansu	Gansu Jieyuan Company
2	Helan Mountain	Nigxia	Ningxia Electric Power Group
3	Huitengxile	Inner Mongolia	Inner Mongolia Wind Power Company
4	Dali	Inner Mongolia	Inner Mongolia Wind Power Company
5	Taonan	Jilin	Jilin Wind Power Company
6	Lichuan	Hubei	Lichuan Electric Grid Company
7	Poyang Lake	Jiangxi	Jiangxi Electric Power Company
8	Gulei	Fujian	Fujian Electric Design Institute
9	Putian	Fujian	Fujian Electric Design Institute
10	Xuwen	Guangdong	Guangdong Electric Design Institute

During 2002 the National Development and Reform Commission initiated the national wind concession program [2], and subsequently sites were candidates for inclusion in the national competitve bidding program. To date,

one site, Huitengxile, has been developed based on inclusion in the national wind concession program.

2.2. Equipment Procurement and Installation

During 2002, the Long Yuan Electric Power Group Corporation was awarded a contract to manage the installation and data acquisition functions of the project and maintain quality control for data collection. Long Yuan was generally responsible for data retrieval, transfer, and archiving in a central database for the project. During 2002 until February 2003, the installation of 40 meteorological towers was carried out at the 10 project sites, under subcontracts between the Long Yuan Corporation with the eight field organizations to carry out the installation and data collection activities. The field component of the wind resource assessment program involved training of field organizations, equipment procurement and transport, installation of systems, development of data collection and data handling protocols, and data collection and transfer to a central analysis group. A quality control program provides certification of the work of the field centers according to project standards established during a resource assessment and training workshop conducted at Huitengxile in August 2002.

Global Energy Concepts (GEC) from the United States was the lead consulting group that designed the tower configurations and did the training for the Long Yuan Corporation and the local field organizations in Huitengxile, Inner Mongolia. The National Renewable Energy Laboratory (NREL) of the United States also provided assistance for the design of the guidelines used for wind resource assessment in China.

2.3. Field Configurations

A total of 38 measurement towers have been installed at the ten project locations, with the relocation of two 40-meter towers in 2003 to two additional sites in Guangdong province to collect wind data for sites targeted for the NDRC wind concession project. A typical installation configuration consists of one 70-meter tower (Rohn 45 GSR series lattice towers) and three 40-meter towers (NRG 40 meter TallTower masts) with redundant anemometer and wind vane sensors. The measurement program is designed to be flexible, since the terrain and topographical configurations differ considerably among the ten sites. The 70-meter towers are fixed and are designed to collect long term data for future reference purposes. The tilt-up 40-meter towers are movable and will be relocated to other locations by the field organizations in charge of the equipment at the end of the measurement program. Table 2 provides the standard configurations of the 70-meter and 40-meter towers used in the project.

The measurement period was conducted for all sites during a two-year (24 month) period within the timeframe of mid-2002 to March 2005. During the measurement period, periodic reviews of the tower installations were performed with local consultants, the Long Yuan Electric Power Group Corporation, and the NDRC/UNDP/GEF Project Management Office. This enabled the project to have a continuing monitoring capability for the equipment operation and local counterpart on-site training to make sure appropriate protocols are being followed. As shown in Table 2, considerable redundancy was built into the tower sensor configuarations, since field visits needed to be conducted approximately every two months to collect data, due to the limited capacity of the NRG 9300 dataloggers used for the project. If the project were initiated today, less expensive dataloggers with greater data capacity are available to improve the reliability of data collection. It is also feasible to use mobile phone modem connections to download data from most regions in China today.

Table 2. Configuration of the 70-Meter and 40-Meter Measurement Towers

	Configuration of 70-meter lattice tower		Configuration of 40-meter tilt-up tower	
Measurement	Data Logger A	Data Logger B*	All inland sites	Guangdong and Fujian
Wind Speed NRG #40C Anemometers	70 meter	70 meter	(2) 39 meter	(2) 39 meter
	60 meter	60 meter	(2) 25 meter	(2) 25 meter
	50 meter	50 meter	(1) 10 meter	(1) 10 meter
	40 meter	40 meter		
	25 meter	25 meter		
	10 meter	10 meter		
Wind Direction NRG #200P Windvanes	70 meter	70 meter	39 meter	39 meter
	40 meter	40 meter	25 meter	25 meter
			10 meter	10 meter
Temperature	3 meter	3 meter	3 meter	none
Barometric Pressure	4 meter	4 meter	none	none

*Redundant

2.4. Data Analysis

Validation and analysis of the wind data from the ten project field sites was performed by the China Water Resources and Hydropower Consulting Corporation in Beijing. International consultants were also contracted to assist the Hydropower Corporation. Risoe National Laboratory in Denmark provided assistance in applying the WAsP software for wind flow analysis and modeling to the wind data and Garrad Hassan provided a review of the results of site characterization analysis for quality control and certification of the results.

A one-year validated database was generated for each site using the most complete contiguous 12-month data sets for wind speed and direction within the raw two-year database. Special software was developed by the Hydropower Corporation and reviewed by Risoe to perform the data validation using criteria recommended by GEC, Risoe, Garrad Hassan, and Hydropower consultants. In 2005 the Hydropower Corporation trained provincial research institutes on the use of this software and now offers the software for sale.

Basic site characterization was performed using the WAsP software to perform analyses on the validated data generally using the datasets from the highest sensors, except for wind shear analysis. Analyses included determining the average annual wind speeds, wind speed and wind power density monthly (seasonal) and diurnal variations, calculating wind direction Rose curves, and wind speed and energy distributions. WAsP wind flow modeling validation analyses were performed to cross correlate predicted wind speed between measurement masts and to determine predicted error ranges. Where weather station data was available nearby some sites, correlations were also performed on 10-meter mast data available from national weather stations to attempt to extend the historical wind performance regime for sites to ten years or more. Wind shear analyses were also performed. The data generated would be used in the course of performing feasiblity studies for project development, but the preparation of feasibility studies fell outside the scope of the project.

2.5. Site Development

Some results from the wind modeling and analyses for site characterizations are shown in Table 3, as well as a summary of some of the development which has occurred at sites during the last few years of the project.

Average annual wind speeds are determined at 70-meter mast heights, except where noted, and wind class is based on the China national standard GB/T 17910-2002.

By the end of 2005, 283 MW of wind power has been developed at four of the project's sites. Most project development has been promoted at the provincial level, except for Huitengxile, which was included in the NDRC's 2002 national wind concession program. Another 430 MW is in various stages of planning pipelines at the provincial level for 100 MW at Yumen, 50 MW each at Taonan, Putian, Gulei, Poyang, and Xuwen, and 80 MW at Lichuan.

Table 3. Wind Site Characteristics and Development

Site	Province	Avg. Ann. Wind Speed (m/s)*	Wind Class (GB/T 17910-2002)	End of 2005 (MW)	Developer
Huitengxile	IMAR	8.2	4	68.5	Beijing International Electric New Energy Co., Huadian IMAR Wind Power Co.
Yumen	Gansu	7.7	4	52.2	Gansu Jieyuan Company
Helan Shan	Ningxia	6.6	3	112.2	Ningxia Electric Power Group
Taonan	Jilin	7.0	3	50	Datang Jilin Electric Power Generation Co.
Putian	Fujian	8.4	3	NA	NA
Gulei	Fujian	6.3	3	NA	NA
Poyang Lake	Jiangxi	6.0	2	NA	NA
Xuwen	Guangdong	5.7**	2	NA	NA
Lichuan	Hubei	5.5***	2	NA	NA
Dali	IMAR	6.5	3	NA	NA

*70-Meter Height; **60-Meter Height; ***39-Meter Height, NA-not applicable

▪ Conclusions

As wind energy development continues in China, increased scrutiny will be made on any new projects to determine the quality and reliability of the wind data and the data analysis work. Previous wind farm analysis work done in China has created expectations for energy production at some sites, which have not been met after construction of the projects. This circumstance has caused some projects to be uneconomical. This problem is avoidable with proper data collection and analysis.

The strengthening of the field procedures and site characterization will give developers and financial institutions more reliable information and lower perceived risk in the financing of these projects. As the industry continues to develop, more project developers will be able to meet these requirements and find a more receptive investment environment.

Strengthening capacity in China for wind resource assessment and analysis is also essential if China is to meet its aggressive targets for wind development by 2010 and 2020. In 2005 the NDRC has established a national wind resource assessment program in oder to support capacity building and update the national wind resource mapping and estimates for wind power potential in China.

▪ References

[1]. A. Cameron, *Renewable Energy World*, Vol. 9, No. 4, 2006, pp. 56-66.

[2]. J. Ku, D. Lew, P. Shi, and W. Wallace, *Renewable Energy World*, Vol. 8, No. 4, 2005, pp. 212-223.
[3]. E. Martinot, *Renewable Energy World*, Vol. 9, No. 4, 2006, pp. 45.