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Prospects and constraints in and institutional context

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Contents

Summary

This study is intended to provide a better understanding of the functional roles and dynamics of institutions in determining the effectiveness of national and regional public-sector initiatives to promote the dissemination of wind turbine technologies in China. The structures, roles, and relationships of relevant institutions involved in wind energy development are analyzed. It examines wind energy development in the last four decades and divides them into four different stages of development.

The objective of the study is to identify the steering mechanisms in wind-energy technology dissemination, and the obstacles involved. It is argued that institutional problems constitute major barriers for cost-effective development of wind turbines in China. These include investment loans, tax systems, electricity prices, technology transfer and adaptation, and human resources development.

Two empirical studies about the Inner Mongolia region and the Dachen Island in Zhejiang Province are presented as illustrative cases. It concludes that establishing stable frameworks for private sector participation in the wind-energy market holds the key for effective dissemination of wind turbine technologies in China.

1 Introduction

The utilization of wind energy technologies (wind turbines) has been proposed as an important component of efforts to achieve sustainable energy development (IPCC, 1996). Wind energy development is part of the global effort to promote renewable energy technologies.

In recent years, we have seen the increase of the production capacity of wind power at the rate of 30% per year worldwide (Financial Times, 1998, p.10). Initiatives have been undertaken to promote the dissemination of wind energy technologies in developing countries, mostly backed up by governments, and some are supported by multilateral and bilateral aid initiatives. This is due, in part, to the perception that wind energy technologies can meet the need for more flexible, decentralized and environmentally-friendly energy systems in rural areas of developing countries (IPCC, 1996). It is claimed that wind energy development can contribute to the reduction of poverty and increase the quality of life for the poor in isolated rural communities. China is a particular case (The World Bank, 1996).

It is commonly recognized that promoting wind energy technology development in developing countries will contribute to efforts to reduce the risk of international conflict over energy resources and to avoid large-scale expansion of the global stock of fossil-based energy-supply systems. Wind energy is also a promising option for mitigating global climate change, in particular carbon dioxide (CO_2) emissions, compared with fossil-fuel based energy technology systems development.

In some developing countries, wind energy technology development has become institutionalized with support from national and regional governments, mostly through subsidies, and partly through policy incentives. Some are supported by multilateral and bilateral aid agencies with the involvement of international corporations. Although there is continued optimism regarding the potential to disseminate wind energy technologies, their uptake has been slower than what was expected in the 1992 United Nations Conference on Environment and Development.

The reasons why the uptake of wind energy technologies has been slower than projected or desired in developing countries are still not well understood. I believe that current governmental policies in some developing countries have provided inadequate conditions, or incentives, for disseminating wind energy technologies. The reasons can be attributed to ineffectiveness in operation, related to institutional barriers. This has been the case in China, although recent changes have shown positive signs of development. It is hypothesized that, in addition to inadequate financial resources and technical obstacles, barriers between and within institutions impede the use of wind energy, and limit their adaptation to societal needs.[2]

Past research on wind energy technologies have focused almost exclusively on technical issues and options for policy intervention. Some emphasize historical successes and failures in project implementation. In particular, most research efforts focus on issues, such as energy modelling, technology assessment, cost-benefit analysis as well as scenarios to project future development. Most studies tend to exclude the social and institutional dimensions of wind-energy technology

[2] One example is shown in the wind power project in the Dachen Islands, which is one of the case studies held by the author.

development and utilization. The process of technology dissemination is neglected in many case studies.

It is argued in this study that institutional barriers are perceived as being primary sources of constraints, including inadequate policy incentives, ineffectiveness in project management, and conflicting sectoral interests between established institutions. For example, different goals and interests of production-oriented energy industrial organizations and governmental agencies can lead to sub-optimal policies that do not support cost-effective wind-energy technology adaptation and dissemination. Instead, policies may be directed toward support of conventional fossil-fuel based energy expansion.[3]

There are also tensions between central and regional governments in priorities and interests in supporting wind power development.[4] The roles and capacity of the private sector in wind energy development are still not clearly understood. In particular, mechanisms to encourage private sector's participation in wind energy development are still in a primitive stage of development in China.

I emphasize that institutional barriers contribute to ineffective use of financial resources in project design and implementation,[5] and they also affect technological choice, and adaptation of infrastructure to meet local circumstances.[6] Increasing industrialization has already led to a strong preference to rely on conventional energy systems, which tends to restrain the adoption of renewable-energy technologies, such as wind turbines.

There exist tensions between institutions in decision-making over choice of different energy systems. On the one hand, there are strong preferences to build up economic competence for raising income; on the other hand, there are dynamic forces that support flexile and environmentally benign energy systems to meet local demands. Small-scale, environmentally friendly technologies are often dominated by supply-oriented, large-scale development, pushed by desires for industrialization. It is assumed that these factors constitute primary sources of conflicts in implementing wind energy development.

This study attempts to analyze the development trajectories of wind energy in China. It is argued that at the current stage of wind technology development in China, most projects still need support from public-sector finance and international aid. The lack of adequate policy support, i.e., various incentives, is often claimed to be a major obstacle to promote the dissemination of wind energy technologies, despite inadequate financial and economic conditions. The case study from China indicates the above assumptions. It demonstrates the need for proper institutional settings as a precondition for effective dissemination of wind energy technologies.

[3] One example is the plan to develop a 1,100 MW coal-burning power plant in the Chongming Island near Shanghai, which is proposed by the Huaneng Corporation, a state owned large energy company, as a major energy development project. This project is considered as an extension to the newly constructed 250 MW coal power plant, due to be completed by 1998. There are disputes over this new plan. Alternative suggestions are made to establish a huge wind farm with 1,200 MW of generating capacity at the same island. See: *Wind Power*, No.2, 1995, pp.23-28.

[4] In China, there are different technology trajectories in different regions in efforts to indigenize foreign wind turbine technologies. This is illustrated in the following sections.

[5] This is the case in the Dachen Island project.

[6] The example is the Inner Mongolia as shown in the case study.

The article describes the historical trend of wind energy development and the main characters in each of the four phases of wind energy development. It shows what actors are involved in the wind energy market and their interest and motivation. It discusses the issues of technology development and market potentials, in which various institutions play a role, in particular investment loans, taxes and price mechanisms. In the last part of the article, two case studies about wind energy development in Inner Mongolia and the Dachen Island in Zhejiang Province are presented as illustrative examples.

2 Development objectives and approaches

China has taken a decentralized approach to wind energy development, especially on off-grid applications, and has placed strong emphasis in exploiting local resources and developing technologies that suit local conditions and needs. Until recently, China's wind energy market has been targeted to small-scale applications of domestically manufactured wind turbines. However, there is an increasing demand for imported large wind turbines (300-600 kW) at the regional level with different purposes, e.g., demonstration, or commercial expansion.

The rationale for promoting wind energy technologies and their applications in China is multiple-faceted. China has large potentials for wind energy development. The exploitable wind resources are very large, estimated at 250 GW (ZERI, 1996, p.4). Historically, promoting wind energy technologies has been linked with such development objectives as providing electricity to poor people in rural communities in order to increase their living standards, or reducing poverty through electrification.

In recent years, objectives for wind energy development have become widened to include: 1) Social: poverty reduction and socioeconomic development; 2) Economic: increasing the cost-effectiveness of wind energy dissemination; 3) Environmental: reducing environmental pollution; 4) Technological: increasing R&D capacity for wind turbine technologies, accumulating operational experience, improving design and competitiveness; 5) Commercial: increasing production capacity of domestically designed wind turbines for export and domestic market expansion; and 6) International relations: improving China's international image and bilateral and multilateral relations.

In light of the historical trends and the recent increase in wind energy development at the regional level, this study investigates the institutions and policies at both the central and regional levels. The objectives, policies, and mechanisms involved to promote wind energy technologies are often different at these two levels. Such differences are also reflected in the promotion of small-scale vs. large-scale wind technologies, as well as local/indigenous vs. imported technologies.

3 Historical perspectives

Wind energy technology in China has gone through four phases of development with different characteristics, approaches, and results as shown in the following sections:

3.1 1958-1977

This is an exploratory stage with the self-reliance policy as the guiding principle, mostly depending on domestic research and development (R&D) of small-scale wind turbine technologies. This technology development is limited by the R&D capacities of the industry. It is mostly dependent on the outcome of R&D from state owned research institutions. Wind turbines developed during this period focused on mini-wind turbines (50-150W). Market demands for such products were high, because of the governmental subsidies and the needs of small off-grid end-users. Small wind turbines with the capacity up to 12 kW were also developed and tested, but failed to commercialize in market, due to lack of demands.

3.2 1978-1983

This is a period of policy adjustment and technology expansion. Small wind turbines were targeted with the increasing emphasis on R&D and technology dissemination. From 1978, the state government prioritized wind energy development, in order to provide electricity to people living in poor rural communities. R&D efforts were combined with demonstration projects. Inner Mongolia was active as the main promoter of this development, with the support from the central government (see the case on Inner Mongolia).

3.3 1984-1989

This is a period for market expansion and institutional establishment. This is particularly seen in the Inner Mongolia region where the development of wind energy was institutionalized through the establishment of the New Energy Office in the government in 1994. Policies to provide subsidies were established, with the aim to support local users. Technology dissemination became widespread across different provinces. In this process, Inner Mongolia has played a leading role in demonstrating the potentials in fulfilling the rural electricity demand. In the period, more than 30 R&D institutions were established and over 20 manufacturers were under operation. Meanwhile, import of foreign technologies (50W-10 kW) was promoted, directed and supported by central governmental institutions, such as the State Planning Commission (SPC) and the State Science and Technology Commission (SSTC).[7]

[7] As part of the restructuring process of the state reform in 1998, the SSTC has become the Ministry of Science and Technology (MST). However, as most of the analysis in this article emphasizes on the past experience, the name of the SSTC is used in the following sections.

3.4 1990-present

This is a period of rapid expansion of imported wind technologies with the increasing involvement of major wind turbine producers from Denmark, USA, Germany and Austria. Indigenization of foreign technologies has been targeted as an important objective of the state policy. This is mostly motivated by the fact that domestically developed technologies for large units (more than 200 kW) have difficulties to compete with imported products in terms of technical maturity and reliability. Domestic R&D and production capacities also cannot meet the rapid growth in market demand for large wind turbines.

Commercialization has become an important feature of the wind energy industry. Focus of development at the regional level has shifted from small units for households toward large wind farms for grid-connected electricity production. Due to the reduction of governmental subsidies and the increase in production costs from 1990, market demand started to decline, particularly with small wind turbines. After several years of adjustment, production of small wind turbines began to recover in 1994. However, the main emphasis is now on large commercial wind farms for grid-connected electricity generation. Regions with large wind resource potentials are eager to lead this development. In particular, we have seen rapid expansion of wind electricity production capacity in Inner Mongolia, Xinjiang and Guangdong Province.

China's growing interest in wind energy is justified by the following factors. Out of the total population of more than 1.2 billion, China has about 900 million people living in rural areas, of which more than 100 million still do not have access to electricity supply and services. About 270 million people still living under the poverty line, despite the progress achieved in poverty reduction in the past two decades.[8] In addition, over-consumption of biomass resources, and the heavy dependency on fossil-fuel based energy sources, especially coal, have all put pressure on the environment of the country. To reduce such an impact, going for wind power is a preferred choice.

China has set a capacity target of 1,000 MW wind-energy by the year 2000. It is estimated that to realize this objective will need about 10 billion Yuan (US$1.2 billion) of investment (Zhou, 1996, p.18). Several large-scale wind farms in Xinjiang, Inner Mongolia, and Guangdong Provinces are under rapid development. In Guandong Province, the first domestically manufactured wind turbines (200 kW and 300 kW) are installed and demonstrated.

There are two ambitious plans of the SDPC. The first is the "China Light Program", which intends to provide electricity to 8 million people living in remote and isolated rural areas. The short-term objective is to install 40-60 MW of wind generating capacity for 2,000 villages, 100 military sits and 100 telecommunication stations in five years from 1997 to 2001. The long-term objective is to provide electricity to more than 23 million people by the year 2010. The main characteristic of this program is the decentralized objective with the emphasis on small wind turbine development. The second program is the "Chengfeng Plan", or "Go with Wind Plan", which aims for large-scale development of wind farms. More than one billion Yuan will be invested in projects to indigenize foreign technologies and establish domestic production capacity for large wind turbines.

[8] According to the World Bank, the poverty rate in China has declined by 60 percent, as 200 million Chinese living in absolute poverty have been raised above the minimum poverty line since 1978. See: Ahuja, 1997.

Another initiative is initialized by the State Economic and Trade Commission (SETC), entitled the "Shuangjia Plan", aiming to speed up the process of technical innovation for wind technology development. During 1996-2000, 1.2 billion Yuan is to be committed to support key state owned industries. Most of the money is to be used to purchase wind turbines from foreign suppliers.

International Development Assistance Agencies are notable stimulators in China for wind energy development. Bilateral aid initiatives from, e.g., Denmark, Germany, the Netherlands, Spain and the USA, have provided incentives or favoured conditions, such as grants and soft loans, for regional programs to take place. So has the financial stimulus from multilateral development assistance agencies. Their initiatives have promoted interest from regions with large wind resources.

4 Companies in the wind energy market

State owned companies are the main players in China's wind energy market. The most dynamic is the China Fulin Windpower Development Corporation established in 1992, which is the main actor in the domestic market. Other active players are at the regional level, particularly the regional wind energy companies in Inner Mongolia, Xinjiang and Guangdong Province where wind energy is a high priority.

The main trend is that most provinces have shown a growing interest in monitoring and exploiting wind potentials. From the central governmental perspective, pragmatic policies are undertaken to allow more flexible arrangement in investment and contract with foreign investors. This is part of the shift in the state energy policy that has, historically, been centralized with state monopoly and control. However, total opening-up of the wind market is anticipated, as barriers for free market competition still exist.

It seems that regional players, such as the Wind Energy Corporation in Inner Mongolia, has made a shift in its business strategy from relaying on domestic finance, i.e., investment from the state, to emphasizing international investment provided by development assistance agencies. However, this may represent a distorted vision of the potentials from domestic sources of financing.

The private sector is active in China's wind energy market, but with different perspectives. Large foreign companies, such as MICON, Vestas, BONUS, started their engagement in China from the late 1980s. Their involvement in China has become intensified in the past few years, particularly through cooperation with regional governments and wind energy companies. Their interest in China has, to a large extent, been motivated by the national strategy to expand grid-connected large wind farms. However, most foreign investors in the wind energy sector are still suspicious about the policy barriers and risks in the wind energy market in China (Moynihan, 1995).

Companies with private ownership in China involved in the wind energy industry are rare. They are still not encouraged by the state policy in practice. This is very much related to high risks in investment, long pay-back times, thin profit margins, and uncertainties in governmental policy.[9] However, there are indications that some private enterprises, and groups, are showing strong interest in investing in wind development, but they are reluctant to take decisive actions because of the lack of policy incentives.[10] This indicates that without adequate policy stimulus, there will be a low-level engagement from private investors, both domestic and international alike.

[9] According to interviews with key company managers in China, conducted in March 1998.
[10] According to an interview with Yan Yize, Executive Director of Xunfeng Wind Power Corp. The company has already accumulated a total amount of 500 million Yuan from individual shareholders with each valued at 250, 000 Yuan. However, they are still reluctant to start the business operation due to lack of proper policy, such as reduction of taxes and electricity price incentives.

5 Technology development and market potentials

Small wind turbine development has been the main objective of the governmental policy until the late 1980s. By 1996, a total of 159,000 units of wind turbines were produced and the installed capacity reached 56 MW. The shift of policy emphasis toward large wind turbines started in early 1990s. Currently, there are 16 wind farms with 237 units and about 60 MW of installed capacity. Almost all of the production units are imported from suppliers in Denmark, USA, the Netherlands, Austria, and Germany.

In 1990, China had wind generating capacity of about 13 MW from wind farms. By 1997, this number has increased to 160 MW, or 12 times increase. This can be compared with the total increase of 150% in world wind generating capacity between 1990 and 1995 (Flavin, 1996). Currently, there are 140,000 small wind turbines in use in remote rural areas in China. The main driving force for this development is from governmental support, particularly at the regional level. In regions where there are active wind energy projects, governmental support holds the key, which is reflected in policy schemes, such as tax relief and subsidized electricity prices. The other dynamic is the assistance from bilateral aid that gives soft loans with lower interest rates and long pay-back times (ten years or more).

A plan for a wind-power site with a generating capacity of 64 MW recently passed the state technical appraisal. The site lies in Dabancheng, in Northwest China's Xinjiang Uygur Autonomous Region and cost $60 million to complete. At present, more than 200 wind generators are under operation. Another 20 units of 600 kW wind generators and 51 units of 500 kW generators will be installed later this year (*China Business Net*, May 19, 1998).

China's small wind turbines have already become a mature technology, and its export potential is increasing. Currently, products are exported to 22 countries in Europe and Asia, in additional to the expanding domestic market. In 1996, about 160,000 units of small wind turbines were produced in China. There are several trends in wind energy development in China as indicated below:

First, from small to large units. One of the dynamics for wind turbine development is the changing demand of rural people. In the past, market demand was mostly on mini wind turbines (50-100W). In recent years, demand for larger units (300-500W) is on the rise, mostly because of the increase of living standards.

Second, from individual to collective use. Utilization of wind turbines has changed from individual household to collective (several households) and communities/village levels, which tend to encourage purchase of larger wind turbines. It is also a reflection of demand for higher operational efficiency of wind turbines.

Third, from single wind turbines to wind/diesel, wind/solar, and wind/solar/diesel systems, which aims to increase the quality of electricity supply, and fulfil the needs of isolated rural communities and individual households.

Fourth, from dependency on domestic design and production to joint ventures with imported foreign technologies. This has increased the competitive advantage of the domestic producers with low production costs. 5 kW and 10 kW units have already become competitive in international market, being exported to many countries.

Fifth, from small off-grid wind units and farms to large grid-connected wind farms. This change is motivated by the desire, mostly governmental driven, to turn wind energy into an important source of electricity supply, and connect these electricity generating capacities into national and regional grids.

6 Institutional conflicts

There are considerable barriers in wind energy development. We see the origins of these barriers coming from different institutions. From an organizational perspective, there are three State Commissions all responsible for wind energy development in China: the State Development Planning Commission (SDPC)[11], the State Science and Technology Commission (SSTC) and the State Economic and Trade commission (SETC).

SDPC is in charge of planning and budget approval for large wind-power projects. SSTC is in charge of planning and administration of R&D activities related to wind energy development. It is also responsible for matters related to technology transfer, particular with regard to foreign technologies. SETC co-ordinates economic operations, enterprise restructuring and reform, and upgrading of technologies in industry.

The three State Commissions all have a particular division dealing with renewable energy development and they often overlap in their operations and sometimes compete for power and control. This management system for renewable energy is, to some extent, ineffective in project approval and implementation, due to conflict of sectoral interests (The World Bank, 1996, p.48).

In addition to these Commissions, there are four key actors at the ministry level: the Ministry of Hydropower, the State Machinery Industry Bureau,[12] the Aerospace Industrial Corporation[13] and the National Electric Power Corporation.[14] They are powerful agents, all attempting to take a share of the wind energy market in China. These actors sometimes have different motivations and interest, which can become sources of conflicts.[15] With this diversification in interest and power relations, there exist considerable problems of coordination.

6.1 Investment loans and taxes

Wind energy development in China is restrained by relatively high investment costs. According to estimates (*Wind Power*, No.4, 1997, p.4), cost for wind energy development in China is at 9,000-12,000 Yuan/kW, compared with solar (50,000 Yuan/kW), nuclear (24,000 Yuan/kW), coal power plants (5,000 Yuan/kW without desulphurization equipment and 8,000 Yuan/kW with desulphurization equipment).

Current bank loans for wind energy investment have certain limitations, e.g., higher interest rates (11.7%), and short pay-back times (less than 5 years). Taxes for imported equipment are: import tax (12%) and VAT (17%). Soft credits provided by foreign governments usually contain 35% grants, but this advantage is overtaken by these taxes. In addition, VAT for electricity produced from wind turbines is also set at 17%. VAT is the same as for the

[11] Formerly the State Planning Commission (SPC) before 1998.
[12] Former Ministry of Machinery Industry.
[13] Former Ministry of Aerospace.
[14] Former Ministry of Electric Power.
[15] For example, the former Ministry of Electric Power supports the reduction of VAT from 17% to 6% for electricity generated from wind farms, but this interest is not consistent with that from the National Electric Power Corporation, which tends to disregard this request.

electricity generated from coal-based power plants, which enjoy depreciation for equipment. No depreciation incentives for wind turbines are available so far. Comparatively, VAT for small hydroelectric development is at 6%. There are only two types of credits: commercial loans and the loans provided by the Shuangjia Program. Long-term (more than 10 years) and low interest loans are generally not available by commercial banks. These are important barriers for wind energy development at the current stage of development. Clearly, wind energy needs policy incentives in order to become competitive in the energy market place.

6.2 Price distortions

Although the potential market for wind energy is high, current development is handicapped by low prices for wind generated electricity. There exists wide energy price distortions in the energy market. Wind energy competes unfavorably with other conventional energy sources. With the lack of proper energy price structure, which could internalize social and environmental costs of energy production, distribution and consumption, wind energy is still unable to compete with conventional energy sources such as coal (Wang and Shi, 1994, p46).

There are large differences in wind electricity prices between provinces, for example, Liaoning (0.9 Yuan/kWh), Xinjiang (0.86 Yuan/kWh), Hainan (0.8 Yuan/kWh), Guangdong (0.7 Yuan/kWh), Inner Mongolia (0.63 Yuan/kWh), Fujian (0.2 Yuan/kWh).[16] In Xinjiang, total pay-back times for Dabancheng Wind Farm is estimated at around 6-7 years under the current price system. This quick return in investment is mostly due to the higher electricity price set up by the regional government. By contrast, The Pingtan Wind Farm in Fujian Province has seen a major decline in performance. It is mostly caused by the low electricity price for which the company has had a budget deficit for years (Lin, 1997, p.32).

The price for imported wind turbines is becoming lower in recent years at around 7,000 Yuan/kW (Zhang, 1997, p.54). If other costs are estimated, including VAT for imported products, large wind turbines may cost 10,000 Yuan/kW. Comparatively, the cost for coal based power plants is around 5,000 Yuan/kW (without desulphurization equipments) and 8,000 Yuan/kW (with desulphurization equipments). Although wind energy is not very competitive at the current stage of development, compared with the investment costs for fossil-fuel based power plants, the inclusion of environmental externality in power generation in coming years could change this situation drastically.

6.3 Foreign technology vs. domestic technology

There are two trends in wind turbine development in China. China has devoted considerable R&D resources and efforts to establish indigenous capacity for wind turbines. Development of small wind turbines has been standardized through eleven national standards and 25 industrial standards. Prototypes for wind turbines of 100-200 kW were tested and demonstrated during 1985-1995, but largely failed to commercialize them in the market place.

[16] In some cases, local governments set up particular policy for wind electricity prices. In order to support the development of the wind farm in Nanao County, which is now the largest wind farm in the coast areas in China, Shantou City government increased the wind electricity prices as follows: 1989-92 (0.42 Yuan/kWh), 1992-93 (0.52 Yuan/kWh), 1993 (0.65 Yuan/kWh). See: *Wind Power*, No.1, 1995, p.10.

The reasons can be attributed to: high-tech contents of large wind turbines, lower input of investment and high costs of 6,300 Yuan/kW (*Wind Power*, No.2, 1997, p.32).

For larger wind turbines (over 200 kW), China has, in practice, relayed on imported foreign technologies. By 1996, out of the 56 MW of installed wind turbines nationwide, only 950 kW of the generating capacity came from domestically made wind turbines. It accounted for only 1.7% of the total installed capacity (*Wind Power*, No.2, 1997, p.21). Clearly, China is still in the early stage of establishing its domestic R&D capacity and manufacturing competence for large wind turbines. In recent years, economies of scale in wind turbine development have become a concern in wind industrial policy. It has been realized that small units are relatively expensive, although they meet decentralized needs and satisfy local demands. To meet industrial development objectives at the regional level, large wind turbines are considered more cost-effective, because of the scales of the economy (Liu and Luo, 1997, p.34).

Government is so far the main player in the drive for wind energy development. There are four different types of technology trajectories so far: 1) self-reliance, i.e., relaying on domestic R&D capacities; 2) assembly of imported spare parts; 3) full import of foreign technologies and products; 4) joint ventures to import foreign technologies and indigenize them by building up domestic production capacities.

Aiming to succeed in the Chinese market, three steps are usually undertaken in disseminating foreign technologies: first, establishing demonstration sites through grants provided by bilateral and multilateral sources; second, selling of wind turbines through soft loans provided by foreign governments; marketing products produced by companies of the credit making country. Comparatively, prototypes made by domestic manufacturers go directly to market development and there is a lack of intermediate steps to test the maturity of products, and so is the demonstration process. This explains in part the insignificant performance of the domestic products.

7 Case studies

The following two cases show how different results can be achieved due to different policy arrangements and corresponding management practice. The cases indicate that back-up of adequate policies and management expertise holds the key to achieve sustained growth in wind energy development.

7.1 Wind energy in Inner Mongolia

Wind energy development in Inner Mongolia started in the 1970s and it is the earliest promoter among different regions in China. Inner Mongolia has very good wind resources with the total exploitable capacity of 100 GW, which accounts for 40% of the total national capacity. Inner Mongolia has adopted a strategy of becoming the pioneer of wind energy development. This is realized through two parallel development: first, widespread small wind turbines for decentralized off-grid household use, aiming for the increase of living standards of 150 million rural residents in the region; and second, large wind farms for grid-connected electricity generation, aiming for industrialization and energy export to other regions.

By 1997, more than 140,000 small wind turbines were installed with an annual increase of 5,000 units. These units are all made within the region, supported by the extensive network of services. By 1997, total installed wind capacity from four wind farms reached 45 MW, which is the No.1 among the regions in China (Chen, 1997, pp.29-31).

The regional government has prioritized wind energy development with an established institution for wind energy technology innovation and management. Subsidies have been instrumental in stimulating interest of rural residents. Farmers receive 200 Yuan of subsidies for each purchased wind turbine unit. Another major stimulation is the demand for energy services, particularly based on electricity, as living standards increase.

Inner Mongolia has two of the ten largest wind turbine manufacturers in the area of small wind turbine production (*Wind Energy*, No.2, 1992, p.2). The utilization of loans from bilateral sources is the main stimulant for large-scale wind energy development. In 1990, the small wind turbines under operation in Inner Mongolia account for 78% of the national total. Among the 88 counties, 60 have established institutional frameworks for wind technology dissemination and maintenance service. 28% of the rural population are now using wind electricity. In the best case of Siziwang Banner, the dissemination rate for wind energy has reached 90% with more than 8,000 installed units (Wang and Chen, 1992, p.2). The widespread use of wind turbines has increased the quality of life for rural people, which can be measured through increasing use of home electric appliances in the region.

There is a problem of dissemination of wind turbines within low wind-resource intensity areas. It was reported that more than 10,000 units were sold in these areas that resulted in inefficient use of capital and low utilization rates of wind turbines. To solve this problem, wind/solar systems were introduced, which showed promising results (Wang, 1992, pp.4-6). The regional government has envisioned the development of wind energy as a key industry, and become a dynamic leader in this field in the country.

7.2 Dachen Islands: Wind/diesel system development

In China, there are 6,500 islands, in which only about 400 islands are inhabited and the rest without inhabitants. The main problem is the lack of energy supply that has limited the development of the island economy. Dachen in Zhejiang Province consists of two big islands and 15 small islands located 54 km to the Eastern China Sea. There are 8,000 people living in the islands with the fishing industry as the major source of income. These are isolated islands with an off-grid electricity supply system (diesel electric generator).

There were big energy shortage problems in the 1980s, which limited the local economic development and affected the lives of the local residents. The desire to solve the energy shortage problem and experiment with new off-grid wind energy systems motivated this wind/diesel energy project as shown below. The project also meant to demonstrate the usefulness of such a technology in isolated coast regions, particularly islands, in China, and in the Asian-Pacific region (European Community, 1986).

The European Community, jointly with the Chinese government, provided a grant of 4 million ECU and technical assistance to build up a wind/diesel system (DES) in Dachen islands in 1988. Three units of Danish-made 55 kW wind turbines were installed, plus two Chinese-made 20 kW wind turbines. This is a demonstration project with ambitious plans to disseminate the experience to other isolated islands and those in the Asian-Pacific region. The project was claimed to be successful by both the European and the Chinese counterparts in 1989 (Lian, 1989).

The project showed its usefulness in the early years till 1993-1994, but stopped operation in 1994. After four years since 1994, the wind turbines have become unusable. This result is different from what was predicted in the project evaluation made in 1989, which showed a promising future for disseminating such a technology in coast areas in China and the Asia-Pacific region (Lian, 1989). Above all, the performance of the wind farm indicates the gap between project design and operation, in which effectiveness is of concern.

The main causes for the problem can be attributed to the following, according to my interview and investigation at the Dachen Island:

The control and management framework for the wind-diesel system is inadequate. This is reflected in the electricity price set up by the local public-owned utility company. The high electricity prices have played a role to disencourage the private sector, mainly the fish processing and ice-making industries, from using the electricity provided by the public utility. Instead, each private enterprise installed its own diesel generator. The cost of electricity production is about 0.5 Yuan/kWh, compared with the monopoly price of 1.3 Yuan/kWh from the public utility.

The public utility is in huge budget deficit (about 800, 000 Yuan per year), due to inefficient management. This has led to higher electricity prices set up for different end-users.[17] This price barrier has limited the local economy to grow.

[17] Electricity prices are for local residents at 1.05Yuan/kwh, industry at 1.3 Yuan/kwh and the service sector at 1.5 Yuan/kwh. However, the cost for the electricity generated from this wind/diesel system is at 0.7 Yuan/kwh (*Wind Power*, No.1, 1994, p.59).

There is a lack of demand for electricity due to: the self-reliance strategy of the local industry, the decline of the fishing industry because of the depletion of fishery stocks,[18] the slow development of the service sector, including tourism. There is a lack of competence in managing the wind-diesel system, mostly due to inadequate training.[19]

Migration of local residents to the mainland, due to better economic opportunities in the mainland, and lack of development in the Dachen islands.

[18] There were more than ten fish processing industry enterprises in the Dachen Islands in the 1980s, but only seven are under operation by 1998.
[19] Based on an interview with the manager at the local public utility.

8 Conclusions

This study indicates the importance of institutional roles in wind energy development process. It shows through the analysis that sustainable wind energy development is not only determined by technical issues and components, but also depended on cost-effective mechanisms for operation, e.g., economic, financial, political and legal institutions.

China's experience in wind energy development demonstrates that lack of adequate policy frameworks constitutes a major barrier for cost-effective wind energy dissemination. This is in part due to distorted energy policy in favor of conventional, i.e., fossil fuel based, energy expansion. There is little doubt that governmental policies and incentives, e.g., tax benefits, subsidies, electricity price, and market mechanisms, can play decisive roles in stimulating wind energy development and dissemination. In addition, improved coordination between different domestic actors is useful in situations such as negotiation with foreign suppliers and contractors.

It must be realized that many distorted policies are made, due to the lack of awareness and understanding of wind energy related social and environmental benefits. It is important to make more efforts in human resources development and capacity building for wind energy development and dissemination. The role of education, training and media reporting is, therefore, crucial in fostering development in the long run.

China is still in the initial stage of wind turbine development. The current development is, to a large extent, sustained by the incentives provided through soft loans and grants from bilateral and other international assistance programs. To reach sustainable development of wind energy programs, mechanisms for encouraging interest from the private sector and commercialization of domestic products should be improved, at both the national and regional levels.

China's move in wind energy development with two ambitions is encouraging: small-scale development for satisfying rural needs, and large-scale development for industrialization and commercialization. It is expected that China has a huge potential to become a dynamic nation in wind energy development, if inadequate institutional barriers are reduced. To realize this potential, vigorous policy measures need to be established.

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