Part of the Climate Change Problem… and the Solution?

Chinese-Made Wind Power Technology and Opportunities for Dissemination

Joanna I. Lewis

China is the second largest energy consuming nation and consequently the second largest national greenhouse gas emitter. Although exempted from mandatory emissions reduction targets under the Kyoto Protocol, China's role in a global regime to reduce greenhouse gas emissions is essential—as has been pointed out by the US government.[1] Flexibility mechanisms like the Clean Development Mechanism (CDM) aim to encourage emissions reductions in developing countries, but recent pilot projects have highlighted serious problems in monitoring and verifying emissions reductions from such projects, as well as identified the potential to incur large transaction costs that will greatly reduce the benefits of any emissions reductions that projects actually achieve.

This does not mean emissions-free technologies will not be utilized in China. China has invested in developing a local wind power industry, motivated in part by the economic potential this industry provides. Wind power is the fastest growing energy source in the world with annual increases of over 20%, and is being implemented on a large scale in countries like Germany and Spain.[2] China has ambitious plans for onshore and offshore wind energy development in the next two decades and plans to meet its domestic capacity targets—currently a target of 20 gigawatts by 2020—by using domestically-manufactured wind turbines to the greatest extent possible.

In fact, this may not be possible, as Chinese-made wind power technology currently lags behind that of the countries producing the most technologically-advanced machines—namely Denmark, Germany, the United States and Spain. China has policies in place to promote the utilization of internationally best-available wind power technology, as well as policies that promote the building of wind farms

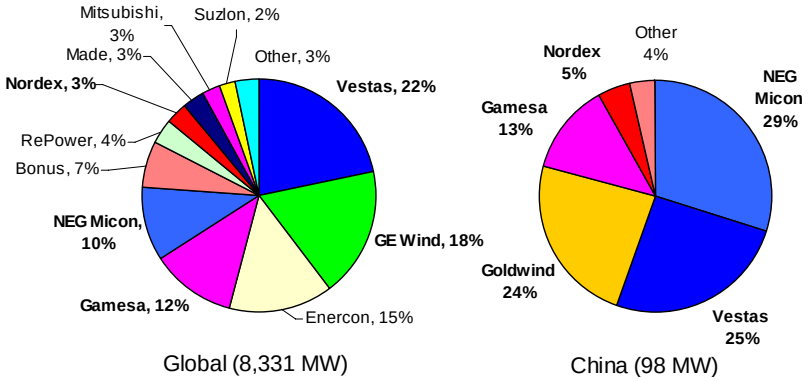
with turbines manufactured domestically. It is currently unclear how these inherently contradictory policy mechanisms will play out. It is possible that Chinese technology will continue to advance, and catch up to European and American turbines. However, since all wind turbine technology currently being produced in China originated from technology transfer and licensing agreements from European and American firms, and since in no situation was the technology being transferred state-of–the art but rather an older or more outdated model (which in the case of wind turbines translates into smaller turbines), this scenario seems very unlikely.

This does not mean that Chinese turbines do not have a very important role to play in global wind energy production. This paper discusses a different scenario for the future in which China continues to produce mid-range wind turbine technology (mid-range in terms of both size and quality) and is able to do so at comparatively low costs due to the lower costs of labor and materials inputs in China. This creates a market for wind power technology in select countries where the cost of wind power technology had previously been prohibitive—primarily other developing countries. There are many opportunities for the dissemination of wind power technology to countries that otherwise would use dirtier fossil fuel generation to meet electricity demands. Consequently, China's local wind turbine industry may play a crucial role in "south-south" technology transfer, helping to facilitate global greenhouse gas emissions reductions.

STATUS OF CHINA'S WIND INDUSTRY

As illustrated in Figure 1, most of the leading global wind turbine manufacturers also represent a large share of the Chinese market. In 2003, Denmark's Vestas had a 22% global market share, and represented 25% of sales in China. Germany's Nordex had about 3% of global market share, and slightly higher market share in China with 5%; however at one time Nordex held as much as 72% of Chinese market share. Denmark's NEG Micon, with 10% globally, had a much higher share of 29% in China—one of its best markets. (NEG Micon has since merged with Vestas.) Gamesa had 12% of global market share, and 13% of Chinese market share. GE Wind, with an 18% global market share in 2003, had just entered the wind business and had yet to expand into the Chinese market, although it are already becoming a

Figure 1. Wind Turbine Sales in China by Manufacturer, 2003



major player in China. The other major player in the Chinese wind turbine market is Chinese manufacturer Goldwind (*Jinfeng*). Goldwind held 24% of the Chinese market in 2003, but held a negligible global market share since currently China is their only market.

Although Figure 1 provides a snapshot of the Chinese wind turbine market in 2003, it does not reflect the role that the turbine manufacturers have played in the Chinese market over time. Table 1 lists total wind turbine installations in China through 2003 broken down by manufacturer. Danish manufacturer NEG Micon has the largest number of turbines installed in China of any manufacturer. NEG Micon no longer exists as an independent company, after merging with Vestas, another leading Danish manufacturer, at the end of 2003.

Goldwind is the leading Chinese turbine manufacturer, having captured a quarter of Chinese market share in 2003 despite strong competition from the leading global wind turbine manufacturers. As of 2003, Goldwind turbines already represented about 9% of total wind turbine installations in China (Table 1), and the company is rapidly expanding production as illustrated in Figure 2. In 2004, Goldwind reportedly installed 66 new wind turbine generators with a total capacity of 39.6 MW—their largest annual installation to date. Production of turbines is currently limited by the company's small size and limited manufacturing facilities.

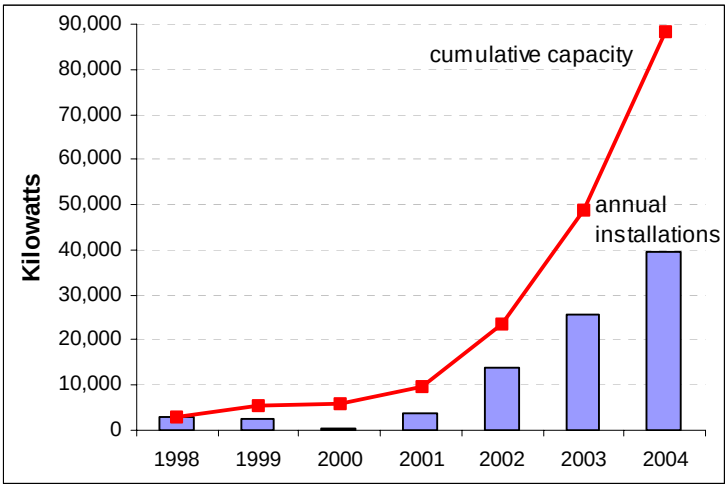
Table 1. Wind Turbine Installations in China through 2003 by Manufacturer

	Installed Capacity (kW)	Percent of Total
NEG Micon	170,390	30%
Vestas	95,920	17%
Nordex	88,550	16%
Goldwind	50,100	9%
Gamesa	20,800	4%
Xi'an-Nordex	21,000	4%
MADE	18,480	3%
Nedwind	17,500	3%
Zond	16,500	3%
Bonus	13,550	2%
Windey	6,150	1%
Other	48,060	8%
Total	567,000	100%

Goldwind received a high-profile order to supply the wind turbines for one of the first pilot wind concession projects in China, a government tender for a 100 MW wind farm located in Huilai, Guangdong. The prices bid by the developers competing for the concession projects were much lower than had been anticipated and reflected the fact that Goldwind had offered to sell its turbines for about 25% less than the price that was being offered by the European companies.[3] Goldwind's turbines consequently became particularly attractive to developers trying to come up low tariff prices so that they would be selected; a number that was directly tied to wind turbine cost. Goldwind's selection for the Guandgong project has attracted the attention of both domestic and international experts curious as to how Goldwind has achieved cost savings.

In order to examine how Goldwind has been able to achieve its cost savings, it is useful to understand the source of its wind turbine technology. Goldwind, based in the Xinjiang Autonomous Region in northwest China, manufactures turbines in the 250 kW, 600 kW and 750 kW size classes, although it is the 600 kW turbine that has been

Figure 2. Goldwind's Installed Wind Power Capacity in China



most crucial to its success to date. In 1996, the Xinjiang Wind Energy Company (Goldwind's parent company) bought a license from Jacobs, a German wind turbine manufacturer, to manufacture its 600 kW wind turbines, with the license paid as a per machine royalty. In 1997, the Xinjiang government recognized that Goldwind's wind turbine manufacturing was helping to promote economic development in the region, and Goldwind consequently received 4 million RMB Yuan from the Xinjiang Science and Technology Commission research and development fund.[4]

Goldwind has produced more than 130 of its 600 kW wind turbines for use in China, and in 2004 developed a 750 kW turbine that is yet to be sold commercially and still includes foreign-made components. Goldwind also has a prototype of a gearless 1.2 MW turbine that is currently being field tested in Germany. The 1.2 MW design is not expected to be available for commercial sale anytime soon, but Goldwind is expected to expand the testing of the prototype into China and eventually manufacture this turbine's generator, and suppliers would be sought for all other components.[5] Goldwind's turbines are not yet fully manufactured in China, although the use of locally-manufactured components increases every year. Although initially blades were a limiting factor for making fully locally produced turbines, Goldwind now uses blades made by Baoding, a blade factory located in eastern China.[6]

Since 1996, Goldwind has pursued a business model that allows it to implement modern, foreign technologies while promoting its own technological advancement, with the goal of creating new ideas and eventually benefiting from its own products and results of its research and development.[7] Goldwind has shown a unique interest in the value of property rights—something often less valued in China's national innovation system.

As local content utilized in Goldwind turbines has increased, costs have declined. To this end, Goldwind expects that domestically-produced wind turbines will represent an increasing share of wind turbine sales in China. The current policy framework in place in China to promote the use of wind power suggests that this will most certainly be the case, due to extensive mechanisms that directly promote the use of domestic wind turbines.

POLICIES PROMOTING WIND INDUSTRY DEVELOPMENT

Goldwind's success in China is also due to the fact that it has been the primary beneficiary to date from government policies that preferentially support the utilization of domestically-manufactured wind turbines in its wind farm projects. Policy measures to support wind industry development can be grouped into two categories: measures that directly target local wind manufacturing industry development (direct policies), and policies that support wind power development in general, and therefore indirectly create an environment suitable for a local wind manufacturing industry (indirect policies). The policy measures that have been used to directly and indirectly support wind industry development in China are listed in Table 2.

Direct Policies

China has taken several steps to directly encourage local wind turbine manufacturing, including policies that encourage joint-ventures and technology transfers in large wind turbine technology, policies that mandate locally-made wind turbines, differential customs duties favoring domestic rather than overseas turbine assembly, and public R&D support, as chronicled in Table 2. Beginning in 1997, the "Double Increase" (*Shuangjia*) policy was aimed at doubling the 80 MW of wind

capacity that were then installed, and encouraged (but did not mandate) that a larger share of local content be incorporated in turbines used. At this time, however, the future outlook for wind power utilization in China was likely too uncertain and 80 MW too small a quantity to encourage local manufacturing by turbine suppliers. Additionally, these local content requirements directly conflicted with the requirements of most foreign government loans which were already being used to support many wind farm ventures in China. These loans were typically in the form of tied-aid, used to support the sales of foreign wind farm technology to China. Therefore, 74 MW of wind power was successfully installed under this program essentially meeting the proposed target, but little incentive for local manufacturing was created.

The Chinese Ministry of Science and Technology (MOST) has subsidized wind energy R&D expenditures at varied levels over time, beginning most notably in 1996 with the establishment of a renewable energy fund.[8] In an effort to help Chinese turbine manufacturers develop products and technologies, MOST funded research to develop technologies for 600 kW machines during the Ninth Five-Year Plan (1996-2000). MOST is now supporting the development of megawatt-size wind turbines, including technologies for variable pitch rotors and variable speed generators, as part of the "863 Wind Program" under the Tenth Five-Year Plan (2001-2005).

In 1997 the SDPC began its "Ride the Wind Program" (*Chengfeng)* in order to promote a model of "demand created by the government, production by joint venture enterprise, and ordered competition in the market."[9] Two joint venture enterprises to domestically manufacture wind turbines were established: one between the Spanish company Made and the Chinese company Yituo, and one between the German company Nordex and the Chinese company Weide. The technology transfers carried out through this program started with a 20 percent local content requirement, and a goal of an increase to 80 percent as learning on the Chinese side progressed.[10] The Made-Yituo joint venture focused on a 660 kW turbine transferred by Made, and the Xi'an-Nordex joint venture focused on a 600 kW turbine transferred by Nordex. The Ride the Wind program experienced limited success, due in part to conflicts between the Chinese and foreign companies likely stemming from the fact that the partnerships were chosen by the government rather than the companies themselves. The Chinese

companies were selected from industries that were thought to be appropriate to wind technology—primarily the aerospace industry—but had little experience, or interest, in manufacturing wind turbines; similar to what happened in the early years of the United States wind industry. Consequently, China's target of 1000 MW of wind by the year 2000 was not met (only about 350 MW had been installed by 2000); the foreign manufacturers blamed this setback on unclear wind project approval procedures and unrealistic local content requirements under the Ride the Wind program.[11]

China continues to implement local content requirements in a variety of forms.[12] Wind farm projects approved by the National Development and Reform Commission (NDRC) during the Ninth Five-Year Plan (1996-2000) were required to utilize wind turbine equipment containing at least 40% locally-made components. More recently, beginning in 2003, NDRC launched the Wind Concession program which includes local content requirements that have been growing more stringent over time. This program aims to encourage international and domestic investors to develop large wind farms (averaging 100 MW each) through a tendering procedure, marking the introduction of market incentives into China's wind farm development process with the goal of bringing down the cost of wind-powered electricity. Developers bidding on the most recent concession projects in September 2004 had to demonstrate the ability to utilize wind power technology that met a 70% local content requirement, while the first two projects required only 50% local content. In addition, the Hainan provincial government recently released a request for bids for a 300 MW project that also encouraged the use of "technologically matured domestic turbines."[13] It is now clear that these local content requirements are causing foreign firms interested in selling wind turbines in China to develop a manufacturing strategy that will allow them to meet these requirements. Many companies have begun to either establish China-based manufacturing facilities or assembly facilities for Chinese-made components.

Indirect Policies

There are several crucial policies that have supported wind power utilization in China, and therefore have created a market for wind turbines that supported the emerging wind power technology industry. The first major policy to specifically support wind power in

China came in 1994 when the Chinese government, led by what was then the Ministry of Electric Power, released "Provisions for Grid-Connected Wind Farm Management." The Provisions mandated that grid operators facilitate interconnection of wind farms, and set a purchasing price for wind power based on a pricing principle of generation cost, plus the repayment of loan and interest, plus a "reasonable" profit.[14] In addition, the Provisions stipulated that any incremental cost of wind power over the average cost of conventional electricity be borne by the entire grid. This cost-plus-profit formula persisted in China for several years, encouraging wind development in certain provinces but reportedly leading to large subsidies in many instances where the profit margin was set relatively high. In 2002, the Ministry of Finance and the State Duty Bureau implemented a new tax policy that reduced the Value-Added Tax for wind generation from 17% to 8.5%.[15]

More recently, China has developed a series of government-run tenders known as Wind Concessions, described above, leading to the development of larger wind farms in China. The highest profile policy to ever be implemented in China in the support of renewable energy passed the State Council on February 28, 2005; this National Renewable Energy Law goes into effect in 2006. In its current form it sets up a framework upon which further implementing regulations will build, encompassing a variety of policy mechanisms that are already being utilized in China, and mandating several new ones such as technology-specific feed-in tariffs. Additionally, in 2004, Guangdong became the first province to implement a province-wide feed-in tariff for wind projects developed there.

Table 2. Policy Measures to Support Wind Power in China

Policy	Year Implemented	Description	Implementing Agency	Policy Type(s)	Interaction with Wind Industry (Direct/Indirect)	Major Results
Provisions for Grid-Connected Wind Farm Management	1994	Mandated the purchase of wind-generated electricity by power companies with additional cost spread over grid	Ministry of Electric Power	Financial incentive	Indirect	Cost-sharing of wind has been disputed; collapsed with power sector reform
Renewable energy fund	1996	Over 60 million RMB made available for RE R&D; focus on developing a 600 kW turbine as part of 9th 5-year plan	MOST	RD&D	Direct	Local wind turbine manufacturers have been able to use funds for international technology transfer
Ride the Wind (*Chengfeng*)	1997	Allocated new technology funds to 2 government-facilitated Sino-foreign joint ventures in wind turbine manufacturing	SDPC, SETC	RD&D; Local content incentive	Direct	One of the two joint ventures is now manufacturing commercially-viable 600 kW turbines (Xi'an Nordex)
Double Increase (*Shuangjia*)	1997	Promoted the doubling of current wind capacity (~80MW) with low- or no-interest domestic loans; encouraged domestic manufacturing	SDPC, SETC	Financial incentive; Local content incentive	Indirect	Met target for capacity installations but failed to encourage local manufacturing
Loans for wind farm development	1996, 1999	Gave priority access to reduced interest domestic loans for wind farms up to 50% lower than commercial rates; preference for local content	SDPC, MOST	Financial incentive; Local content incentive	Indirect	Used to develop several wind farm demonstration projects; total capacity relatively small

Policy	Year Implemented	Description	Implementing Agency	Policy Type(s)	Interaction with Wind Industry (Direct/Indirect)	Major Results
Income tax exemptions	Varies year-to-year	Provincial-level income tax exemptions; Inner Mongolia and Xinjiang allow a 2-year exemption followed by 3 years at 50% of the normal tax rate, then an additional 15 years at 15% (2002).	Provincial tax bureaus	Tax incentive	Indirect	Encouraged capacity installations in certain regions
Reduced import duties	1998, 2000	Initially removed import duty on wind turbines and reduced the import duty on components; eventually removed duty on components.	Ministry of Commerce	Tax incentive	Direct	Favoring the import of full turbines over components was recognized to potentially hurt domestic industry development
Local content requirement	2000	Mandated 40% local content for all new wind power projects	SDPC	Local content requirement	Direct	Local content loosely interpreted therefore had limited industry impact; set stage for more stringent future requirements.
836 Wind Program	2001	Promotes the development of megawatt-size wind turbines, including technologies for variable pitch rotors and variable speed generators, as part of the 10th 5-year plan	MOST	RD&D	Direct	Status unclear, no word of successful Chinese megawatt-size turbine as of yet

Policy	Year Implemented	Description	Implementing Agency	Policy Type(s)	Interaction with Wind Industry (Direct/Indirect)	Major Results
VAT reductions	2002	Reduces the Value-Added Tax for wind generation from 17% to 8.5%; value-added tax on electricity from wind farms has been reduced even more in several provinces; are specific reductions for foreign and JV enterprises	Ministry of Finance and the State Duty Bureau	Tax incentive	Indirect	Reduced the final price of wind power in some provinces
Wind Concessions	2003	Government-run competitive auction to develop selected wind farm sites; mandates 50% local content, increased to 70% in 2004	NDRC	Government auction; local content requirement	Indirect and Direct	Approximately 500 MW of projects under contract to date and 3600 MW in pipeline

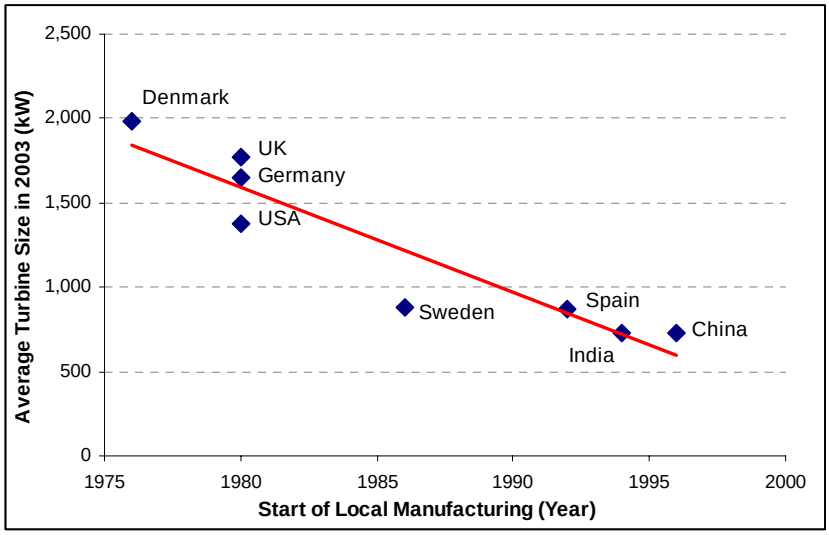
OUTLOOK FOR CHINA'S WIND INDUSTRY

Many studies have examined the determinants of China's success across various technologies and industries,[16] while others have looked at China's potential to leapfrog to more advanced technologies through international technology transfers.[17] An investigation of China's wind industry raises both issues: the extent to which China can complete with foreign wind turbine technology manufacturers on the global market, and the extent to which China will be able to leapfrog in the electric power sector and utilize advanced renewable energy technologies to supplement its dependence on coal-fired power generation.

There are already several examples of renewable energy technologies being manufactured in China where quality is already equivalent to the highest technological level of the global industry, including solar water heaters, some biomass technology, and small-scale wind turbines.[18] However, for large wind turbine technologies, this is not yet the case. Table 3 illustrates how Chinese wind turbines are currently smaller on average than turbines being developed elsewhere. The global trend as wind turbines become more advanced is that they also become larger.

Figure 3 illustrates that there is a smaller average turbine size in emerging markets for wind power technology—including Spain and India, as well as China—due to the fact that similar models for technology development have been used in each of these countries. All have acquired wind turbine technology through international technology transfers of older technology since this is typically what companies are wiling to transfer.[19] Although wind turbines being produced in China are smaller on average than those being produced in more technologically advanced markets, this does not mean that the Chinese turbines are necessarily of lower quality or less reliable than foreign turbines. In fact, the 600 kW turbines being manufactured by Goldwind have proven to be very reliable. The 600 kW turbine technology now has years of operating experience, and history has shown that there are likely to be problems with any new wind turbine technology, reflected in early problems with offshore wind turbines.[20]

Figure 3. Manufacturing Experience and Average Turbine Size



In addition, a smaller turbine size is still highly useful in some markets, particularly where infrastructure to install turbines is limited. Many countries that are interested in exploiting wind resources for electricity do not have the necessary infrastructure, such as tall enough cranes, to install the large, state-of-the-art turbines being manufactured for more advanced markets. There have been examples of a project in Eritrea being canceled in the final stages, after developers realized that the major limiting factor would be crane availability for turbine erection.[21] This has also been discussed as a limiting factor in wind projects in South Asia, including in coastal Pakistan. Therefore, there currently exists a possible niche market for the smaller turbines that are already being made by Chinese companies—even before they are able to "catch up" to manufacturing the larger turbine models that dominate current global wind turbine sales.

Regardless of turbine size, the main attraction to Chinese wind turbines lies in the potential for low cost technology. The actual cost reduction that can be realized through localizing production is a calculation that will vary greatly from country to country depending on the availability of local components, and the local cost of labor and materials. In the case of China, studies have estimated that local production of wind turbines could reduce the cost of the technology by

anywhere from 20 to 40%,[22] with early sales evidence supporting this estimate.

Countries with lower wage rates such as India and China expect to be able to realize cost savings compared to their European and American counterparts through domestic manufacturing of wind turbines. This cost reduction is potentially significant for those turbine components that are particularly labor intensive. Rotor blade manufacturing, for example, is labor intensive and thus could benefit significantly from lower labor costs, though the manufacturing process is complex and difficult to outsource to inexperienced producers.[23]

Cost savings from in-country production could also be realized if a country is dependent on importing foreign turbines from overseas and shipping costs are high. Transportation costs can be particularly severe for sizable, heavy equipment. As a result, towers are often the first component to be manufactured in a local market (towers are also not as technically sophisticated as other components). The Canadian Wind Energy Association estimated that transport costs for wind turbines, composed of both overseas shipping costs and on-land freight transport, represent 5-10% of the entire system cost for imported turbines, and 3-5% for domestically made turbines.[24] Reduced delivery lead times for wind turbines and components are another cost-saving factor in local manufacturing; shipping wind turbines to the Asia/Pacific region from Denmark takes approximately eight weeks.[25] Better customer service and faster access to customer service and technical staff, as well as to spare components in the case of mechanical problems, may further reduce costs and improve company operations.

Goldwind has been able to distinguish itself from other Chinese wind turbine manufacturers by producing a commercially viable large wind turbine with reasonable quality assurance. What is somewhat surprising about Goldwind's success is the relative simplicity of its business model, and its apparent lack of domestic competition. Goldwind is the first Chinese company to sell a commercially viable large wind turbine, but it is unlikely to be the last. Many companies could purchase similar turbine licenses and attempt to compete with foreign turbine manufacturers in the way that Goldwind has by taking advantage of the low cost labor and materials available in China, as well as the local content requirements of Chinese policies that favor domestic manufacturers in wind farm development. It is therefore

very likely that additional Chinese manufacturers will enter the wind turbine market following a similar strategy, and Goldwind's only remaining advantage will be its early entry in to the marketplace and its accumulated on-the-ground experience.

Although Chinese policies that mandate local content currently favor domestic manufacturers, as foreign companies shift towards locally manufacturing their turbines in China these policies will no longer be as favorable for Chinese companies. This could result in a loss of market share for Chinese wind turbine manufacturers unless they are able to compete by continuing to produce lower cost turbines—even as foreign companies incorporate local labor and materials into their turbines. It is currently unclear whether the cost reductions that have been achieved by Goldwind are unique to its manufacturing process, or whether it will be easily duplicated by foreign manufacturers as they shift facilities to China. However, a shift to local manufacturing does not come without a cost for the foreign companies—and a potential benefit to Chinese manufacturers—in the form of additional technology transfer opportunities. The mere presence of more local manufacturing operations of advanced wind turbine technology in China provides opportunities for the informal transfer of information that can be utilized by the Chinese manufacturers. There are concerns not only of intellectual property theft, or successful reverse engineering, but also of training a skilled labor force in China that will possess the technical expertise of the Danes, for example, but be willing to accept much lower wage rates.

There is certainly the potential for China to become a leading domestic manufacturer, or global exporter, of wind turbines. There appear to be similarities between China's experience with manufacturing wind turbines and manufacturing technologies in other sectors in which they have been successful and where a similar path was followed: beginning with technology transfer, and then incorporating further cost reductions through local manufacturing. Past examples include consumer electronics and hand tools, and recent evidence suggests private automobiles may soon follow. A detailed analysis of the similarities and differences between China's industries and experiences with learning is a useful area for future work. It is very likely that a successful domestic wind turbine industry could allow China to leapfrog in its choice of electric power technologies by including wind power in a diverse generation portfolio. In addition,

China's large-scale entry into wind turbine manufacturing could make wind power a more cost-effective option for countries around the world looking to leapfrog to cleaner energy technologies. China has a history of being a leader among less developed countries, including in the area of facilitating technology and information transfers in renewable energy.[26]

CONCLUSIONS

China's wind industry highlights models of technology procurement, adaptation and commercialization in a rapidly growing industry with important global applications. There is currently a trend towards localizing the manufacturing of wind turbines in China, even by foreign-owned wind turbine manufactures. The impact of expanded local manufacturing by foreign turbine manufacturers on Chinese turbine manufacturers is unclear; transfers of technology and learning may be gained, while market share may be lost if local manufacturing brings cost reductions in foreign technology.

Current Chinese government policies to promote wind power development are directly influencing firm strategy with respect to wind turbine manufacturing, particularly as local manufacturing is repeatedly encouraged and local content requirements are increasingly stringent. It remains to be seen, however, whether the government will be satisfied with the current trend towards the localization of manufacturing without the transfer of technology or intellectual property into the hands of Chinese firms. Foreign firms moving towards local manufacturing in China plan to do so without the joint ventures with Chinese enterprises that force them to share intellectual property rights.

Only one Chinese firm has succeeded in developing a commercially available large wind turbine, likely due to its decision to purchase a license to manufacture a turbine designed in Germany, allowing it to quickly produce a turbine that was more advanced than those of other Chinese competitors. Goldwind's technology transfer under license proved to be more successful than several attempts to develop Sino-foreign joint ventures in wind turbine manufacturing, and it remains to be seen whether other Chinese companies will opt to follow this technology transfer model to enter the Chinese wind industry.

The future of China's wind industry is uncertain, but it is likely that Chinese-made turbines will enter the global marketplace in the coming years. Although Chinese firms have yet to export their turbines overseas, exports are likely to be forthcoming. There already exists a possible niche market for the smaller turbines that are currently being made in China, particularly in less developed countries that are looking for inexpensive, smaller turbines. These market opportunities, in conjunction with the continued implementation of Chinese government policies that differentially support locally-manufactured turbines, are likely to provide the necessary stimulus for China's domestic wind industry development, and its eventual emergence in the global wind industry.

Energy and Resources Group, University of California, Berkeley

NOTES

[1] Byrd-Hagel US Senate Resolution No.98, 105th Congress, 1st session. Passed by the US Senate 95-0.

[2] World wind installation data available from the American Wind Energy Association website, available: http://www.awea.org; and the European Wind Energy Association website, available: http://www.ewea.org.

[3] Although exact turbine prices vary, Goldwind's turbines are being offered for 15-30% less than the cost of imported turbines being sold in China.

[4] Brown, Carol-Ann. 2002. *Commercialising Wind Power in China: The Policy Challenge*. Ph.D. Dissertation, Department of Geography and the Environment and the Environmental Change Institute, University of Oxford; Xinjiang Wind Energy Company website: http://www.xjwind.com.

[5] May, Hanne. 2004. "Wind over the Wall." November. Available: http://www.wind-energie.de/zeitschrift/new-energy/year-2004/inhalte/Wind_over_the_Wall.htm.

[6] Yu, W. M. and Wu, G. 2004. "The Development of China's Wind Turbine Manufacturing Industry and the Strategy of Goldwind Co." Proceedings of the *World Wind Energy Conference,* Beijing, China, November.

[7] Yu and Wu, 2004.

[8] China Center for Renewable Energy Development (CRED) and Beijing Jikedian Renewable Energy Development Center. 2002. *Evaluation of Policies*

Designed to Promote the Commercialization of Wind Power Technology in China. May 15. Available: http://www.efchina.org/documents/WindPowerTech-complete.pdf.

[9] State Development Planning Commission, (Department of Basic Industry Development, PRC). 2000. *China New & Renewable Energy, 1999 White Book*. Beijing: China Planning Press, April.

[10] Lew, Debra J., 2000. "Alternatives to Coal and Candles: Wind Power in China." *Energy Policy* 28, 271-286.

[11] Feifel, Karl-Eugen. "Wind Power in China, a German Company's Experience." *Industry & Environment*, 2001.

[12] Additional policies that directly support local manufacturing in China not discussed here include the reduction or elimination of customs duties on importing wind turbine components.

[13] "Chinese island to supply mainland." *Windpower Monthly*, October 2004:32.

[14] Liu, Wen-Qiang, Xiliang Zhang and Lin Gan. 2002. "Wind energy development in China: institutional dynamics and policy incentives." *International Journal of Energy Technology and Policy* Vol. 1, No. 1-2.

[15] National Renewable Energy Laboratory. 2004. "Grid Connected Wind Power in China." NREL/FS-710-35789. April. Available: http://www .nrel.gov/international/china/pdfs/35789_grid.pdf

[16] McDonald, T. David. 1990. *The Technological Transformation of China*. National Defense University Press, Washington, D.C.; Liu, Xielin and Steven White. 2001. "Comparing innovation systems: a framework and application to China's transitional context." *Research Policy* 30, 1091-1114.

[17] Amsden, Alice H. 1989. *Asia's Next Giant: South Korea and Late Industrialization*. Oxford University Press, New York; Lee, Keun and Chaisung Lim. 2001. "Technological regimes, catching-up and leapfrogging: findings from the Korean industries." *Research Policy* 30, 459-483.

[18] Zhang, Zhengmin, Wang Qingyi, Zhuang Xing, Jan Hamrin, Seth Baruch. 2002. *Renewable Energy Development in China: The Potential and the Challenges*. March. Available: http://www.efchina.org/documents/China_RE_Report_ EN.pdf.

[19] One possible exception to this rule was Vestas' technology transfer and joint venture with Spanish company Gamesa of a turbine that was essentially state-of-the-art at the time of transfer.

[20] "Strong winds delay Horns Reef repairs." *Windpower Monthly*. November, 2004:49

[21] Bushey, Doug. 2005. *Wind Development in Eritrea*. Master's Thesis, Energy and Resources Group, University of California, Berkeley. May.

[22] Taylor, Robert and Bogach, Susan. 1998. "China: A Strategy for International Assistance to Accelerate Renewable Energy Development." World Bank Discussion Paper Number 388.

[23] Krohn, Soren. 1998. "Creating a Local Wind Industry: Experience from Four European Countries." Helios Center for Sustainable Energy Strategies. May 4.

[24] Canadian Wind Energy Association (CanWEA). 2003. "Manufacturing Commercial Scale Wind Turbines in Canada." April 14. Available: http://www.canwea.ca/downloads/en/DOCS/Manufacturing_Backgrounder.doc

[25] Allen Consulting Group. 2003. *Sustainable Energy Jobs Report Wind Manufacturing Case Study*. Prepared for The Sustainable Energy Development Authority, Government of Australia. January. Available: http://www.seda.nsw.gov.au/pdf/PDF_GH_DIS_PAGE13_43.pdf.

[26] Jia, Hepeng. 2004. "China to train developing nations in solar technologies." *Science and Development Network*, August 20. Available: http://www.scidev.net/News/index.cfm?fuseaction=readNews&itemid=1561&language=1