3.2 Annex II – Wind Energy Development

The DOE and the Ministry of Electric Power (now called the State Power Corporation of China – SPCC), signed Annex II in October 1996. The objective of Annex II is to promote the sustainable, large-scale deployment of wind energy systems for both grid-connected and off-grid village power applications in China. This is to be done by information exchange, training and demonstrating the technical and economic feasibility of wind energy technology to enhance its commercialization in China for the benefit of both countries.

These objectives are being met through a variety of cooperative activities. The Annex II activities are in three categories: (1) analysis and pilot project demonstration of various wind power applications, (2) information exchanges, and (3) collaborative research and exchange visits. Activities are designed to support China's goals to install 1,000 MW of wind systems by the end of year 2000 and 3,000 MW by 2010 [20]. The DOE supports China's goals and is hoping to create new business opportunities for the wind industry in both countries.

Through NREL, the DOE has provided training and the exchange of technical information between U.S. counterparts and Chinese Institutes entering the renewable energy field. Through this program, researchers and companies in the U.S., have learned about the electric power system in China. Chinese visitors have gained first hand experience using American built wind turbines, laboratory equipment, and commercially available software.

To date, four personnel exchanges have been completed on wind energy topics. Visiting scientists and engineers were give specific research topics and sent to work at the National Wind Technology Center for two to three month assignments. Specific training assignments were: (1) wind resource assessment and data collection methods, and wind project planning techniques for two engineers from the SPCC's Hydropower Planning General Institute, (2) economic analysis of large scale wind power plants connected to the Northeast China grid done by an engineer from the Electric Power Research Institute for the SPCC, and (3) a study of hybrid power systems using wind turbines for remote village power applications in Tibet by an engineer from the Research Institute for Electrical Engineering of the Chinese Academy of Science. To increase the involvement with U.S. industry, the Chinese visitors participated in the American Wind Energy Association annual conference and attended the intensive one week Wind Energy Applications and Training Symposium (WEATS) sponsored jointly by the wind industry, the DOE, and the U.S. Agency for International Development. Additional personnel exchanges are planned for 1999 and 2000.

3.2.1 Technology and Application Descriptions

Wind energy systems are one of the most promising new renewable energy technologies for China to providing significant amounts of electric power to the national grid and to provide electricity for many people in rural areas beyond the reach of the grid. Wind energy resource potential in China is estimated to be between 160 and 253 GW [1 and 21]. In contrast, the total installed generating capacity (including thermal, nuclear, and hydropower plants) in all of China in 1995 was 217 GW. The wind data was compiled by the Chinese Academy of Meteorological Science and included the total amount wind energy technically available to be utilized, without considering economic and social constraints. Of course practical constraints would preclude meeting the entire national electricity demand from wind turbines alone. The intermittent nature of the wind and constraints on power transmission would make such large scale use impractical, but the potential for using grid-connected wind power is huge in many diverse regions in China. The best wind sites were found along the southeast coast and in northern areas inland in the

Provinces and Autonomous regions of Inner Mongolia, Xinjiang, Heilongjiang, Gansu, Jilin, Hebei, Liaoning, Shandong, Jiangxi, Jiangsu, Guangdong, Zhejiang, Fujian, and Hainan. There are also isolate sites with good wind energy potential in most other Provinces.

Wind Energy Applications Analysis and Development – The SPCC and World Bank recognize that there is tremendous potential in wind power in China. There are three primary categories of applications for wind energy systems. (See Figure 8) First, wind turbines are being installed in large scale wind power plants, typically 20 to 100 MW in total capacity, that can produce electricity that is distributed through the national grid. This is the largest potential application for wind power, with at least one 100-MW plant expected to be on-line by the end of year 2000 in Inner Mongolia.

The second type of application is to install wind turbines in townships and villages for rural electrification and to reduce the use of expensive and heavily polluting, diesel engine driven generators in areas that are beyond the reach of the national electricity grid system. These off-grid applications may include installing clusters of smaller wind turbines in the size range for 10 to 100 kW each, on off-shore islands, in isolated communities, and for enterprises that generate their own power.

The third application of wind power is in individual homes to provide electricity for light, communications (television and radio), health, and comfort (refrigeration, washing machines and heat). These applications can be used with solar/photovoltaic and small gasoline engine power generators and are discussed in detail in Section 3.1 above.

China's Progress in Wind Power Plant Deployment – The total capacity of wind turbines in China was 223 MW by the end of 1998. The progress in wind power development in China has been the fastest in the renewable energy field. Since the first International Conference on Wind Energy was held in Beijing in 1995, wind power plant installations have increased ten fold. Currently 12 provincial and autono-

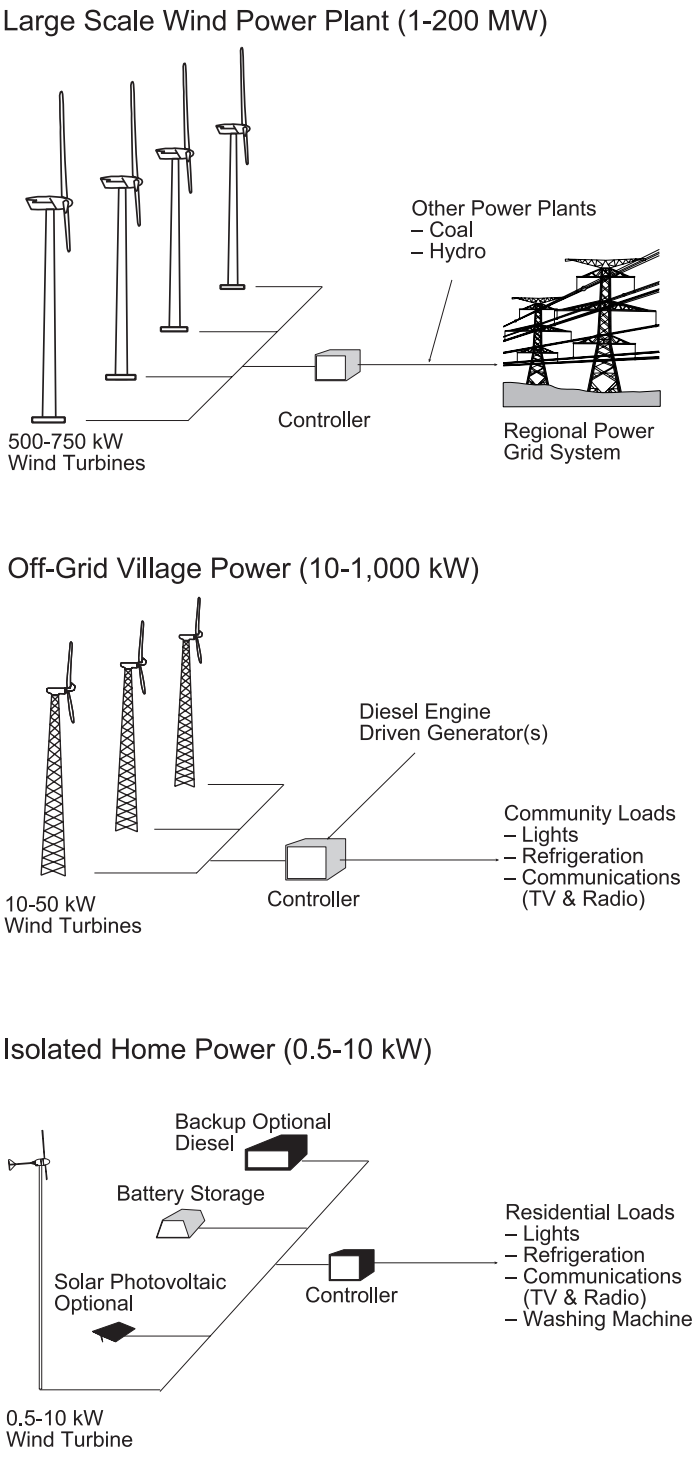

Figure 8. Typical-Wind Energy Applications in China

mous power corporations are engaged in developing wind power and 19 wind farms have been established in two high wind zones in China. Up to now, Xinjiang Dabancheng Wind Farm, with a capacity of 64 MW, is the largest wind plant in China. Guangdong Nanao Wind Farm, with a capacity of 42 MW, is the biggest island-based installation in Asia.

Many Channels to Construct Wind Plants and Attract Capital – China's wind power industry was financed initially using construction capital from Denmark, the United States, Germany and The Netherlands. From 1994 through 1997, there was more than $57 million USD in foreign investments in wind plants in China, most in the form of tied-aid grants and loans. More recently, construction of wind plants has been included in the central government plans and projects are being planned using commercial financing from the World Bank, the Global Environmental Facility, and the Asian Development Bank.

Technical and Economic Progress in the Industrialization of Wind Power – China has adopted rules and regulations to encourage wind power deployment. Many home owners, farmers and herdsmen in rural areas can now independently buy, install and operate small turbines. Wind farm owners can now independently construct, install, and operate wind turbines following the technical documents provided by the turbine manufacturer. Several factories on China now have experience manufacturing wind turbines in sizes from 0.1 kW to 300 kW. Larger turbines, up to 600 kW, can also be assembled in domestic factories. Many joint ventures for manufacturing wind turbines will be established in the future. Experts in a wind energy magazine said, "It was the China Wind Power Year in 1997."

3.2.2 Wind Energy Resource Assessment in Southeast China

Wind energy resource estimation and mapping are one of the first steps in planning wind energy projects and this was one of the initial areas of cooperation under the Wind Energy Annex to the Protocol. This task was supported by U.S. DOE, Environmental Protection Agency, and the American Wind Energy Association through a program called the Energy Technology Initiative. On the Chinese side, participation involved the State Power Corporation of China through the Hydropower Institute and the Chinese Meteorological Service.

Wind Measurement Program – The first part of the wind energy assessment task was to initiate a wind measurement program to collect detailed meteorological data needed to evaluate the energy production potential at sites under consideration for future large scale wind power plant projects. SPCC installed wind measurement stations at 12 locations; one near Shanghai, two in the Poyang Lake region near Lu Shan in Jiangxi, and at sites along the coast in Fujian and Guangdong. U.S. built anemometers for measuring wind at two heights were installed along with digital data collection systems. Chinese technicians and engineers were trained on installation, operation, and maintenance of the equipment as well as methods for analyzing and interpreting the results. To date, several thousands of hours of wind records have been compiled by the 12 systems and the results are providing the accurate and reliable data needed for evaluating project energy production potential and economics.

The second part of the wind energy assessment program underway involves regional wind resource analysis and mapping. This is an effort to assess overall wind potential in large areas of key provinces and to find good potential wind sites where wind measurement programs are needed. Preliminary wind assessment and mapping were conducted for two regions in southeastern China. The first region was the coastal area stretching from south eastern Guangdong up to northern Fujian. The second region was centered around the Poyang Lake in northern Jiangxi and included parts of two other provinces, Anhui and Hubei, extending from near Anqing southward to near Nanchang.

Using atmospheric flow models developed by the NREL, three regional wind maps, based on the Geographic Information System (GIS), have been developed. Terrain data in digital form was used in the modeling process. Wind and other meteorological data were combined into a very large database drawing from several sources. These databases included: information from 85 selected meteorological stations in the region; surface weather observations from World Meteorological Organization stations in southeastern China available through the National Climatic Data Center in the United States; marine data reported from ships at sea; near shore wind speed estimates derived from wave height measurement taken by satellites using microwave imaging; and from upper air data sets from rawinsonde instruments and pilot balloons.

Results from the wind mapping show many sites in the two study areas have good-to-excellent potential. The most productive sites were found along the coast and on offshore islands especially in Fujian. See Figure 9 [22]. Average annual wind speeds greater than 5.5 meters/second (m/s) are considered usable for wind power development. Many sites with much higher wind speeds have been found in the mapped area, although some of these sites are mountainous and may be difficult to develop due to steep terrain. Overall the study concluded that the coastal areas in Fujian and Guangdong, including off-shore islands and land up to 10 km inland, had wind resource potential of 47,388 MW.

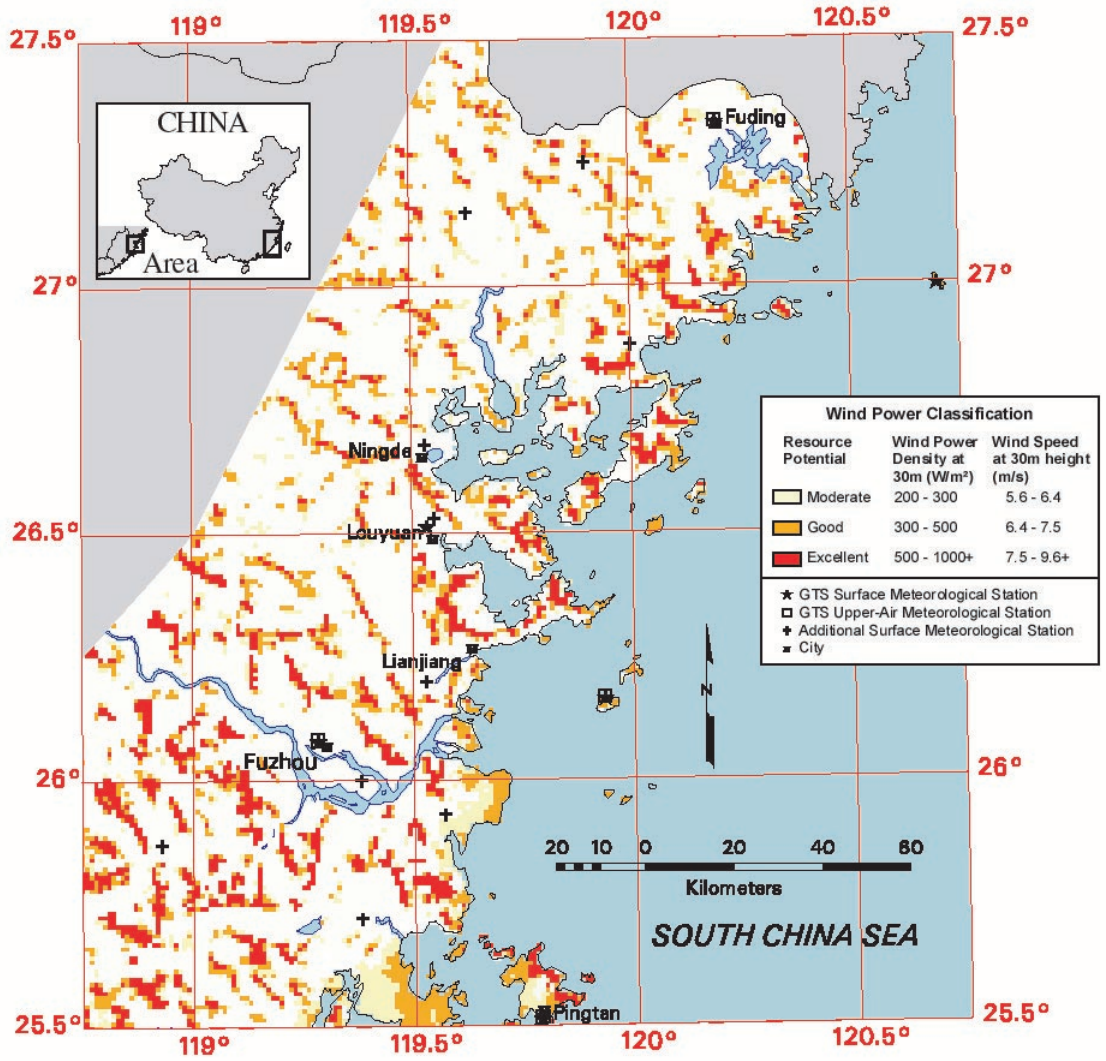

Figure 9. Regional wind resource mapping on Southeast China coast and estimates of average annual wind speed in standard wind power classes [22]

Wind mapping is also helping to identify the best locations for turbines at specific sites. One part of the study focused on Nanao Island in Guangdong province. This island, shown in Figure 10, was found to have many excellent wind sites and is the location of numerous wind power plant projects including one plant with ten 550-kW turbines supplied by the American company, Zond Energy Systems, Inc.

3.2.3 Grid Connected Wind Power Plant Analyses (Northeast Region Study)

One of the initial areas of cooperation was analyzing the economics and technical issues associated with integrating large-scale wind power plants into the existing grid network. Rising costs for other energy sources, declining costs for wind turbines, excellent regional wind resources, and the adaptability of the grid system to accommodate large-scale wind plants, making them an increasingly attractive option. This topic was the subject of a study completed in August 1997 by a visiting scientist from China's Electric Power Research Institute (EPRI - China) working at NREL for three months. Latest commercial computer models were used to evaluate integrating wind power into a section of the Northeast Regional grid in China. The northeast grid network studied is located in the Provinces of Heilongjaing, Jilin, and Liaoning with some connections to Inner Mongolia. See Figure 11.

The study focused on determining the value of installing significant amounts of wind power to the Northeast grid to determine economic costs and benefits. Results showed favorable economics, even at very low penetrations. An Electricity Financial Model (ELFIN) developed by the Environmental Defense Fund with support from the DOE, was used to compare the utility operating cost both with and without wind plants. Results from a partial study showed that by adding several thousand MW of wind plants that produced 1.5% of the regional energy, reducing emissions of NO_X 2.3%, SO_X 2.1% and CO_2 2.5%. The value of the wind energy was $0.042/kWh (0.34 RMB/kWh), with a resulting decrease in the marginal energy cost of 10.5% [23]. China EPRI has obtained a license to use the ELFIN model in China and is continuing this work. In addition, China EPRI plans to study effects on power quality and on grid system transient stability and control at higher penetration levels of wind power.

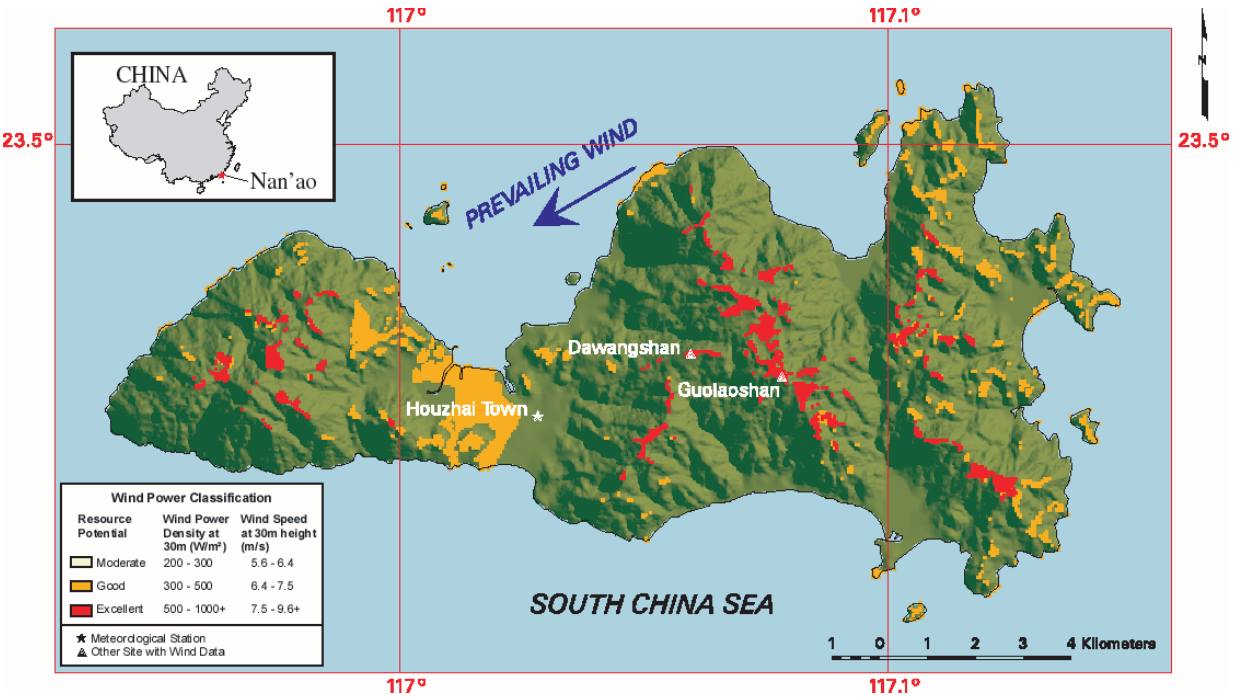

Figure 10. Wind site and digital terrain mapping of Nanao Island in Guangdong Province [22]

3.2.4 High Altitude Wind/PV Hybrid Tradeoff Study

An economic tradeoff study for various wind/PV hybrid systems for off-grid generation application at a high altitude site was carried out under the Annex II personnel exchange program. Three configuration options: wind/battery, wind/PV/battery, and PV/battery were studied for a village in Tibet. The village, Nace, located at 91° 30' E and 31° 50' N, is about 130 miles north of Lhasa, the Capitol of Tibet, in Ando County, Naqu District. Most people in this District are without any electricity. The average elevation of Naqu District is about 4,800 m (15,745 ft.). The annual average wind speed is 4–6 m/s and the annual average of 2,900 sunshine hours with an average temperature of -3°C (28°F). Nace village has 57 families and one school. The estimated daily loads are: five hours of 60 watts for TV and 20 watts lighting per family. Using the Hybrid-2 computer model developed at NWTC, the trade study indicated that the most economic system is wind/battery followed by wind/PV/battery. Despite a general concern about wind energy from the low air density at this high elevation, the relatively low cost of wind turbines makes them most economical in this application. The results were published on Acta Energiae Solaris Sinica (Quarterly), No. 3, Vol. 19, 1998 with the title, "The Optimization Design for 4-kW Wind/PV Hybrid Generating System in Tibet."

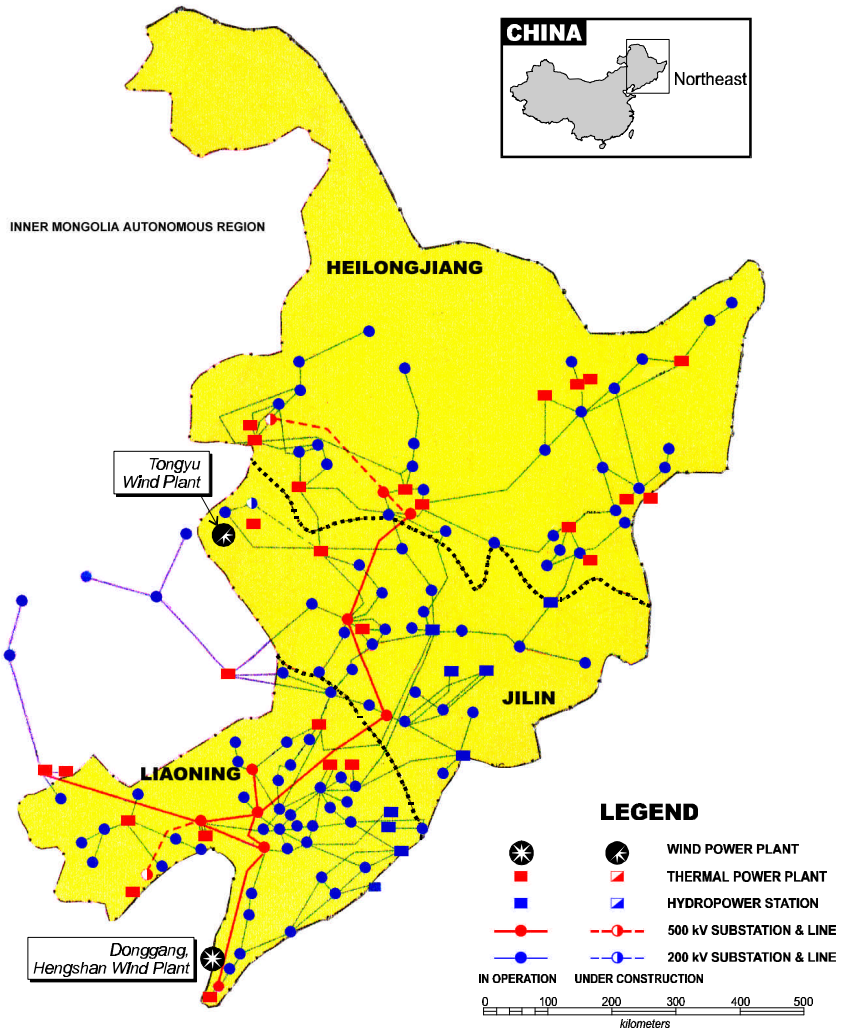

Figure 11. Schematic map of Northeast China power network and wind power plant sites [23]

3.2.5 Village Power Wind/Diesel Hybrid Pilot Project

In order to demonstrate the application of wind energy in medium scale off-grid applications, a pilot project, using U.S. turbines from Bergey Windpower, will be built on the island of Xiao Qing Dao in Shandong Province four nautical miles from Rushan City. SPCC choose the site as a typical island power system application, with good wind resources, easy access, and strong support from the locals, including the city of Rushan, the City Power Bureau, and the Island Council.

The island of Xiao Qing Dao has 346 inhabitants living in 123 homes that currently only have electricity available intermittently, which is typical of many island applications. The principal industries on the island

are fishing and tourism. Power is produced by a 20-year-old, 13-kW diesel engine driven generator set, distributed through a local grid network at a cost of 3.0 RMB/kWh ($0.42/kWh). Electricity is used for street lighting and residential loads, including: lighting (50 watts), TV (80 watts), refrigerator (120 watts for 80 homes), washer (120 watts for 50 homes), and electric cooker (800 watts for 20 homes). Electricity is normally available 3-4 hours in the evening.

The planned wind/diesel pilot project will be installed during 1999. Current plans are to install four 10-kW wind turbines in a small wind power plant connected to a 30-kW diesel generator along with an inverter and battery bank. The turbines and other electronic equipment will be supplied by U.S. manufacturers (three turbines supplied by DOE and one by private industry). The Chinese will provide: turbine towers; foundations; electrical equipment; and operation, maintenance, and data collection support.

3.2.6 Workshop on Wind Plant and Business Development

A training workshop on Wind Power Business Development and Policy Analysis was held in Hangzhou, China on March 15-19, 1999 by Princeton Energy Resources International. The SPCC and the DOE sponsored the meeting that was hosted by the Zhejiang Provincial Power Bureau. Participants included 70 executives, planners, engineers, and economists from electric utilities, provincial and central government, local wind plant companies, and equipment manufacturers. Lectures covered topics on wind energy business trends and government run financial incentives employed worldwide, project debt and equity financing, cash flow planning and management, costs and economics of wind and other renewable energy technologies, and policy options needed to accelerate the deployment of wind plants in China. A case study was presented on financing 100-MW wind plants installed in China. Seven variations on the case study illustrated effects of wind speed, project scale, deployment experience and learning curves, tied-aid and Chinese tax laws, and special Bank of China financing terms. Representatives from Mees Pierson, a commercial Bank with offices in Shanghai, presented views on bankers' role and criteria for financing projects and equipment. Mees Pierson was selected because they had financed several large wind projects in the U.S.