A Review of International Experience with Policies to Promote Wind Power Industry Development

FINAL REPORT

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Executive Summary

China, along with many other countries, is looking not only to expand its domestic use of renewable energy but also to develop accompanying local renewable energy technology industries to serve that expansion. This paper explores the motivations behind establishing a local wind power industry, and the paths that different countries have taken to develop indigenous large wind turbine manufacturing industries within their borders. The core of this report is a series of detailed country case studies of how 12 different countries have sought—successfully or unsuccessfully—to encourage local wind turbine manufacturing. The objective is to begin to identify lessons learned from other countries that might be applied to China. The report serves to provide information that will be used to support the future work of grantees of the Energy Foundation's China Sustainable Energy Program in promoting the development of China's wind industry.

As this paper shows, most of the leading large wind turbine manufacturing companies in the market today were rooted, at least in part, in wind power technology research and development that began in the late 1970s, most notably in Denmark, the Netherlands, Germany and the United States. Countries that were not part of the first group of innovators have used different strategies to foster the development of their own domestic large wind turbine manufacturing companies, including establishing joint ventures and transferring turbine technology, and creating incentives or mandates for overseas manufacturers to establish manufacturing facilities within their borders.

Strategies for Localization

Wind turbine technology, either for components or for the entire wind system, is traditionally either locally acquired through the transfer of technology from overseas firms, or developed through local innovation initiated by the firm itself or in combination with other domestic research organizations. Technology acquisition from overseas firms may not result in the transfer of actual "know-how" associated with wind turbine production, and may require little or no in-country innovation to take place. It is crucial for governments hoping to promote local manufacturing within a region to be very clear about whether the goals of creating this industry are to create local jobs and a demand for raw materials, or whether the goals are to facilitate the transfer of advanced wind power technology and the associated know-how required to develop a domestic wind turbine manufacturing company within its borders. It is also important to learn from failed attempts at localization, including failed technology transfers, to understand the factors that contributed to the failure and how to correct them in future models.

Potential Benefits of Localization

The potential benefits of local wind turbine manufacturing include economic development opportunities through job creation and sales of new products; opportunities for the export of domestically-made wind turbines to international markets; and cost savings that result in lower cost wind turbine equipment, lower cost of wind-generated electricity, and higher growth rates in domestic wind capacity additions. Another, less tangible benefit to wind technology localization, but clearly a motivating factor for several countries, is a desire for national technological achievement in what is viewed as an emerging industry.

Barriers to Entry: The Challenges of Local Manufacturing

There are significant barriers to entry into what has become a relatively mature industry, particularly as turbine size grows larger and the technology becomes more complex. Many existing manufacturing companies have decades of experience in research and development and the leading turbine manufacturers are becoming larger and encompassing more global market share through mergers and acquisitions. Limited indigenous technical capacity and quality control makes technology development in new markets difficult, particularly when policies require local manufacturing. In addition, national standards requiring the use of advanced technology can initially shut out emerging firms with inferior technology. The absence of skilled workers and intellectual property protection, as well as WTO rules, can also present barriers.

Policy Support for Wind Industry Development

Countries interested in supporting wind industry development are increasingly using some of the *direct* policy measures identified below to specifically encourage local manufacturing. In addition, successful wind manufacturers are almost always located in countries that have established *indirect* policies to create both a sizable wind power market in which to emerge as a leading manufacturer, and a stable policy environment that provided consistency to investors looking to develop wind farms and to innovate in new wind power technology.

DIRECT POLICIES
Local content requirements
Policies that mandate the use of locally-manufactured technology, often by requiring a certain percentage of local content for wind turbine systems installed in some or all projects within a country, force wind companies interested in selling to a domestic market to look for ways to shift their manufacturing base to that country or to outsource components used in their turbines to domestic companies.
Preference or incentives for local content
Local content and manufacturing can be encouraged without being mandated through the use of incentives that award developers selecting turbines made locally with low-interest loans for project financing, or provide wind companies that relocate their manufacturing facilities locally with preferential tax incentives.
Favorable customs duties
Customs duties can be manipulated to favor the import of turbine components over the import of entire turbines, creating a favorable market for firms trying to manufacture or assemble wind turbines domestically.
Tax incentives
Tax incentives can be used to encourage local companies to get involved in the wind industry, or a reduction in sales or income tax can be used to increase the international competitiveness of a domestic technology.
Export credit assistance
Export credit assistance can be in the form of low interest loans or “tied-aid” given from the country where the turbine manufacturer is based to countries purchasing technology from that country.
Certification and testing programs
A national certification and testing program that meets international standards can promote the quality and credibility of an emerging wind power company’s turbines by

building consumer confidence in an otherwise unfamiliar product.
Research, development and demonstration programs
Sustained public research support for wind turbines, particularly demonstration and commercialization programs, can be crucial to the success of a domestic wind industry, particularly when R&D between private wind firms and public institutions is coordinated.

INDIRECT POLICIES
Feed-in tariffs
Feed-in tariffs provide fixed prices for wind electricity that with a long time frame and sufficient profit margin create a signal of future market stability to wind farm investors and firms looking to invest in long-term wind technology innovation.
Mandatory renewable energy targets
This type of policy requires that a fixed percentage of electricity in a given portfolio be generated by renewable resources, and can be custom-tailored to specific domestic markets depending on market structure and local resource availability.
Government auctions or resource concessions
The government can directly solicit long-term power purchase agreements with wind power developers, reducing many of the uncertainties in investing in wind projects in an unstable policy environment.
Financial incentives
A charge on electricity generated from non-renewable sources, or directly on an electricity consumer's utility bill (often called a system benefits charge), can be used to collect funds that can then be used to encourage renewable energy development.
Tax incentives
Tax-related incentives, either in the form of a corporate income tax deduction for investment in wind power technology, or a property tax deduction, may promote investment in renewable power generation.
Green power markets
Several countries have programs that permit electricity consumers to voluntarily purchase green electricity at a premium cost to support the higher cost of renewable power and encourage investment in new renewable generation projects.

Conclusions from the Country Case Studies

The full report contains 12 country case studies: Denmark, Germany, Spain, Netherlands, USA, Canada, UK, Australia, India, Japan, Brazil, and China. Each case study describes the successful and unsuccessful policy efforts used to encourage local wind manufacturing, as well as the experiences of the various wind turbine manufacturers. Based in large part on these case studies, several important conclusions can be reached about how to successfully encourage local wind manufacturing:

An attractive local market for wind power development is often a prerequisite to the robust development of a local manufacturing industry. Wind turbine manufacturers usually get their start in their home country markets, as was the case in Denmark, Germany, Spain, the US, and India. A stable home market provides companies with the necessary testing ground to sort out their technology and manufacturing strategies and gives the long-term planning horizon necessary to allow for investing in the future.

A local wind manufacturing industry must be supported by large, stable annual demand. It is estimated that a minimum annual demand of 150-200 MW for 3 or more years is crucial to developing a nascent local manufacturing industry, while a more capable and aggressive local industry is likely to require a minimum of 500 MW a year (CanWEA, 2003). Germany has maintained a stable market of over 200 MW installed per year after 1994, while Denmark and Spain did so after 1997. Germany and Spain are now maintaining markets that are well over 500 MW per year. Experience in the US and the UK, where demand for wind has not been stable from one year to the next, shows the difficulty in building a robust local industry without market stability.

Indirect policies that create a sizable, stable environment for wind power have been crucial in both promoting wind power development and promoting a local turbine manufacturing industry. Achieving a sizable, stable local market requires aggressive implementation of policies to support wind power. Denmark, Spain and Germany have each built their local manufacturing industries through what have historically been stable and profitable feed-in tariff policies. Government-run competitive bidding for wind concessions has been or is being used in Canada, the UK, India, Japan, China, and Brazil. The US's Production Tax Credit has been successful in stimulating wind development, while government loans and capital grants have been used by Denmark, Germany, the US, Australia, India, China and Brazil to support wind farm construction.

Policies that directly support local manufacturers can be crucial in countries where barriers to entry are high and competition with international leaders is difficult. Local content requirements and incentives are being used in the emerging wind markets of Spain, Canada, China, and Brazil. Spain's preferential polices for local manufacturing have helped Spanish manufactures like Gamesa grow in experience and begin to expand abroad, while simultaneously bringing international manufacturers into the Spanish market to manufacture turbines locally and create Spanish jobs. Customs duties that support turbine manufacturing by favoring the import of components over full turbines have been used in Australia, India and China with some success. Canada has implemented a tax credit on wages paid out to local labor forces in an attempt to encourage large wind turbine manufacturers to shift jobs to Canada. Quality certification and standardization programs were particularly valuable to Denmark in the early era of industry development when they essentially mandated the use of Danish-manufactured turbines due to a lack of competition.

Recommendations for China

In its pursuit of a local wind turbine manufacturing industry, China can learn from the experiences of other countries. The findings presented in this study are not comprehensive recommendations, but rather a starting ground for Energy Foundation grantees to build upon in future work.

Clarify national goals on localization. Clarity of short and long term goals is an essential pre-requisite to developing an appropriate policy response. China must therefore first determine whether it will be satisfied with the local manufacturing of wind turbines that may hire local Chinese labor and provide some local economic benefit, but will not result in the transfer of property rights, innovation knowledge or know-how surrounding the manufacturing of large wind turbines (e.g., with foreign manufacturers developing Chinese manufacturing facilities). This sort of "technology transfer" may contribute to the Chinese economy, but not to its industrial knowledge base. Alternatively, China might be interested in helping to develop its own wind manufacturing firms.

Implement indirect policies to support aggressive and stable wind power capacity additions. The most important requirement for successful local wind manufacturing is to create sizable, stable domestic demand for wind turbines. A long-term, stable feed-in tariff has proven to be the most successful mechanism for promoting wind energy utilization to date, however, several policies may be effective if implemented carefully, including a mandatory market share or RPS, or government-run project auctions or concessions.

Implement direct policies to encourage local manufacturing. China can maximize its attractiveness for local manufacturing by establishing a combination of policies to support wind industry development. This might include providing differential support to companies that are locally manufacturing their wind turbines, and/or creating strong incentives for companies to shift from importing their turbines to establishing a local manufacturing base. Incentives should be directed not only at manufacturers of full wind systems but also to manufacturers of wind turbine components. The policy mechanisms described earlier can all be used, if applied carefully, to encourage local manufacturing.

Develop a plan for escalating the local wind industry. China must develop a coherent short- and long-term plan for encouraging local manufacturing, including further research that analyzes China's historic attempts to support local wind manufacturing; assesses the benefits of local manufacturing; evaluates China's competitive advantages in wind turbine manufacturing; and develops detailed policy recommendations for consideration by the government.

1. Introduction

China, along with many other countries, is looking not only to expand its domestic use of renewable energy but also to develop accompanying local renewable energy technology industries to serve that expansion. This paper explores the motivations behind establishing a local wind power industry, and the paths that different countries have taken to develop indigenous large wind turbine manufacturing industries within their borders. Large wind turbines are defined as utility-scale wind turbines that are connected to the electricity grid, and typically range in size from hundreds to thousands of kilowatts. As the technology development strategies for large wind turbines have been very different from that of small wind turbines, this paper focuses primarily on the government policies that have either directly or indirectly supported or disrupted industry development of large wind turbines specifically. The objective is to begin to identify lessons learned from other countries that might be applied to China. The report serves to provide information that will be used to support the future work of grantees of the Energy Foundation's China Sustainable Energy Program in promoting the development of China's wind industry.

Electricity generated from wind power currently represents only 0.5% of global electricity production, and about a 7 billion dollar annual industry (IEA, 2004:1). This market is expected to double over the next four years (BTM, 2004), and it is this perceived potential for future growth and the rapid growth rates to date that are causing many nations to look toward developing domestic wind technology manufacturing industries. Countries around the world are therefore establishing policies to promote the construction of new wind installations, and some countries have developed targeted policies to encourage local manufacturing of wind technology.

As this paper shows, the leading large wind turbine manufacturing companies in the market today were all rooted, at least in part, in wind power technology research and development that began in the late 1970s, most notably in Denmark, the Netherlands, Germany and the United States. Many studies of innovation in the wind power industry have also shown that the dominance of the Danish wind companies Vestas and NEG Micon stemmed in large part from their first-mover advantage (Karnoe, 1990; Connor, 2004; Kamp et al., 2004). However, the dominance of Denmark as a wind industry base is waning as countries like Germany and Spain, with larger exploitable wind resources and with higher electricity demands, show that stable, supportive government policies to promote wind energy utilization can be critical to creating a market for wind and the rise of local manufacturers producing world-class turbines.

Countries that were not part of the first group of innovators have used different strategies to foster the development of their own domestic large wind turbine manufacturing companies, including establishing joint ventures and transferring turbine technology, and creating incentives or mandates for overseas manufacturers to establish manufacturing facilities within their borders. Spain is one country that clearly benefited to a substantial degree from a joint venture with Denmark's Vestas to form the company Gamesa, while China's joint ventures have struggled, including Germany's Nordex Weide. The Indian company Suzlon's success, meanwhile, may be a product of the presence of many world class manufacturers located within India stimulating the industry, as well as the fact that Suzlon has based its research and development facilities in

Germany and the Netherlands and likely benefits from the innovation networks in those countries.

Fundamental to the growth of a domestic industry is the formation of a stable domestic market, which inevitably means a stable demand (Johnson and Jacobsson, 2003). In addition, a nation can most easily act to support its own economic and social interests in its own home market (Connor, 2004). To seriously evoke a new internationally competitive industry, such as wind turbine manufacturing, a nation must provide policies which deliver a stable demand for the goods provided by the new industry if such a demand does not already exist (Connor, 2004). Many countries have also utilized policies to specifically promote the development of a local wind manufacturing industry, including Germany, Spain, Canada, Brazil and China. These policies include local content requirements and incentives, favorable customs duties, tax policies, and export credit assistance.

The remainder of this paper addresses these points in more detail. Section 2 examines strategies for localization, including models for wind turbine manufacturing and technology acquisition, and incentives for technology transfers. Section 3 describes the potential benefits of localization, including domestic employment opportunities, international exports, technology cost reductions, and national achievement. There are also significant barriers to entry in the wind business, however, and Section 4 discusses those barriers generally, including existing international competition, technological advancement, limited indigenous technical capacity and quality control, requiring use of technology that cannot be made locally, limited locations with skilled labor and components network, intellectual property issues, and barriers to trade. Section 5 identifies the various policy measures that might be used to directly or indirectly support wind industry development, while Section 6 provides a series of country case studies. Each of these case studies describes the approaches used to successfully or unsuccessfully support local wind technology manufacturing in specific countries. The country studies include discussions of the experiences of wind turbine manufacturers which are grouped by the country in which majority ownership is based. Countries covered in this paper include Denmark, Germany, Spain, the United States, the Netherlands, the United Kingdom, Australia, Canada, Japan, India, Brazil, and China. The paper offers several conclusions in Section 7, and in Section 8 provides policy recommendations for consideration in China or other countries interested in supporting local wind technology manufacturing.

2. Strategies for Localization

2.1. Models for wind turbine manufacturing

A government's strategic decision to encourage the development of a domestic wind manufacturing industry is based on national economic interests. In the wind electric technology industry, there are three key possibilities for local manufacturing:

1) Assembly: Local assembly of foreign turbine components into complete wind turbine systems,
2) Component Manufacture: Local manufacturing of select components (e.g., towers, blades, generator, gearbox)
3) Turbine Manufacture: Local manufacturing of complete wind systems

Each of these approaches implies different: goals for manufacturing, degrees of localization and technology ownership, and policy incentives at work. The first step for China is to determine which of these models of local manufacturing are realistic in the short and long term and best suited for China, and then shape policy incentives accordingly.

2.2. Models for technology acquisition: purchasing versus internal development

Wind turbine technology—either for components or for the entire wind system—is traditionally either:

- locally acquired through the transfer of technology from overseas firms that have already developed advanced wind turbine technology, often through a licensing agreement, or
- developed through local innovation or research and development initiated by the firm itself or in combination with other domestic research organizations.

In some cases, after acquiring wind turbine technology through a technology transfer arrangement, a firm will then further innovate based on the transferred design and create a new design. A technology transfer typically includes the transfer of the technology design as well as the transfer of the necessary property rights needed to reproduce the technology in a particular domestic context. A common form of property right included in a technology transfer is a patent license: a legal agreement granting someone permission to use a patent without a change in patent ownership.

In general, the acquisition of foreign technology is typically superior for technically sophisticated wind components or systems where prior experience is highly valuable. An example of such an arrangement was the joint venture, Gamesa Eolica, formed between the Spanish turbine manufacturer Gamesa holding a 60% share and the Danish manufacturer Vestas holding a 40% share, in which Gamesa paid licensing feeds to Vestas that allowed it to manufacture turbines made with Vestas technology solely within the Spanish market (Wüstenhagen, 2003).[1] However, less sophisticated technology, such as towers, may be readily

[1] This arrangement was terminated when the companies split in December 2001 when Vestas decided to sell its 40% stake in Gamesa Eolica for 287 million € to Gamesa, the parent company.

developed locally without a foreign partner. Towers are already being manufactured in countries where other components are not yet being manufactured (Allen Consulting Group, 2003). Since most components must be custom designed for specific wind machines, typically arrangements are reached between a components manufacturer and a turbine manufacturer before production begins.

It deserves note that a technology transfer may or may not include technological know-how associated with the development of the technology itself. The physical transfer of technology is likely insufficient to ensure the transfer of the technological knowledge that recipient companies would need to produce comparable wind technology domestically and to ensure its continued operation and maintenance in the field. Cases have shown that the transfer of technology without supplemental "know-how"—also referred to as the "software" needed to accompany the "hardware"—may detract from the lasting effectiveness of the technology transfer (IPCC, 2000). For example, a purchase of the blueprints and license to produce one model of wind turbine will likely be less valuable than an arrangement that along with the purchase of blueprints and a license includes on-site training of the workers in the purchasing company by the transferring company. It is important to learn from failed attempts at localization, including failed technology transfers, to understand the factors that contributed to the failure and how to correct them in future models. There has been much written on failed technology transfers (IPCC, 2000; Mansfield, 1994; Yin, 1990), including within China's wind turbine manufacturing industry (Lewis, 2005).

2.3. Incentives for technology transfers

Incentives for technology transfer differ for the transferor and the transferee, and their respective incentives will also vary across geographical locations. Incentives for the transferor may range from a one-time payment for a blueprint and license, to a share of future profits from a joint-venture company in which it retains an ownership share and portion of control over the transferee. A common example of this latter arrangement is an international joint-venture arrangement, where the foreign transferor forms a partnership with the domestic transferee in order to receive preferential treatment within a desired domestic market that it might otherwise not have had access to, and in return will often transfer its technology at a lower cost than it would have without an interest in the company's future earnings.

2.4. Implications

When discussing the benefits of developing a local wind technology manufacturing industry it is important to recognize that each of the models listed above, both for manufacturing and for technology acquisition, may not result in the transfer of actual "know-how" associated with wind turbine production, and may require no technology transfer or in-country local innovation to take place except possibly at the component level. For example, if a foreign wind turbine manufacturer chooses to set up a factory in another country to manufacture its turbines, it may do so with imported labor and materials, in which case very little economic benefit from that factory's presence would flow to the town where the factory is located. Or, even if some local laborers were used in the manufacturing process, laborers could be subject to strict non-disclosure agreements preventing their taking the information they learned on the job and bringing their expertise to other employers or using it to start their own companies. The purchase of local materials such as steel could benefit the local economy financially, but still would not require the transfer of any of the knowledge associated with incorporating the steel in the turbine design.

It is crucial for governments hoping to promote local manufacturing within a region to be very clear whether the goals of creating this industry are to create jobs and a demand for raw materials, or whether the goals are to facilitate the transfer of advanced wind power technology and the associated know-how required to develop a domestic wind turbine manufacturing company within its borders. Governments and companies aware of the various models of technology acquisition and manufacturing, and of examples of successes and failures within each, will be best prepared to move forward with localization.

3. Potential Benefits of Localization

The potential benefits of local wind turbine manufacturing include: 1) economic development opportunities through job creation and sales of new products; 2) opportunities for the export of domestically-made wind turbines to international markets, further enhancing the prospects for local economic development; and 3) cost savings that result in lower cost wind turbine equipment, lower cost of wind-generated electricity, and higher growth rates in domestic wind capacity additions. Another, less tangible benefit to wind technology localization, but clearly a motivating factor for several countries, is a desire for national achievement in what is viewed as an emerging industry.

3.1. Domestic economic development and employment

The development of any new industry, including wind power, creates new domestic job opportunities. Wind development is often found to create more jobs per dollar invested and per kWh generated than fossil fuel power generation—one study from the United States, for example, estimates that wind power creates 27 percent more jobs than the same amount of energy produced by a coal plant and 66 percent more jobs than a natural gas combined-cycle power plant (NWCC, 1997).[2] Direct jobs are typically created in three areas: manufacturing of wind power equipment, constructing and installing the wind farm, and operating and maintaining the wind farm over its lifetime. Approximately two-thirds of the labor requirements are in the manufacturing of the wind power equipment which includes turbines, blades, towers and other components, and the remaining one-third is accounted for by installation, services, transport and development (Allen Consulting Group, 2003). Of these components, rotor blades are the most labor-intensive and therefore are a crucial element of local manufacturing of wind turbines since they will bring the most jobs (Allen Consulting Group, 2003).

Several studies have estimated the total jobs created by the wind industry, including the European Wind Energy Association's report on Industry and Employment (EWEA, 2003) that calculated the total number of direct and indirect jobs in the EU created by the wind industry (including manufacturing, installation and maintenance) to be 72,275 for 2002, with the majority of the jobs in the manufacturing sector (47,625) and the rest in installation (21,150) and maintenance (3,500). Gipe (2004) estimates that there currently are a total of 80,000 jobs in the wind industries of Germany, Denmark and Spain, as detailed in Table 1. While EWEA (2003) estimates an average of 12 jobs per MW of installed wind capacity for Europe, yet another source (Krohn, 1998) cites the global average of jobs from wind to be closer to 18-21 jobs per MW installed. The EU number is explained to be lower than the world average because the EU imports raw materials for wind turbines, which creates jobs abroad (EWEA, 2003).[3]

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[2]For more information see references on wind and economic development in the US at: http://www.windustry.com/opportunities/ecodev.htm.

[3] It should be mentioned that there is much ambiguity over whether the net economic impact of job creation is positive or negative, since anytime new jobs are created in the wind industry impacts may felt on other parts of the economy, such as through increased electricity rates that may be levied upon consumers.

Table 1. Jobs in the Wind Industry for EU Countries (2002)

Country	Direct Jobs	Indirect Jobs	Total
Germany	7,500	37,500	45,000
Denmark	8,600	4,300	13,000
Spain	7,000	15,000	22,000
Total			80,000

Source: Gipe, 2004

3.2. International exports

Many countries aspire to create a domestic wind turbine manufacturing industry so that they can then export their turbines overseas and tap into the expanding global market for wind energy. Denmark's Vestas, the largest turbine supplier in the world, sold over 98% of its turbines outside of Denmark in 2003, as did NEG Micon (BTM, 2004). Some wind companies focus a large part of their sales within their home countries such as GE Wind, where less than half (41.9%) of their turbines are exported or manufactured overseas (BTM, 2004). India's Suzlon currently exports only 13% of their turbines, but aspires to increase this percentage and is currently setting up manufacturing companies and subsidiaries in several other countries (BTM, 2004; Suzlon, 2004).

Table 2. Percentage of turbines sold abroad by manufacturer (2003)

Manufacturer	Home Country	% of Turbines Made or Exported Overseas
Vestas	Denmark	98.6%
GE Wind	USA	41.9%
Enercon	Germany	31.2%
Gamesa	Spain	11.4%
NEG Micon[4]	Denmark	98.6%
Bonus	Denmark	69.2%
REpower	Germany	2.6%
Nordex	Germany	47.3%
Made[5]	Spain	4%
Mitsubishi	Japan	92.1%
Suzlon	India	13%
Goldwind	China	0%
DeWind	UK	100%

Source: BTM, 2004

3.3. Technology cost reductions

Local manufacturing of wind turbines or wind turbine components can potentially reduce costs through 1) a reduction in labor costs; 2) a reduction in raw materials costs; and 3) a reduction in

[4] Acquired by Vestas at the end of 2003.
[5] Acquired by Gamesa at the end of 2003.

transportation costs. The improved servicing and response times that come from local manufacturers may further reduce costs and/or improve operations.

The often-cited approximate cost for installed wind power capacity is $1000/kW for onshore turbines, and about $2000/kW for offshore turbines. These costs are estimated by some to be decreasing by about 2.5% per year with technology improvements and economies of scale—both scale in manufacturing and in turbine size as turbines continue to get larger and thus require the installation of fewer machines for the same installed capacity.[6] The cost of the turbine itself is about 70-75% of total installed costs for onshore projects or 40-50% for offshore. The remaining costs primarily include construction costs (foundations, grid connection, roads, and sea cables), development and legal costs and land acquisition costs, and there will be variation in these remaining costs depending on the location of the wind farm site.

Countries with lower wage rates such as India and China expect to be able to realize cost savings through domestic manufacturing of wind turbines compared to their European and American counterparts. This cost reduction is potentially significant for those turbine components that are particularly labor intensive. Rotor blade manufacturing, for example, is labor intensive and could thus benefit from lower labor costs, though the manufacturing process is complex and difficult to outsource reliably (Krohn, 1998).

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 (CanWEA, 2003) 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.

Reduced delivery lead times for wind turbines and components are another cost-saving factor in local manufacturing.[7] Better customer service and faster access to customer service staff and technical staff as well as spare components in case of mechanical problems may further reduce costs or improve project operations.

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. An initial step for China might be to better estimate this potential cost savings. Initial studies have estimated that local production of wind turbines could reduce the cost of the technology by anywhere from 20 to 40% (Taylor & Bogach, 1998).

[6] The installation of fewer machines to reach a target installed capacity can result in cost savings. Even though larger machines are more expensive than smaller machines on a per-unit basis, a significant portion of the cost is saved through reduced tower, foundation and construction costs. Maintenance costs may also be saved because there are fewer turbines to be maintained per unit area. Cost savings also occur due to increases in turbine productivity over time. In Denmark, the annual energy yield per square meter of rotor area has grown by 5 percent per year since 1980 (Krohn et al., 1998).

[7] Shipping turbines from Denmark to the Asia/Pacific region takes approximately 8 weeks (Allen Consulting Group, 2003).

3.4. National pride and technological achievement

Another benefit in some situations comes from a national goal to develop a domestic wind power technology company as a means of both national pride and national technological achievement. Most countries favor domestically-manufactured products when given a choice between domestic and imported products if quality is perceived to be equivalent. Wind turbines can serve as a symbol of national technological success in engineering a cutting-edge, green technology that can be displayed to the nation. For example, several wind farms are planned for Beijing, China in conjunction with the 2008 Olympic Games.

4. Barriers to Entry: The Challenges of Local Manufacturing

While there are many potential benefits to local wind manufacturing, there are also many challenges to developing a new industry. As discussed in more detail in this section, there are significant barriers to entry into what has become a relatively mature industry, particularly as turbine size grows larger and the technology becomes more complex. Many companies have decades of experience in research and development and the leading turbine manufacturers are becoming larger and encompassing more global market share through mergers and acquisitions. Limited indigenous technical capacity and quality control makes technology development in new markets difficult, particularly when policies require local manufacturing. National standards requiring the use of advanced technology can initially shut out emerging firms with inferior technology. In addition, there are limited global locales possessing a skilled labor force in wind power, with Denmark being the leading location offering both skilled laborers and an experienced network of key components suppliers to support turbine manufacturers.

There also exists a disincentive for leading manufacturers to license their property rights to new companies wanting to learn from their expertise, since this may end up creating a competitor (as eventually happened in the Gamesa-Vestas joint venture mentioned above). In addition, the World Trade Organization (WTO) has established stringent trade regulations among member countries that prevent the use of trade barriers. Policies that favor the import of components while taxing the import of full turbines at a higher percentage may be construed as a barrier to trade and thus the legality of protectionist policies remains in question. The remainder of this section describes these barriers in more detail.

4.1. Existing international competition

Currently over three quarters of global wind turbine sales come from only four turbine manufacturing companies: Vestas, GE Wind, Enercon and Gamesa (BTM, 2004).[8] These companies either have spent years building strong global reputations, as in the cases of Vestas and Bonus,[9] or provide a unique product such as Enercon's "gearless" turbine, or are affiliated with a company that already has renowned international presence such as GE Wind's affiliation with General Electric Company. Players are also becoming increasingly larger as demonstrated by General Electric's entrance into the industry in 2002 and, more recently, Siemens' entry in October 2004. The industry is also continually consolidating as in the case of the merger between Vestas and NEG Micon—two Danish wind companies with the highest and second highest global market shares respectively at the time of their merger at the end of 2003. The top two Spanish turbine manufacturers, Gamesa and Made, also merged at the end of 2003. New entrants will need to compete with these dominant, powerful companies with strong reputations in the industry.

There are several reasons for this trend towards industry consolidation, but a key factor is that wind has sizable upfront costs that can only be repaid if the turbines have a long lifetime and

[8] Vestas' current market share (mid-2004) is estimated by combining its 2003 market share with NEG Micon's 2003 market share due to the merger of the two companies at the end of 2003.
[9] Recently acquired by Siemens.

require little in the way of unplanned operation and maintenance expenses. Wind companies with the financial backing of superpowers like GE and Siemens can provide this assurance to customers, both through their reputation and through their ability to offer multi-year service warranties that dramatically reduce investment risk.

4.2. Technological advancement

Technological innovation in the wind industry is currently being pushed by the desire to develop larger onshore and offshore wind turbine technology, reduce costs, increase efficiency, and improve grid interactions. These continuous advancements create a barrier to new entrants that may struggle to catch up to the best available technology. Firms looking to enter will have to decide whether to compete with another model of a currently popular turbine and risk it being outdated in the near future, or to develop a larger size turbine that does not yet have a commercial application in the hope that it soon will, or will have to find another competitive edge such as producing a popular turbine type at a lower cost.

4.3. Limited indigenous technical capacity and quality control

Certain wind turbine components are technically sophisticated and must last for years with little maintenance. Quality control is therefore of primary importance in the wind industry. Many technologically advanced countries have been able to enter the wind market at a late stage without much prior experience in wind turbine manufacturing due to their relatively developed technical knowledge base, often referred to as technical capacity. Countries with less indigenous technical capacity will have a harder time attempting to develop new technologies, particularly wind turbine technology where experience in other industries has been shown to result in spillovers that can be an asset in wind technology development (Kamp et al., 2004). Even the perception of poor quality will severely limit market growth.

4.4. Requiring use of technology that cannot be made locally

Another related barrier to developing a local wind turbine industry is the potential presence of policies that favor advanced technologies that are only produced in other countries. If a policy mandates the use of best available wind technology internationally, for example, and current domestic technology is less advanced than what is available from other countries, the policy will shift demand away from local manufacturers.

4.5 Limited locations with skilled labor and components networks

When establishing a new wind turbine manufacturing facility in a country with minimal experience with wind power development the burden lies on this company to either manufacturer or import all necessary components for the wind system. In addition, spare parts must be kept in hand in case repairs are needed, as must skilled maintenance technicians. A company that is starting from scratch in a new country will either need to import skilled labor from its home country if it was previously established elsewhere, or train local workers to be able to manufacture, sell and service its turbines.

There are currently only a handful of established wind power markets, including Denmark, Germany, and to a lesser extent the US, which have a history of wind companies within their borders and therefore have trained a skilled labor force in the wind industry. In addition, the presence of large turbine manufacturers leads to the establishment of supporting technology industries, and these countries also have a relatively established network of wind turbine components suppliers on hand. There are many examples of new wind turbine manufacturers locating to these well-established markets with labor and components readily available; for example Suzlon recently decided to base its international headquarters in Denmark even though it has stated that it is unlikely to sell its turbines to the Danish market (WPM, October 2004:25).

4.6 Intellectual property issues

Although the acquisition of technology from overseas companies is one of the easiest ways for a new wind company to quickly obtain advanced technology and begin manufacturing turbines, there is a major disincentive for leading wind turbine manufacturers to license proprietary information to companies that could become competitors. An example of this fear has been realized by Vestas, which licensed its turbine technology to Gamesa and now views them as a major competitor in the global market. This is particularly true for technology transfer from developed to developing countries, where a similar technology potentially could be manufactured in a developing country setting with less expensive labor and materials, and result in an identical but cheaper turbine. The result is that developing country manufacturers often obtain technology from second or third tier wind power companies that have less to lose in terms of international competition and more to gain in fees paid from the license. Examples of this are the multiple licensing arrangements that have occurred between Germany’s REpower Systems (formerly Jacobs Energie) and several foreign manufacturers based in Australia, Canada and China.

4.7 Barriers to trade and the WTO

In addition, the World Trade Organization (WTO) has established stringent trade regulations among member countries that prevent the use of trade barriers. The WTO Technical Barriers to Trade Agreement “tries to ensure that regulations, standards, testing and certification procedures do not create unnecessary obstacles” to trade, and “discourages any methods that would give domestically produced goods an unfair advantage” (WTO, 2004). To this end, policies that tax the importation of wind turbines, or even policies that require the use of domestically produced turbines, could be construed as “protectionist” and barriers to trade. The legality of protectionist policies to differentially support local industries like wind turbine manufacturing remains in question.

5. Policy Support for Wind Industry Development

This section identifies the policy mechanisms that have been used by countries attempting to promote a local wind manufacturing industry. Policy measures to support wind industry development can be grouped into two categories: direct and indirect measures. Direct measures refer to policies that specifically target local wind manufacturing industry development, while indirect measures are policies that support wind power development in general and therefore indirectly create an environment suitable for a local wind manufacturing industry.

As demonstrated later in Section 6, where we report country case studies, successful wind manufacturers are almost always located in countries that have established indirect policies to create both a sizable wind power market in which to emerge as a leading manufacturer, and a stable policy environment that provided consistency to investors looking to develop wind farms and to innovate in new wind power technology. In addition, countries are increasingly using some of the direct policy measures identified below to specifically encourage local manufacturing.

5.1. Policies that directly promote local wind industry development

Local content requirements
One direct way to promote the development of a local wind manufacturing industry is by requiring the use of locally-manufactured technology in domestic wind turbine projects. A common form of this policy requires a certain percentage of local content for wind turbine systems installed in some or all projects within a country. Such policies force wind companies interested in selling to a domestic market to look for ways to shift their manufacturing base to that country or to outsource components used in their turbines to domestic companies.

Preference or incentives for local content
Preference for local content and local manufacturing can be encouraged without being mandated through the use of incentives. This includes awarding developers that select turbines made locally with low-interest loans for project financing, providing wind companies that relocate their manufacturing facilities locally with preferential tax incentives, or subsidies on wind power generated with locally-made machines.

Favorable customs duties
Another way to create incentives for local manufacturing is through the manipulation of customs duties to favor the import of turbine components over the import of entire turbines. This creates a favorable market for firms trying to manufacture or assemble wind turbines domestically by allowing them to pay a lower customs duty to import components than companies that are importing full, foreign-manufactured turbines. This type of policy may be challenged in the future, however, as it could be seen to create a trade barrier and therefore illegal for WTO member countries to use against other member countries.

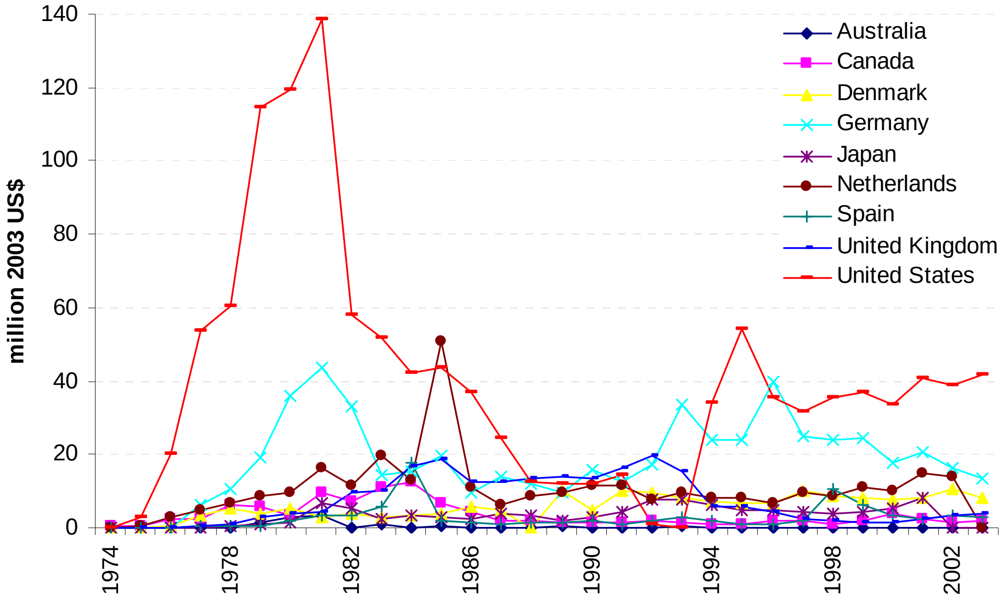
Tax incentives
Tax incentives can come in many forms, and can be used to support local manufacturing. First, tax incentives can be used to encourage local companies to get involved in the wind industry through, for example, wind manufacturing or R&D tax incentives. Alternatively, a reduction in sales or income tax for buyers or sellers of wind turbine technology can increase international competitiveness. Tax advantages can also be applied to certain company types like joint ventures between foreign and local companies to promote international cooperation and technology transfer in the wind industry. In addition, a tax deduction can be permitted for labor costs within the wind industry.

Export credit assistance
One way that governments can support the expansion of domestic industries operating in overseas markets is through export credit assistance. Such assistance can be in the form of low interest loans or "tied-aid" given from the country where the turbine manufacturer is based to countries purchasing technology from that country.

Certification and testing programs
A fundamental way to promote the quality and credibility of an emerging wind power company's turbines is through participation in a certification and testing program that meets international standards. There are currently several international standards for wind turbines in use, the most common being the Danish approval system and ISO 9000 certification. Standards help to build consumer confidence in an otherwise unfamiliar product, help with differentiation between superior and inferior products and, if internationally recognizable, are often vital to success in a global market.

Research, development and demonstration programs
Many studies have shown that sustained public research support for wind turbines can be crucial to the success of a domestic wind industry. R&D is often most effective when there is some degree of coordination between private wind firms and public institutions like national laboratories and universities. For wind turbine technology, demonstration and commercialization programs in particular can play a crucial role in testing the performance and reliability of new domestic wind technology before those turbines go into commercial production.

Figure 1. Annual Wind Energy R&D Budget by Country 1974-2003



Source: IEA, 2004:3

5.2. Policies that indirectly promote local wind industry development

Success in a domestic market has been demonstrated to be an essential foundation for success in the international marketplace, and is the arena over which governments can most easily act to promote their own economic interests (Connor, 2004). Fundamental to growing a domestic wind power industry is a stable and sizable domestic market for wind power. The policies discussed below aim to create a demand for wind power at the domestic level.

Feed-in tariffs

Feed-in tariffs, or fixed prices for wind power set to encourage development, have historically offered the most successful foundation for domestic wind manufacturing, as they most directly provide a stable and profitable market in which to develop wind projects. The level of tariff and its design characteristics vary across countries. If well designed, including a long term reach and sufficient profit margin, feed-in tariffs have been shown to be extremely valuable in creating a signal of future market stability to wind farm investors and firms looking to invest in long-term wind technology innovation.

Mandatory renewable energy targets

Mandatory renewable energy targets, also called renewable portfolio standards, mandatory market shares, or purchase obligations, are a relatively new policy mechanism being put to use in several countries. In its most common design, this type of policy requires that a fixed percentage of electricity in a given portfolio be generated by renewable resources. Policies can be custom-tailored to specific domestic markets depending on market structure. Experience with this policy is too limited to assess whether it can drive local wind development as well as feed-in tariffs have in the past.

Government auctions or resource concessions

One way for the government to create an environment for wind farm development is to directly solicit long-term power purchase agreements with wind power developers. This system reduces some risks because many of the uncertainties in wind development are eliminated through government backing of the project. However, government tendering programs of this type have historically not provided long-term market stability or profitability, due in part to long lead times between tenders and fierce competition among project developers.

Financial incentives

Often paid for through a charge on electricity generated from non-renewable sources, or directly on an electricity consumer's utility bill (often called a system benefits charge), financial incentives of various forms can be used to encourage renewable energy development. Without a long-term power purchase agreement, however, this policy mechanism has been found to generally play a supplemental role to other policies in encouraging stable and sizable growth in renewable energy markets.

Tax incentives

Some governments provide tax-related incentives to promote investment in renewable power generation, either in the form of a corporate income tax deduction for investment in wind power technology, or a property tax deduction to the owner of land on which wind turbines are sited. Other examples of tax incentives are aimed at wind power generation companies and can be in the form of reduced income tax or a reduction in value-added tax (VAT) that must be paid per kWh of power generated. Tax incentives are typically not a replacement for feed-in tariffs or mandatory renewable energy targets.

Green power markets

Several countries have programs that permit electricity consumers to purchase green electricity at a premium cost. This premium can be used to support the higher cost of renewable power and encourage investment in new renewable generation projects, though investment through this mechanism is typically rather limited.

6. Country Studies

In order to determine the relative importance of different policy mechanisms in promoting the development of a local wind power manufacturing industry, this section examines the conditions and policies being used within the countries that are either already home to successful wind turbine manufacturing companies or are currently attempting to promote local manufacturing in conjunction with local wind power capacity development. Table 3 lists the national leaders in terms of total installed capacity and annual installed capacity, as well as turbine manufacturers and the percent of turbines purchased in 2003 that were manufactured locally.

Table 3. Leading World Wind Markets and National Turbine Manufacturers

	Installed Capacity, end 2003 (MW)	Annual Installed Capacity, 2003 (MW)	Leading Wind Companies (Rank in 2003)	Percent of Installed Turbines Made by a Domestic Company (2003)
Germany	14,609	2,674	Enercon (#3), REpower (#7), Nordex (#9), Fuhrlander (#14)	48%
US	6,374	1,687	GE Wind (#2)	53%
Spain	6,202	1,377	Gamesa (#4), Made (#8), Ecotecnia (#13)	71%
Denmark	3,114	218	Vestas (#1), NEG Micon (#5), Bonus (#6)	99%
India	2,120	423	Suzlon (#11)	35%
Netherlands	905	233	None	0%
Italy	904	116	None	0%
UK	648	195	DeWind (#12)	0%
China	566	98	Goldwind (#15)	24%
Japan	506	275	Mitsubishi (#10)	8%
Australia	239	50	None	0%
Brazil	31	6.6	None	0%
Canada	351	85	None	0%
WORLD	40,301	8,344		

Source: BTM, 2004.

Table 4 lists the leading wind turbine manufacturers by home country, their total amount of wind capacity installations last year and to date, and their global market share in 2003. Of all turbines currently installed in the world, Table 4 also lists the total percentage of installations that were manufactured by that company.

Table 4. Top 10 Wind Turbine Manufacturers by Country

		Total installed capacity (MW)	2003 installed capacity (MW)	Global market share 2003	Share of total global turbines
Denmark					
	Vestas	8,400	1,812	21.8%	20.0%
	Bonus	3,367	552	6.6%	8.0%
	NEG Micon	6,398	855	10.3%	15.2%
USA					
	GE Wind	4,428	1,503	18.0%	10.6%
Germany					
	Enercon	5,758	1,218	14.6%	13.7%
	REpower	893	291	3.5%	2.1%
	Nordex	2,219	242	2.9%	5.3%
Spain					
	Gamesa	3,935	956	11.5%	9.4%
	Made	1,273	243	2.9%	3.0%
Japan					
	Mitsubishi	806	218	2.6%	1.9%
Others		4,489	441	5.3%	10.7%
Total		41,966	8,331	100.0%	100.0%

Source: BTM, 2004.

The following sections examine countries with established or emerging wind industries. The countries discussed below have either made localization of wind technology a key part of their wind development strategy, or are home to a leading wind technology company as a result of the policy environment created for wind energy development in general. Although companies are often owned by subsidiaries in several countries, for the purposes of this report the wind turbine manufacturers discussed are listed within the case study of the country that currently holds majority ownership of the company. [10] Each section presents an overview of the wind industry in that country, policies that both directly and indirectly support local manufacturing in wind turbine technology, and a short discussion on the current status and outlook for each market.

6.1. Denmark

Wind Industry Overview

Denmark's manufacturers have been the most successful in the world in terms of developing state-of-the-art technology and dominating global sales. Denmark's total installed wind capacity

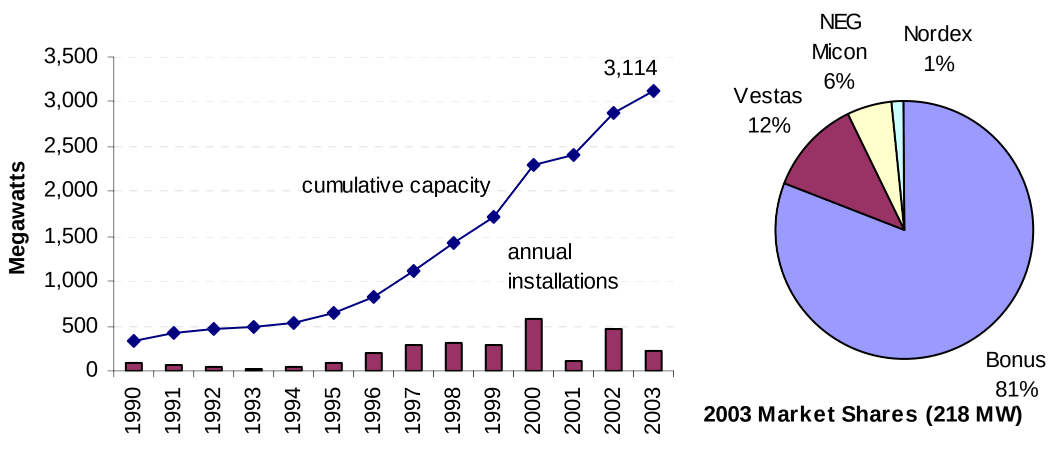
[10] There are limitations to categorizing wind turbine manufacturing companies by the country in which majority ownership is based, since many of these companies have substantial manufacturing bases located across international borders. The complexity involved in discerning each company's relationship to every country in which they operate is beyond the scope of this paper.

at the end of 2003 was 3,114 MW (Table 3), and 20% percent of the country's electricity generation in 2003 came from wind energy (BTM, 2004). Installed capacity has increased steadily each year providing a stable market for Danish turbine manufacturers, which represent 99% of Danish market share.

The modern Danish wind industry was created around the Danish home market that provided it with the necessary testing ground to sort out both wind technology and manufacturing processes (Krohn, 1998). Denmark is home to the largest wind turbine manufacturer in the world, Vestas Wind Systems A/S, which merged with another large Danish manufacturer, NEG Micon, at the end of 2003. Of turbines sold in 2003 before the merger, Vestas had 21.7% of global market share, of which 98.6% were sold in external markets (either exported from Denmark or manufactured by Vestas' overseas subsidiaries and joint ventures). Vestas develops, manufactures, sells, markets, and maintains wind energy installations, but does not participate in the development, financing or ownership of wind projects. Bonus is the oldest wind turbine manufacturer in Denmark. Established in 1979, in 2003 it had 6.6% of the global market, but over 80% of domestic market share (BTM, 2004).

Denmark's turbine manufacturers relied on the domestic market to develop their expertise and global market position, but with 20% of the Danish electrical system powered by wind already and few on-shore sites left, the Danish industry has dramatically increased its export share over time. As the early global wind industry leaders, Danish firms had been able to compete for many years due to their first mover advantage in the industry that put their turbines ahead of all other technology being developed internationally. However, this dominance is beginning to fade as other countries' firms catch up and Danish firms are forced to consolidate to maintain market share.

Figure 2. Denmark's Cumulative and Annual Wind Power Capacity 1990-2003 and 2003 Market Participants



Direct Policies
In Denmark, a combination of early well-targeted R&D along with stringent certification standards, were the primary policy drivers in developing a large wind turbine manufacturing industry. Government-guaranteed loans and export assistance were secondary drivers.

The Danish government funded significant R&D programs in the early stages of wind turbine technology development focused on reducing the cost of large-scale wind systems so that wind could compete with conventional electricity. Early R&D focused not just on wind turbine technology but also site investigations, grid integration studies, and wind resource assessments (Sawin, 2001). In the early 1990s turbine manufacturers expanded their own R&D programs for technology development and government funding was shifted to support wind resource data collection and public education on wind power. The current government research agenda includes grid-related issues as well as offshore wind development and testing, though federal R&D funding levels have declined in recent years now that the technology is considered mature (Sawin, 2001). Danish manufacturers have also benefited from the European Union's R&D programs.

The early Danish R&D program targeted, to some degree, the development of a number of smaller wind turbines by companies with backgrounds in agricultural or marine technology manufacturing. In contrast, other early R&D programs, such as those in Germany and the U.S., focused funding towards the development of a small number of large-scale turbines developed by the aerospace industry (Sawin, 2001; Kamp, 2002). The success of the more diverse R&D approach taken by Denmark is reflected in the dominance of the Denmark-based wind turbine manufacturers to this day. Despite the clear success of Denmark's R&D efforts, the total amount invested by the United States from 1974-2003 amounts to approximately 7 times the money invested by Denmark over the same period (Figure 1).

Denmark was the first country to promote aggressive quality certification and standardization programs in wind turbine technology and is still a world leader in this field. Only turbines that passed aggressive safety and quality tests were able to be installed in Denmark. Riso National Laboratory began approving turbine design to ensure reliability and safety standards were met beginning in 1979 (Sawin, 2001). The Danish approval scheme for wind turbines was established at the request of wind turbine manufacturers, owners, and authorities who desired a coherent set of rules to ensure the quality of turbines installed in Denmark. Certification is based on both a type approval and a certified quality system which covers the production and installation of the turbine and basic power curve tests and noise measurements. Grid connection guidelines have also been in effect since 1998. Today the Danish certification rules have been developed and adopted in "Technical Criteria for Type Approval and Certification of Wind Turbines in Denmark" and all manufacturers have an ISO 9000 quality system (Lemming and Anderson, 1999). The Danish Energy Authority is responsible for administrating the program and Riso National Laboratory acts as secretariat and information center.

Stringent safety regulations on turbines that can be installed in Denmark make it very difficult for outside manufacturers to enter the market. The presence of several Danish manufacturers (at least until recently) has also led to stiff competition among domestic competitors and has kept outside competitors essentially out of the market, with Danish turbines comprising essentially 100% of the turbine market. Although establishing stringent safety criteria for turbines installed in Denmark has effectively created a requirement for the use of Danish turbines, market consolidation and the spread of international certification practices based on Danish standards may change this dynamic in the near future.

Another program implemented by the Danish government to support its local turbine manufacturing companies is the Danish Wind Turbine Guarantee which offers long-term financing of large projects using Danish-made turbines and guarantees the loans, significantly reducing the risk involved in selecting Danish turbines for a wind plant.

In order to further promote the use of Danish turbines overseas the Danish International Development Agency (DANIDA) offers direct grants and project development loans to qualified importing countries for use of Danish turbines. This tied aid has been offered to countries including India, Egypt, China and Somalia (Sawin, 2001).

Indirect Policies

Denmark's local wind manufacturing industry was built and strengthened by one of the world's first and most successful and stable feed-in tariff systems. The size and stability of the market built with this policy can be seen in Figure 2 above, and this stability extends into the previous decade as well. Additional policies, including tax policies to support community wind ownership, also played an important role.

The Danish Ministry of the Environment mandated grid interconnection for wind as early as 1979, and required utilities to pay part of the connection costs as negotiated on a case-by-case basis. Beginning in 1992, utilities were required to buy wind power at 85% of the net utility power price not including taxes on production and distribution costs, with the price paid varying across regions depending on average electricity rates. Production subsidies for wind began as early as 1981, and later were revised to include a CO2 tax subsidy.

Capital grants subsidizing turbine installation costs have been offered by the government for the installation of Danish-certified wind turbines beginning in 1979 starting at a 30% subsidy, which later declined, and were eventually phased out. Since the early 1990s Denmark has had a re-powering scheme that subsidized 20-40% of the costs of replacing smaller turbines or poorly sited turbines with new, larger-capacity turbines (so the total number of turbines in Denmark is actually decreasing while total capacity is increasing). From the early 1980s to mid 1990s, income earned from wind turbine power generation was not taxed. National energy plans have incorporated wind power for years including site identification for future wind farm construction. The central government has put pressure on local governments to make wind power planning a priority as well.

The Danish market has essentially provided a constant production subsidy for wind for the past 20 years and required a fixed power purchasing rate by utilities. However, the details of the policies have been altered on several occasions and stability is no longer the rule. Today, offshore projects are being supported through government tendering, while onshore projects are supported through a series of bonus production payments (IEA, 2004:2).

Conclusions and Outlook for the Future

Denmark's domestic industry was built primarily through a combination of effectively allocated government funding for R&D, early quality standards, capital grants and subsides as well as a stable policy environment that provided a fixed and attractive tariff for wind power. Government support for domestic wind farm development in the form of resource measurements and loan guarantees also helped create a stable investment environment. The establishment of domestic demand created a market for turbine suppliers, enabling them to gain extensive experience in learning by doing that competing manufacturers in other countries were not able to duplicate.

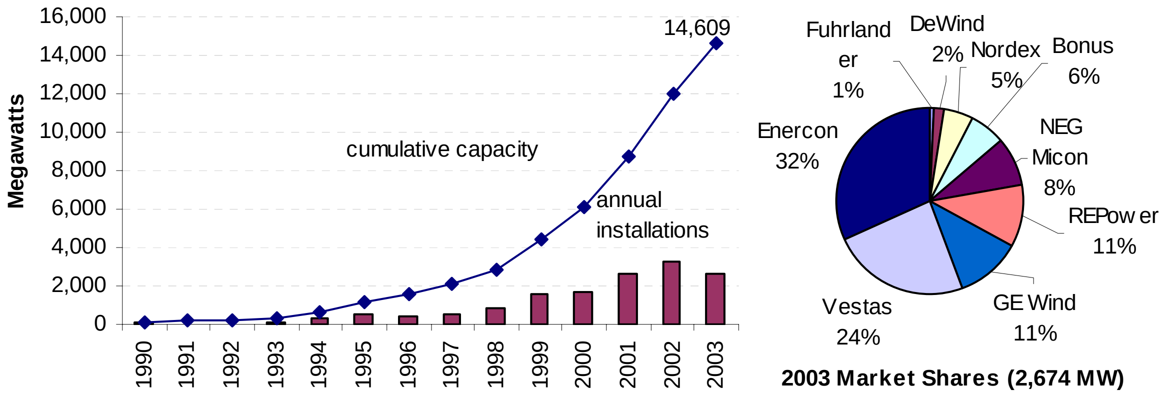
Danish manufacturers are now in a unique position in which their home market is becoming saturated, so they have had to shift their focus to selling turbines overseas. This is likely to put the Danish manufacturers at a disadvantage in those domestic markets that are trying to promote local manufacturing. One strategy is for Danish companies to shift manufacturing overseas to enable them to meet local content requirements. Vestas already manufacturers turbines in Germany, Italy, India and Scotland (as well as Denmark) and is looking into manufacturing in other countries, including China. Another strategy for Danish companies is to focus primarily on offshore wind development, which has substantial potential for future development in Denmark.

6.2. Germany

Wind Industry Overview

Germany has exhibited a sizable, stable market for wind power since the early 1990s, and is currently the international leader in total installed wind power capacity with a total of 14,609 MW installed by the end of 2003, 2,674 MW of which was installed that year (Table 3).

Figure 3. Germany's Cumulative and Annual Wind Power Capacity 1990-2003 and 2003 Market Participants



Germany is home to several major large wind turbine manufacturers including Enercon, Nordex, REpower, and Fuhrlander. Enercon had the largest share of the German market in 2003 with 32.1%, had 14.6% of the global market, and is the largest in-house components manufacturer in the industry (BTM, 2004). Enercon holds the patent on a successful gearless turbine technology which has given it a competitive edge over many other manufacturers despite its patent dispute with GE Wind (discussed further in US section). The remainder of the German market in 2003 was supplied by Vestas with a 3.6% share, GE Wind with a 11.3% share, REpower with a 10.9% share, NEG Micon with a 8.3% share, Bonus with a 6.5% share, Nordex with a 4.9% share, DeWind with a 1.6% share, and Fuhrlander with a 0.9% share (Figure 3). Nordex and REpower, with a 2.9% and 3.5% global market share respectively, both have an overseas presence and have participated in joint-ventures and technology transfers. REpower has subsidiaries in Greece, France, Italy and Spain, and has transferred technology to China, Australia and Canada; Nordex has subsidiaries in 17 countries including the Weide joint venture in Xian, China. Nordex was initially a Danish company but is now German-owned. Other smaller German manufacturers include Jacobs, AN Wind and Sonstige. UK's DeWind was initially a Germany company before it was sold to the UK firm FKI in 2002.

Direct Policies

In Germany, a combination of R&D targeting large wind turbine technology, production based electricity credits, and numerous indirect policies creating a demand for wind power, were primary drivers in developing a large wind turbine manufacturing industry. Soft loans and export assistance were secondary drivers.

Germany has the second largest national public expenditure on wind energy R&D from 1974-2003 after the United States, which spent about twice as much as Germany over this period (Figure 1). Some of Germany's R&D went into small and medium turbines and grid connection issues, but the majority was spent on large wind turbine R&D and recently on developing large-scale projects. The highest levels of funding were allocated in the 1980s, as in the US. Funding from the European Community, particularly on MW-sized turbine R&D, was also beneficial to Germany. Like in the US, much of the early federal R&D funding went into the development of large turbines by the aerospace industry, which at the time was a less successful industrial skill set to bring to wind turbine manufacturing than that of other industries. Funding levels were also inconsistent year to year, as in the US.

In July 1989 the German Ministry for Research and Technology paid out production-based credits for electricity generated by wind turbines that were accepted into demonstration programs, beginning with 100 MW of turbines and expanding to 250 MW of turbines. It offered a 10-year federal generation subsidy for those turbines that demonstrated they would help raise the technical standard of German wind R&D and selected projects were required to participate in a measurement and evaluation program. Although this program had a limited reach it enabled manufacturers to sell their turbines for a higher price and put extra money into their own private R&D programs. This program, which extends through 2008, in conjunction with the Electricity Feed Law, provides a good environment for domestic investment in wind farms and wind power technology.

The German government also has several international aid programs, one specifically with the purpose of testing German turbines under different climatic conditions while strengthening cooperation with partner countries. It subsidizes cooperative ventures between German and developing country firms to develop wind farms using German technology with subsidies granted directly to the equipment manufacturer, not the project developer. Germany also has pursued a design assessment and type certification program, and all wind turbines installed in Germany must be certified by accredited institutions (Woebbeking and Nath, 2004).

Despite the fact that German companies have dominated their home market since Germany began developing its wind resources in the early 1990s, German companies have experienced problems in achieving significant penetration into international markets where Denmark continues to dominate (Connor, 2004). This success at home may in large part be due to several government policies that have directly provided advantages to German manufacturers over foreign suppliers. Germany has employed a number of instruments, in addition to both versions of its tariff mechanism, ostensibly aimed at promoting the growth and penetration of capacity, that have particularly benefited German turbine manufacturers over their competitors. One example is the 100MW/250MW program discussed above which provided an additional 6pfg/kWh to the 16.52pfg/kWh of the feed-in tariff. Over two-thirds of the total project funding for this subsidy went to projects using German built turbines (Johnson and Jacobsson, 2003). In addition, there is further evidence of support for German industrial efforts at the regional level, where schemes again ostensibly aimed at stimulating capacity displayed notable bias towards local manufacturers (Connor, 2004).

A further German policy that may have preferentially supported German turbine technology was the large-scale provision of "soft" loans (loans which are available significantly below market rates) for wind energy projects. The structure of German industrial policy with a built-in interdependence between financing, industrial, and government institutions permits the government to intervene in sectors where it wishes to stimulate industrial development (Connor, 2004).

Indirect Policies

The success of Germany's wind industry has been primarily attributed to its profitable and stable feed-in tariff program. The Electricity Feed Law (EFL), implemented in January 1991, required utilities to pay at least 90% of the retail rate for electricity (excluding 15% taxes) for wind electricity fed into the system. Due to strong regional variations in electricity prices and resource variations, development was uneven. The EFL was criticized early on when charges of excessive profiteering brought opposition from utilities and factions of the government. It was therefore amended in 1997 with a 5% cap on electricity generation by renewables through 2000.

The Renewable Energy Law (EEG) was then adopted in April 2000 which both set a target for 10% of Germany's electricity from RE by 2010, and included legislated feed-in tariffs as a means to compensate for distortions of the conventional electricity market and make renewables more economically attractive. The EEG sets tariffs for each technology based on its cost with the tariff reevaluated very two years by the ministries of Economy, Environment and Agriculture based on technology advancements and market developments. It also abolished the 5% cap set in 1997, with renewable costs now apportioned to all electricity suppliers depending on total sales, and with grid extension costs being borne by the grid operator that then can recuperate costs as a surcharge on the grid fee.

The German government has also historically offered investment grants and low interest loans for projects that are designed to protect the environment, and various German banks offer credit schemes for wind power development.

Conclusions and Outlook for the Future

Germany's success at local manufacturing has been primarily driven by a sizable and stable market supported by a feed-in tariff, as well as some direct policies to support local manufacturing through R&D programs that focused on improving German turbine technology, a technology certification program, and the 100 MW/250 MW demonstration programs that appear to have favored German wind technology. Also important was the aggressive expansion of German firms overseas where they were able to test their technology in many different local conditions and build up their international reputations.

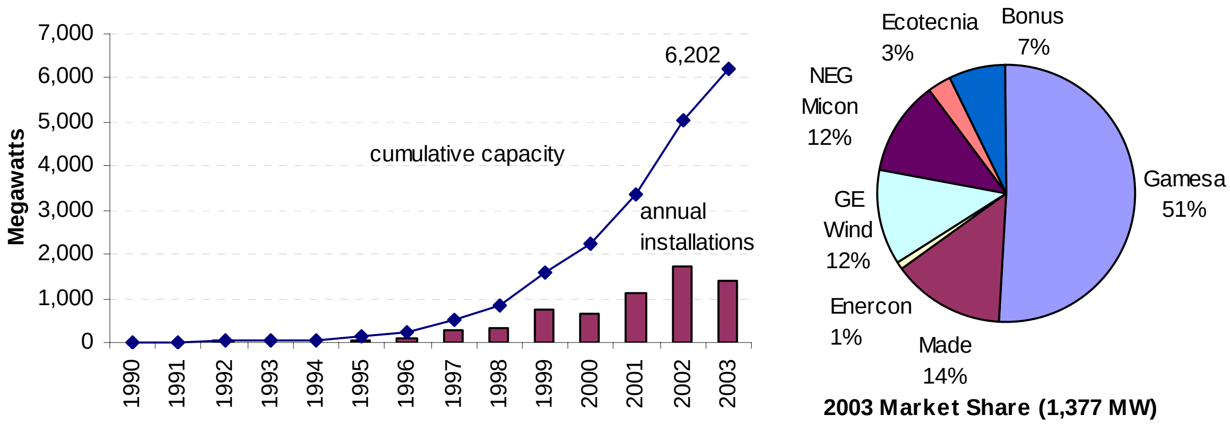
There is concern that Germany may run out of economically viable domestic sites for wind development before its companies have made sufficient inroads into the international market (Connor, 2004). It is possible their international expansion has been held off through patent disputes (as in the case of Enercon and GE), though there is also evidence that German companies have been relatively confident with their superior and in some cases unique technology (as in the case of Enercon's gearless turbine) and have stayed out of some international markets by choice. Several studies predict that German installation rates have peaked and are likely to decline until offshore sales substantially increase (Connor, 2004; BTM, 2004). There is also concern that the rapid rate of expansion to date will eventually render the tariff mechanism economically and politically insupportable, despite the changes that were made in the restructuring of the tariff mechanism in 2000 (Connor, 2004). Critical to Germany's continued success in wind development is its ability to maintain a stable domestic market that provides crucial support to its own companies until they have increased their market share overseas.

6.3. Spain

Wind Industry Overview

Spain had a total installed wind power capacity of 6,202 MW at the end of 2003, 1,377 MW of which were installed that year (Table 3). Wind comprises about 5% of Spain's total electricity production and is expected to increase. Spanish turbine manufacturer Gamesa had the largest market share in Spain of any manufacturer in 2003, with just over half the market, followed by another major Spanish manufacturer, Made Energias Renovables, with 11.5%, and NEG Micon and GE Wind, each with 12% (Figure 4). Gamesa also had about 12% of global market share in 2003 (956 MW), of which 109 MW was sold overseas (BTM, 2004).

Figure 4. Spain's Cumulative and Annual Wind Power Capacity 1990-2003 and 2003 Market Participants



Gamesa has 15 manufacturing facilities around the world that make turbines and/or blades. In 2003 Made was acquired by Gamesa, solidifying Gamesa as the dominant Spanish manufacturer and positioning it to be a major player in the world market. Gamesa's turbine technology is based on that of Vestas, since it began as a Vestas joint venture and only became independent from Vestas in 2003. Gamesa is 50% owned by Iberdrola, one of Spain's major electric utility companies (WPM, February 2000:18). Other Spanish manufacturers include Ecotecnia, part of the MCC Group (one of the world's largest cooperatives), Corporacion Energia Hidroelectrica de Navarra (EHN), and new manufacturer MTorres (IEA, 2004:1).

In addition, many foreign wind companies are currently manufacturing their turbines in Spain, including the US manufacturer GE Wind; Germany's Enercon, Nordex and REpower; and Denmark's NEG Micon. Bonus turbines are being manufactured by Spanish company Izar through a technology transfer arrangement with the Danish company (IEA, 2004:1, WPM, October 2004:6).

Direct Policies

A relative latecomer to the wind power scene, Spain has been able to increase installed wind capacity and simultaneously develop a local wind industry by actively supporting local manufacturing with policies that encourage foreign companies to shift manufacturing bases to Spain in return for access to domestic markets.

Spanish government agencies have mandated the incorporation of local content in wind turbines installed on Spanish soil. Vestas' Spanish joint venture with Gamesa, for example, was initially established in 1995 to comply with regulations requiring a percentage of local content in order to participate in the subsidized wind development in Spain at that time (WPM, February 2000:18). Local content requirements are still being demanded today by several of Spain's autonomous regional governments that "see local wealth in the wind"—in Navarra alone, it is estimated that its 700 MW has created 4000 jobs (WPM, October 2004:45). Other regions, including Galicia, Castile & Leon and Valencia, insist on local assembly and manufacture of turbines and components before granting development concessions (WPM, October 2004:6). The Spanish government has clearly played one of the most pro-active roles in kick-starting a domestic wind industry of any country, and despite a few reports of corruption related to these deal-making activities, the success of Gamesa and other manufacturers is very likely related to these direct policies.

Incentives for local manufacturing have also been sporadically employed. In the southern province of Chubut, the government is offering an incentive of $0.005/kWh if local content percentages are met. The federal government also offers a $0.01/kWh incentive, bringing the total incentive available to $0.015/kWh if all criteria are met. These local content percentages increase over time, from 30% in January 2001, to 60% in January 2003 and 80% in 2005. From January 2007 all the equipment must stem from local companies if a project is to qualify for the incentive (WPM, February 2001:20).

The Spanish government also provides some support for R&D in wind technology under the Research Centre for Energy, Environment and Technology (CIEMAT),[11] the main public R&D organization in wind energy. Spanish private wind companies invest heavily in R&D, estimated at about 11% of their gross value added, which is above average for other sectors and companies in Spain (IEA, 2004:1). Public R&D has been relatively consistent over time but small compared to the amount invested by countries like the US and Germany, as illustrated in Figure 1.

Indirect Policies

In addition to the direct policies noted above, Spain's rapid emergence as a center for wind manufacturing is due to an aggressive feed-in tariff policy, which accounts for the explosive growth and relative stability in the wind market in recent years. Spanish utilities are obligated to pay a fixed, guaranteed price for wind for 5 years that includes a bonus incentive; this price and bonus are set each year based on variations in electricity market prices.

Spain has also adopted the European target of 12% of primary energy demand from renewables for a national target by 2010, and has set a target for wind of 21.5 terawatt hours per year by 2010, or around 9000 MW installed capacity. After realizing that this target will likely be met early, the target has been raised to 13,000 MW of wind by 2011, or 28.6 terawatt hours per year (IEA, 2004:1). Wind is further benefited by the deferral of tax payments on earnings for 15 years (WPM, February 2001:20).

Conclusions and Outlook for the Future

Spain's several years of aggressive policies to directly encourage local manufacturing, combined with a sizable and stable local market built on a feed-in tariff, have resulted in the establishment of several wind turbine manufacturers that are poised to dominate the Spanish market and well-positioned to move into the global market in the years to come. The Spanish market has also attracted several international manufacturers to establish manufacturing facilities in Spain, including GE Wind. The success of the leading Spanish manufacturer, Gamesa, is certainly in part due to its strategic decision to form a joint-venture with Vestas and later purchase the rights to Vestas' technology and end Vestas' involvement in Gamesa's operations. Spain's wind industry combines a healthy mix of both leading international companies locally manufacturing

[11] More information available at: http://www.ciemat.es.

foreign technology, and Spanish companies locally manufacturing Spanish-owned technology. It is likely that this combination creates a constructive environment for learning and innovation.

Direct policies implemented by Spain have certainly attracted local manufacturing, but indirect policies including a feed-in tariff have created a stable market for wind which in turn attracts manufacturers as well. Spanish efforts have been aided by the degree of legitimacy that has been brought to the industry by the commitment of all relevant actors including national, regional and municipal government, utilities keen to develop their own manufacturing and development arms, and local investors and farmers keen for a new source of income (Connor, 2004). The Spanish experience therefore demonstrates the results of an effective combination of direct and indirect wind manufacturing incentives that has attracted the interest of leading global turbine manufactures and benefited the Spanish economy.

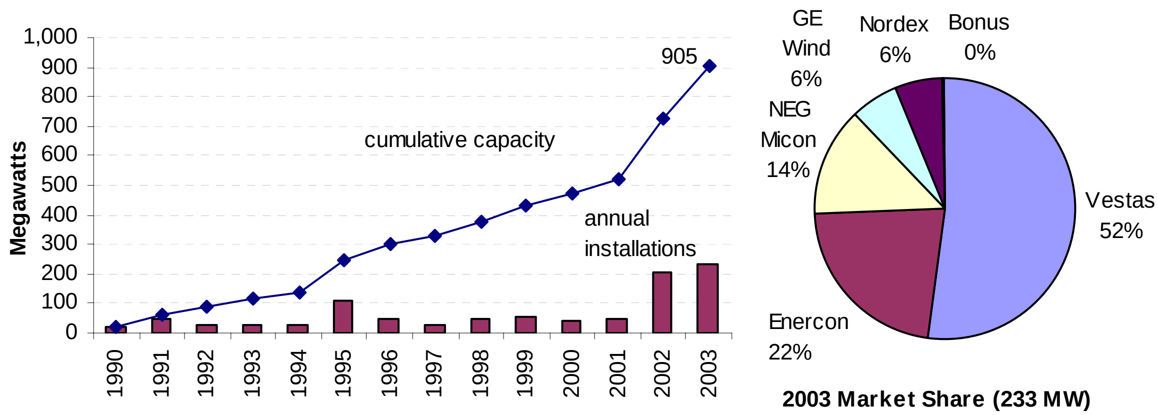
6.4. The Netherlands

Wind Industry Overview
The Netherlands was a leader in early wind turbine technology development, along with Denmark, but was not able to maintain its early-mover advantage in the industry. Wind power development in the Netherlands has remained small, and the Dutch turbine manufactures have experienced limited success. The Netherlands' total installed wind power capacity at the end of 2003 was 905 MW, 233 MW of which was installed that year (Table 3), with wind comprising just 1.5% of total electricity generation.

The Netherlands has had one significant domestic wind turbine manufacturer that has been active since 1980, Lagerwey the Windmaster, currently producing a 750 kW turbine that has been primarily sold abroad. However, in 2003, Lagerwey was forced into bankruptcy and purchased by a Delaware-based investment company, VINAK Inc. (WPM, November 2003:26). Around the same time, a fire contributed to GE Wind's decision to permanently close the Dutch Almelo rotor blade production facility it had acquired as part of its purchase of Enron Wind. Surrounded by failures, one Dutch firm—Zephyros BV—appears to be gaining market share. Zephyros bought the rights for the Lagerwey designed Zephyros 2 MW direct drive wind turbine in 2002, and has been experiencing moderate success with overseas turbine sales to Taiwan and the establishment of a joint-venture elsewhere in China (WPM, March 2004:73).

The Dutch market is dominated by Danish manufacturer Vestas holding a 51.9% share in 2003, followed by Germany's Enercon with 22.4%, Denmark's NEG Micon with 13.6%, GE Wind with 6.1%, and Nordex with 5.7% (Figure 5).

Figure 5. The Netherlands' Cumulative and Annual Wind Power Capacity 1990-2003 and 2003 Market Participants



Direct Policies

The Netherlands does not appear to have emphasized direct policies to encourage local manufacturing, with the exception of R&D support. The Dutch National Research Program on Wind Energy (NOW) began in 1976, providing subsidies for R&D on wind turbines and on wind resource assessments, with a goal of developing significant installed capacity (Kamp et al., 2004). In 2003 The Netherlands has allocated over 300 million dollars to wind energy R&D from 1974-2003, the third largest national public expenditure after the US and Germany (Figure 1).

According to Kamp et al. 2004, the Dutch wind turbine innovation system was a typical 'science-push' innovation system, with a goal of developing large wind turbines at a fast pace, based on the results of scientific research. However, the lack of contacts between the researchers and the wind turbine producers was a factor in the Netherlands' failure to develop viable large wind turbine technology.

Indirect Policies

The market for wind in the Netherlands was supported by a feed-in tariff for several years. More recently, policy instability has been the norm, with attempts to use voluntary targets, green power market support and, most recently, a revised feed-in tariff. The Netherlands' current feed-in tariff for wind is called the MEP, intended to promote environmentally-safe electricity in the Netherlands. The Dutch government has also adopted an informal target of 10% of power generation from renewables (mainly wind and biomass) by 2020. In 1986, investment subsidies were introduced to encourage utilities to invest in wind farms (Kamp et al., 2004).

Conclusions and Outlook for the Future

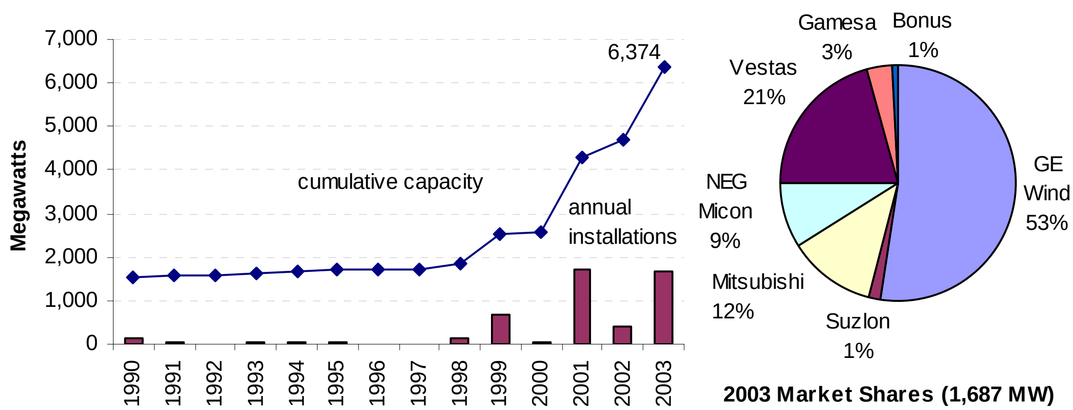
With a relatively modest market size, and modest prospects for significant growth, the Netherlands is an unlikely locale for significant wind turbine manufacturing. This fundamental fact, combined with recent policy instability, signals that the Netherlands is not currently poised to become a major base for wind turbine manufacturing.

6.5. USA

Wind Industry Overview

The US has a total installed capacity of 6,374 MW, with 1,687 MW installed in 2003 (Table 3). Although the US is estimated to have a much larger exploitable wind resource than Europe, it has lagged behind Europe in terms of installed capacity, and less than 1% of electricity generation comes from wind. Although the US ranks second in the world in terms of installed capacity, annual installations have not been constant over time due to unstable policies to support wind power. This has created a volatile market for developers and consequently has not provided US-based manufacturers with a stable market in which to sell turbines. This instability appears to be changing, as is the shape of the US market with the entry of mega-company GE into the wind turbine business in 2002.

Figure 6. USA's Cumulative and Annual Wind Power Capacity 1990-2003 and 2003 Market Participants



The US turbine manufacturer GE Wind had 18% of the global wind market in 2003, with 1,503 MW installed, of which 41% were sold in overseas markets (either exported from the US or manufactured overseas). GE currently manufacturers turbines in Germany and Spain as well as the US, and has blade manufacturing facilities in the US and Denmark. GE Wind represented over half of the US market share in 2003, with 52.6%, followed by the Danish manufacturer Vestas (Figure 6). Formed when GE purchased Enron Wind in May 2002, GE Wind now represents the wind technology manufacturing knowledge of a long line of US wind manufacturers that began with US Windpower, then became Kenetech Windpower, then Zond Systems, then Enron. Enron represented the experiences of both Zond and Tacke Windtechnik GmbH, a German company formed in 1990, which were both acquired by Enron in 1997 (Connor, 2004).

Direct Policies

In the US, direct policies to support the domestic large wind turbine industry have consisted primarily of public R&D; however this public support is thought to have played a rather limited role in the development of a viable local wind manufacturing industry.

The US has relatively few policies to directly support local manufacturing, aside from sizable but inconsistent investments in federal R&D and a recently developed national technology certification program. The US has sponsored R&D in wind power technology since the 1973 OPEC oil embargo, totaling over 1200 million dollars from 1974-2003—the largest national public expenditure on wind energy R&D over this period. The US annual wind energy R&D expenditure peaked in 1981, then declined throughout the 1980s, then increased again in the mid 1990s (Figure 1). Although the total funding from the US government for wind power R&D is significantly larger than that invested by other countries, funding has been very unstable over time, and history has shown that very early R&D efforts targeting the development of large wind turbines were unsuccessful relative to the efforts of Denmark that began with the development of smaller turbines.

Early R&D support was given primarily to companies in the aerospace and defense industry that had relatively little long term interest in developing wind power technology. The government had assumed the experience of these industries was relevant and useful to developing wind turbines, though Denmark's experience shows that companies with prior experience in the lower-tech agricultural and marine technology industries were in practice more successful in early wind turbine technology development. The difference could be explained either through technical differences between airplanes and wind turbines that slowed down research progress, or by the fact that US engineers trained in industries with narrowly focused applications ignored technical development and design modifications that had been made in the wind turbine technology decades earlier in Germany and Denmark (Sawin, 2001). More recent R&D funding has been more directly targeted to areas dictated by current industry needs.

The eventual success in large wind turbine manufacturing by US leaders like Zond came primarily through "learning by doing" with smaller wind turbines erected in California in the 1980s. In fact, much of the "know-how" used to make GE Wind's current turbines stems not from US-based technology developments, but rather from a combination of experience gained from their inheritance of Tacke's technology in their purchase of Enron, as well as experience working in other power systems technology including gas and hydropower turbines.

The US National Renewable Energy Laboratory's National Wind Technology Center, in collaboration with Underwriters Laboratories Inc., now provides accredited wind turbine certification services for US and international standards, primarily the International Electrotecnical Commission's 61400 Series of Standards (NREL, 2004). However, NREL only became accredited to do this starting in 1998—almost 20 years after Denmark's first wind certification program. This lack of certification put US manufacturers at a major disadvantage in the international market until recently.[12] US standards have also been criticized as restricting innovation. US standards were design-specific and therefore locked manufacturers into specific size and design types unlike the less restrictive EU standards that were based on noise emissions levels and power curves (Sawin, 2001).

Another way the US has been able to keep foreign technology out of the domestic market is through the use of patents. There has been a long, drawn out legal battle between US and

[12] Lacking a US certification program, many US manufacturers had their turbines certified in Europe.

European manufacturers over patents surrounding the use of variable speed wind technology. In 1995, US manufacturer US Windpower sued Germany's Enercon for patent infringement and won, thus preventing Enercon—a major competitor—from selling its variable speed technology in the US (WPM, May 2003:30). Leading US manufacturers have successfully been able to keep European competitors out of the US market with this variable speed patent, and consequently forced European manufacturers (including Vestas) to make special modifications to their turbine models to get around patent infringement. European manufacturers have found this to be costly and inefficient, and claim it has prevented technological progress in turbine development and the global dissemination of wind technology (WPM, June 2004:26; July 2003:23; May 2003:29). This dispute now continues between Enercon and GE Wind, which holds patents tracing back to US Windpower. Since purchasing Enron in 2002, GE has filed similar patent infringement suits in Europe and Canada.[13]

The National Renewable Energy Laboratory supports the sale of US-manufactured renewable energy technologies overseas through business tours and exchanges abroad and trade conferences. The Ex-Im Bank has provided limited tied aid to support the sales of US turbines overseas.

Finally, local and state governments in the US have begun to provide incentives for local manufacturing facilities for wind turbines and turbine components, often consisting of favorable tax treatment and other concessions.

Indirect Policies

Policy support for wind power installations in the U.S. has been notoriously inconsistent. The US wind industry was first established in the 1980s in the state of California, due to California's interpretation of the federal legislation PURPA in such a way that it essentially established a feed-in tariff for wind projects. The market slowed in the 1990s as the feed-in tariff expired, but the market has revived since 1999.

In addition to these state incentives, federal tax incentives have played a very important role in encouraging wind power development, in particular the Production Tax Credit (PTC), which is an inflation-adjusted per-kWh credit applied to the output of a qualifying facility during the first 10 years of its operation, amounting to 1.8 cents/kWh in 2003 (Bird et al., 2004). The PTC was originally established under the Energy Policy Act of 1992 which covered wind projects from 1994 through 1999, but was subsequently extended through December 2001, then again to December 2003, and was recently extended through 2005. The PTC has been very effective at

[13] GE's actions have been described by others in the industry as "aggressive, negative and restrictive," saying that "GE's move is diverting attention from the real business of building up a healthy wind industry" and that "It is a naked attempt to dominate the wind market with some dodgy old Yankee patent." In rebuttal, Steve Zwolinski, head of GE Wind Energy, says that GE believes it is important for the long term growth of the industry that the intellectual property (IP) structure is upheld and clearly understood. "We are intending to invest quite a lot money in this industry. We intend to make sure that the value of that investment is protected in the IP structure" (WPM, May 2003:30). A partial settlement was reached in June 2004 which appears to now allow Enercon to sell turbines in the US, but a legal battle remains in the European Patent Office. Enercon has filed a similar suit against GE to prevent its selling turbines in Germany (WPM, June 2004:26; July 2003:23).

promoting wind installation, but its on-again, off-again nature has resulted in an unstable market for wind farm investment, as shown in Figure 6, above (Bird et al., 2004).

Other historical tax credits for renewable power generation include a program in the mid-1970s that classified renewable generation as pollution control facilities that received a business investment tax credit of 10% (Sawin, 2001). There were additional tax credits that benefited wind power in the Energy Tax Act of 1978 (part of the National Energy Act), the Crude Oil Windfall Profits Tax Act of 1980 which increased the prior credit for wind from 10 to 15 percent, and the 25% Federal Investment Tax Credit in place until 1985 that supported businesses purchasing a wind turbine but did not apply to utilities.

The current demand for wind power in the US is also being led by state-level Renewable Portfolio Standards that mandate different shares of renewables over different time frames. Eighteen states have implemented mandatory renewable portfolio standards, of which wind is a major beneficiary (UCS, 2004; Kohler, 2004). Fourteen states, meanwhile, have developed renewable energy funds to support renewable energy generally, and wind power in particular.

Conclusions and Outlook for the Future

The US wind manufacturing industry was initially developed out of a strong combination of policies in California, including an aggressive feed-in tariff and favorable tax incentives. Industry growth slowed significantly in the 1990s due to a lack of continued policy support, as well as a lack of quality certification procedures. US R&D efforts, although substantial in aggregate amount, were unstable and less successful in the early years than efforts in Denmark. The US industry has been recently revitalized with the entry of GE. GE Wind's success to date is in part due the magnitude of resources at its disposal to support its commitment to wind turbine manufacturing, as well as its international reputation. More indirect forms of recent policy support have included federal tax incentives, and state-level renewable portfolio standards and renewable energy funds.

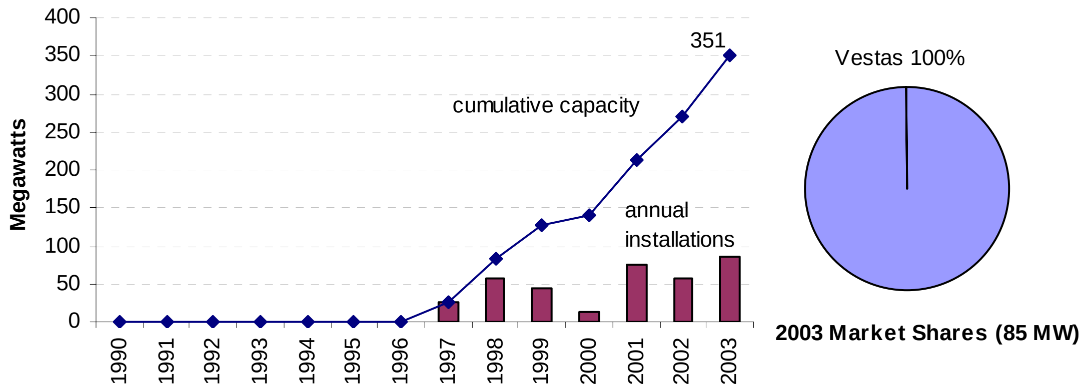
US policy instability, primarily due to inconsistent federal support, continues to slow industrial development. Before its merger with Vestas, for example, NEG Micon had planned to establish a factory in Portland, Oregon (WPM, November 2002:20) but later decided against it—partly due to the Vestas merger but also due to the fact that they were "put off by the market bumps created by the US's on-again, off-again production tax credit" (WPM, November 2003:32). A representative from Vestas Denmark has stated, "I think as soon as we can see a more stable market in North America than what we have seen up to now, we'd certainly consider local manufacturing of some kind" (WPM, November 2003:32). For wind turbines to be manufactured in the US, whether by domestic or foreign companies, federal policy support for wind will most certainly need to become more stable. Since this is unlikely to happen under the current political climate in the US, state policies to support wind power will likely be the most crucial mechanism to ensure the expansion of the wind industry in the coming years.

6.6. Canada

Wind Industry Overview

At the end of 2003 Canada had about 351 MW of installed capacity, with 81 MW installed that year (Table 3). Canada is just beginning to develop a local manufacturing industry, primarily at the initiative of the Canadian provincial governments, which view the wind industry as a way to promote local economic development and job creation. The Canadian national government has recently launched a study examining how to attract investment in the manufacturing side of the wind power industry (WPM, October 2004:12). Currently Vestas dominates the Canadian market and had 100% market share for capacity installed in Canada in 2003, though GE Wind will likely dominate the market in the near future due to recent project announcements (Figure 7). Other major wind turbine suppliers to Canada include Nordex, Enercon, France's Jeumont, Lagerwey, and Belgium's Turbowind. All turbines to date have been imported, and domestic assembly has been limited to 133 NEG-Micon 750kW and 3 Jeumont 750kW turbines (Synova, 2004).

Figure 7. Canada's Cumulative and Annual Wind Power Capacity 1990-2003 and 2003 Market Participants



Canada is hoping to attract investment from foreign wind companies looking for a North-American manufacturing base, and the industry hopes that a stable policy environment, in combination with lower labor and operation costs, will cause companies to choose Canada over the US (CanWEA, 2003). According to Vestas, Canada's current domestic market does not have sufficient demand to support the establishment of a local manufacturing base, but Vestas believes that this may change in the future (WPM, May 2003:35). Several companies, including NEG Micon before the Vestas merger, have signaled their interest in setting up local manufacturing in Canada to meet the government's local content requirements (WPM, June 2003:40). Most significantly, GE Wind was recently selected to supply about 990 MW of wind capacity—the largest single award for new wind generation capacity in the history of the global wind energy industry—for eight projects in Quebec slated to go on line between 2006 and 2012, and has announced that it will set up facilities to enable up to 60% of the wind energy components, materials and services to be supplied, manufactured and assembled locally (GE Wind, 2004).

There have been several recent technology transfer activities by Canadian Companies looking to manufacture wind turbines, including a joint venture of Sudbury's Consbec Construction and

Gagnon Renewable Resources with REpower Systems AG to form REpower Wind Corporation, the licensing of Dutch company Lagerwey's technology by American Wind Energy (AWE), the licensing of Jeumont Industrie's technology by GEQ, and the licensing of German company Fuhrländer's technology by AAER Systems Inc of Montreal, Quebec. AAER Systems Inc. has announced plans to invest over $7 million Canadian dollars over the next three years in a turbine making facility on Quebec's Gaspe Peninsula with the hope of taking advantage of Quebec's stringent local manufacturing requirements (WPM, April 2004:41). However, all of the Canadian companies listed are new to the wind business and therefore lack high level of technical expertise. The wind industry in Canada is plagued by very high entry barriers, and little support from developers and investors (Synova, 2004).

There is some Canadian expertise in the industrial supply chain that is relevant to wind turbine manufacturing, including experience with tower and base frame manufacturing, rotor blade manufacturing, nacelle assembly, electric inverters, general machining and metal fabrication, with the main industrial supply bases located in Montreal and the greater Toronto area. It is expected that a local wind industry could bring 10.5 person years of employment per MW of capacity manufactured, and it is predicted that aggregate industry employment could reach over 13,000 new jobs by 2012 (Synova, 2004).

Direct Policies
Several provincial governments in Canada are pursuing aggressive local content requirements in conjunction with wind farms developed in their region, mandating that fixed percentages of the cost of new wind projects be invested directly in the local economy.

In May 2003, for example, Hydro-Quebec issued a request for proposals (RFP) for 1000 MW of wind for delivery between 2006 and 2012, including a local content requirement (WPM, April 2004:41). This target was twice the target initially planned by Hydro-Quebec, but it was doubled by the Quebec cabinet after it decided the wind industry had the potential to contribute to economic revival of the Gaspe Peninsula (WPM, May 2003:35). The government has insisted that Quebec's wind power development support the creation of a true provincial industry that includes local manufacturing and job creation by requiring that 40% of the total costs of the first 200 MW be spent in the region—a proportion that rises to 50% for the next 100 MW and 60% for the remaining 700 MW (WPM, May 2003:35; April 2004:41). In addition, the government has stipulated that the turbine nacelles be assembled in the region, and that project developers include in their project bidding documents a statement from a turbine manufacturer guaranteeing that it will set up assembly facilities in the region (WPM, May 2003:35).[14] GE Wind ended up being selected for 990 MW of development in Quebec as mentioned above and has agreed to meet a 60% local content requirement.

[14] This desire in Quebec for local manufacturing and wind energy revenue flowing to the local economy stems from several projects in which expectations for local economic benefit were not met. In the 1990s, when the 100 MW le Nordais project was built, many were upset that upon getting the region's first large scale wind project, much of the economic benefit flowed elsewhere. Later a 54 MW Miller Mountain project near Murdochville was stalled due to protests from local companies that had bid on the project who were upset that Vestas Canadian Wind Technology (the supplier for the project) had hired subcontractors from outside the region (WPM, Oct 2004:35-37).

To provide further incentive for local manufacturing, a Quebec provincial government program also offers a 40% tax credit on labor costs to wind industries located in the region, and a tax exemption for the entire manufacturing sector through 2010 (WPM, June 2003:40). The Canadian government has also been providing R&D support for wind energy, investing a total of 100 million dollars from 1974-2003 (Figure 1).

Indirect Policies
Canada has not yet developed policies that would create a sizable and stable market for wind, but appears to be on the verge of doing so. Canada's June 2003 Wind Power Production Incentive (WPPI) gives a $0.01/kWh credit to wind generated electricity, with a cap on the amount of capacity to be supported (CanWEA, 2003). Canada also offers several tax breaks for wind power generation and capital grant programs. Several provinces are also discussing the implementation of Renewable Portfolio Standards and government-run wind farm procurements, and several local governments and commercial customers have purchased green power voluntarily. The largest procurement for wind to date was initiated by the utility, Hydro-Quebec.

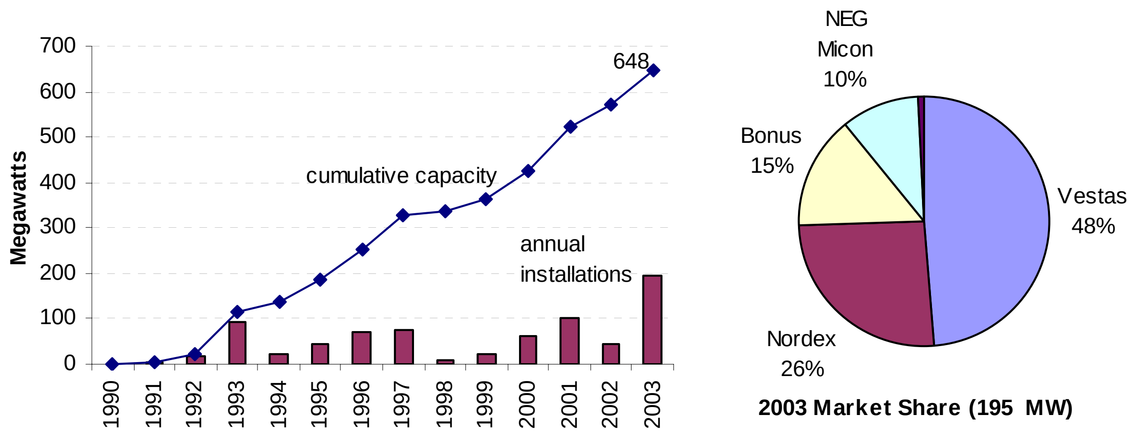
Conclusions and Outlook for the Future
Canada recognizes that a strong signal from the government to support wind manufacturers, and continued policy uncertainty in the US, could lead manufacturers in search of a North American manufacturing base to settle in Canada. Provincial governments have taken the lead by initiating several proactive polices that create an enticing environment for wind turbine manufacturing geared at stimulating regional economic development. GE Wind's decision to develop a local manufacturing facility in Canada was likely driven by both the local content requirements imposed on Canadian projects, as well as the potential for a sizable Canadian market as indicated by its single procurement of just under 1,000 MW of capacity. Despite its direct support of local manufacturing, at the moment Canada is notably lacking in strong indirect policies to support the growth of its domestic wind market such as a feed-in tariff. However, with over 4,300 MW of new projects already proposed and an expected potential of 30,000 MW of exploitable wind resources (Synova, 2004), the Canadian market is likely to be of increasing interest to international developers in the near future.

6.7. UK

Wind Industry Overview
The UK has a total installed wind power capacity of 648 MW, 195 MW of which was installed in 2003 (Table 3). The UK is also home to one of the first state-of-the-art offshore wind farms, with several more under development and construction. The UK is believed to have the best wind resources in Europe (IEA, 2004:1), however until recently it was home to only one reasonably sized wind turbine manufacturer, DeWind, which was purchased from Germany in 2002 and still manufacturers its turbines there. It now looks that DeWind may never make it off the ground in the UK. In November 2004 its primary investor, FKI Energy Technology Group, announced it would no longer invest in the wind turbine business, citing the rapid consolidation of wind turbine manufacturers and the increasing influence of major wind power developers as making competition extremely difficult for smaller players (DeWind, 2004). The leading turbine supplier to the UK was Vestas in 2003, with 48.6% of market share, followed by Germany's

Nordex with 25.9%, and Danish suppliers Bonus and NEG Micon with 14.8% and 9.8% respectively (Figure 8).

Figure 8. UK's Cumulative and Annual Wind Power Capacity 1990-2003 and 2003 Market Participants



The UK is home to several wind technology component suppliers that manufacture blades, rotors, turbines, castings, towers, pitch bearings, and elastomerics (IEA, 2004). Historically, Britain has also been home to a number of small but innovative wind turbine manufacturers, including Carter and Wind Energy Group (WEG). These two companies failed to win major sales, however; Carter folded in 1996, while WEG, following an initial bankruptcy, was acquired by Denmark's NEG-Micon in 1998 together with its sister company, Taywood Aerolaminates, makers of wood epoxy blades and suppliers of blades for the 1.5 MW NEG-Micon machine (Krohn, 1998).

Direct Policies

The UK has employed few incentives to directly support local wind industry development so far. The UK government has, however, provided relatively constant R&D support for wind program development since the late 1970s, investing a total of over 200 million dollars from 1977-2003 (Figure 1).

Indirect Policies

Renewable energy policy in the UK has been anything but stable, resulting in unstable annual wind capacity additions as illustrated in Figure 8. The Non-Fossil Fuel Obligation provided periodic tenders for renewable energy generation during the 1990s, but those tenders were not sufficiently certain and the contracts not sufficiently profitable to draw much manufacturing interest to the UK. Licensed electricity suppliers in the UK currently must meet a mandated Renewables Obligation (RO), which begins at 3% of their annual supply in 2002-3, and rises to 10.4% for the period 2010-2011. The RO is intended to stay at the 10.4% level, at a minimum, until 2027 (Mitchell et al., 2004). Electricity generated from renewables is also exempted from paying the Climate Change Levy (a tax on business use of energy), and capital grants are available for offshore wind projects (IEA, 2004:1). Despite what are now rather attractive incentives for wind power in the UK, the market remains somewhat unstable, with siting and permitting difficulties continuing to plague industry growth.

Conclusions and Outlook for the Future

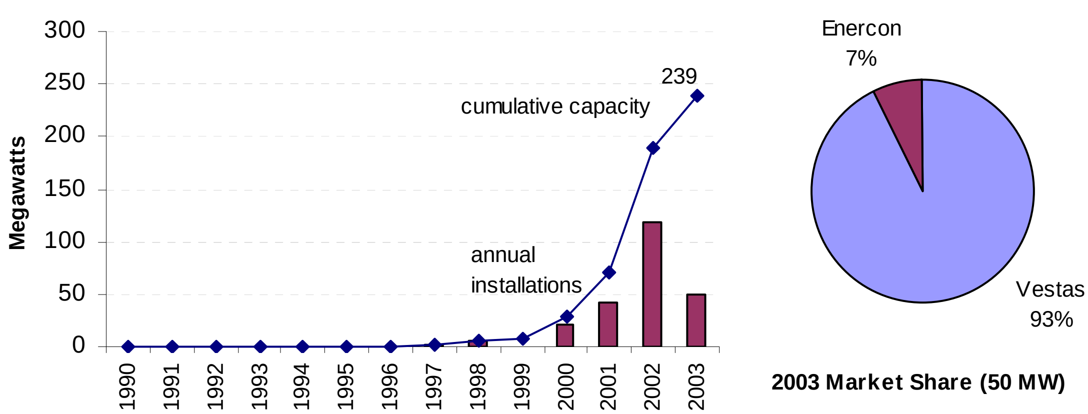
The UK has been unsuccessful at establishing a stable domestic market for wind, leaving UK-based manufacturers like DeWind to look for markets overseas. UK manufacturers have remained small, and in the face of a rapidly consolidating market comprised of larger and larger players, have been almost shut out of global turbine sales. The UK has several component manufacturers and a technologically-sophisticated labor force which should create a supportive environment for new wind turbine manufacturers. However, the lack of a stable, sizable domestic market for wind has clearly hurt UK manufacturers. The UK attempted to promote the wind industry using competitive bidding without other policies to support local industry development. The result was that manufacturers from other countries could out-compete UK manufacturers even in their home market, so UK manufacturers never had the chance to get off the ground. A shift to supportive policies with a long time frame, and a push for continued exploration in offshore wind development, could potentially turn the UK market around.

6.8. Australia

Wind Industry Overview

Australia's total installed capacity for wind was just 239 MW at the end of 2003 (Table 3). In 2003, 50 MW of new capacity was installed, down from the 119 MW of capacity that had been installed in 2002 and had raised expectations for a quickly expanding market for wind in Australia. Vestas dominated Australia's domestic market in 2003, manufacturing 92.7% of turbines installed that year. Enercon's turbines are also present, comprising the other 7.3% in 2003 (Figure 9).

Figure 9. Australia's Cumulative and Annual Wind Power Capacity 1990-2003 and 2003 Market Participants



Australia has a relatively strong small wind turbine manufacturing industry of 5kW-20kW turbines, but a domestic large turbine industry has failed to materialize. Vestas has recently begun manufacturing turbines in Tasmania, and a second wind energy manufacturing facility run by German company REpower is planned for Victoria (WPM, May 2004:46). Steel towers for several wind farms have been manufactured locally, but to date no rotor blades have been manufactured in Australia. Blade manufacturing is viewed as the key element to local manufacturing in Australia since it is relatively labor intensive (Allen Consulting Group, 2003).

Direct Policies

Although Australia has little in the way of historical policies to support wind power development, the Australian government's Sustainable Energy Development Authority (SEDA) has recently implemented a series of programs to promote new renewable electricity generation and the substitution of fossil fuels by renewables. For example, the Renewables Investment Program (RIP) supports capital investments in new renewable energy production equipment. In addition, the Australian government has several programs to encourage companies to invest in R&D which could potentially be beneficial to early wind companies. This includes the Research and Development (R&D) Start program, a merit-based program designed to assist Australian industry to undertake R&D and commercialization through a range of grants and loans; and the R&D Tax Concession, enabling Australian companies to deduct up to 125% of eligible expenditure on R&D activities from assessable income when lodging their tax returns (Allen Consulting Group, 2003). Public expenditure on wind energy R&D has been minimal (Figure 1).

The Commonwealth Government also has several programs that allow for the duty-free or concessional entry of goods into Australia, including capital goods or certain inputs to manufacturing where equivalent goods are not available in Australia, which could help support the local manufacture or assembly of wind turbines. In addition, the Innovation Access Program (IAP) is designed to promote the innovation and competitiveness of Australian companies by improving access to global, leading-edge research and technologies and facilitating their uptake by Australian firms (Allen Consulting Group, 2003).

To promote wind power development in Australia, SEDA has set up a network of high quality wind monitoring towers around the State to promote the availability of information on wind resources to potential developers (Allen Consulting Group, 2003). More recently, the Australian government appears to be promoting the manufacturing of wind turbines in Australia, and has been very proactive in encouraging foreign wind firms to locally manufacture turbines. Although the specific terms of these agreements have not been disclosed, they likely include financial incentives that make the move to Australia and the transfer of technology more enticing. For example, with the hope of kick-starting a domestic industry, the government of Victoria brokered a deal with REpower of Germany in which REpower will join forces with local wind companies—two manufacturers and a project manager—to form the Victorian Wind Energy Network (VWEN). Under the agreement, wind turbine blades and towers will be manufactured and assembled in Victoria for use in Australia and for export to the world market. The government forecasts the creation of 300 jobs within two years, primarily in provincial Victoria (WPM, May 2004:46). Many other provincial governments are likely to follow Victoria's lead, particularly if they prove successful in their attempts to create jobs and stimulate the local economy through wind power industry development.

Indirect Policies

Australia has adopted a Mandatory Renewable Energy Target (MRET) requiring the generation of 9,500 gigawatt hours of new renewable electricity per year by 2010 (Australian Greenhouse Office, 2004). The Australian wind industry is lobbying for a stronger target of 5000 MW of wind by 2010, as the MRET is not believed to be sufficient to encourage the establishment of a significant manufacturing base for wind in Australia. Australia also has several state-based greenhouse gas abatement programs that provide grants, loans and equity for renewable energy projects, as well as a green power marketing program.

Conclusions and Outlook for the Future

Currently, Australia's small domestic market for wind power development is constraining its ability to attract local manufacturing from foreign companies. A lack of government policy support for wind industry development until recently means Australia currently has no domestic large wind turbine manufacturers, although it has several smaller turbine manufacturers. Australia is being closely watched by foreign manufacturers since its wind resource potential is sizable, and manufacturers are likely to expand into Australia with the hopes of supplying not only to Australia but throughout the pacific region. The establishment of the national Mandatory Renewable Energy Target may serve as the beginning of a stable policy environment for wind, as it is expected that over one quarter of the target will be met by new wind farm development.

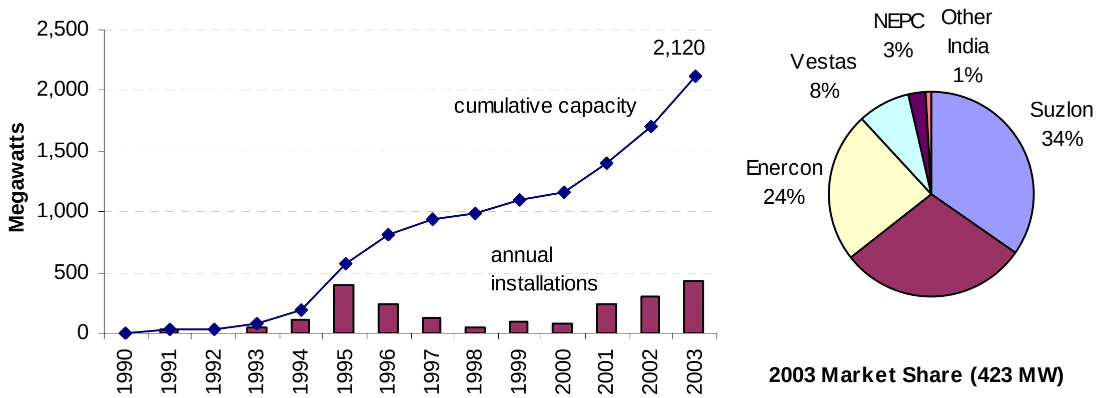
6.9. India

Wind Industry Overview

India is currently the leading developing country in wind turbine manufacturing capability, and in total installed wind capacity. India had a total installed wind capacity of 2,120 MW as of the end of 2003, of which 423 MW were installed in 2003 alone (Table 3). Suzlon was the largest supplier in India in 2003, with 34.6% of the domestic market. It currently only comprises 2.1% of the global market (2003) but has plans for extensive international expansion in the next few years.[15] In fact, Suzlon has developed significant local manufacturing capacity for wind turbines and components that are already being exported to the US, Europe and several developing countries (WPM, March 2004:57). NEG Micon was also active in the Indian market with a 29.8% share in 2003, followed by Germany's Enercon with 23.6%, and Vestas with 8.3% (Figure 10). Another smaller Indian turbine manufacturer, NEPC, has 2.8% of market share in India.

[15] Suzlon just completed its first US project with a 24 MW wind farm in Minnesota in 2004.

Figure 10. India's Cumulative and Annual Wind Power Capacity 1990-2003 and 2003 Market Participants



Suzlon is owned by 4 brothers that diversified into wind 10 years ago from the textile industry. Within five years Suzlon had made the list of top 10 wind companies, and the company has remained there since. Co-investors include two major American investment funds, City Group and Chryscapital, each of which injected $25 million into the company (WPM, October 2004:25). Suzlon recently established its international headquarters in Aarhus, Denmark, strategically selecting Denmark due to its base of wind energy expertise and extensive network of components suppliers (WPM, October 2004:25).[16] Suzlon has also developed sales offices in Australia, China and the US (as well as India) and R&D centers in Germany, the Netherlands, and India (Suzlon, 2004).

The leading rotor blade supplier, LM Glasfiber, is in the process of manufacturing blades for large turbines at its Indian facility in Bangalore, which will be sold to turbine manufacturers throughout Asia (WPM, June 2004:38). NEG Micon recently expanded its manufacturing facilities in Chennai and Pondicherry to include production of large turbines, including an additional $5.5 million to upgrade plant and equipment, with plans to supply the Indian market and export throughout Asia (WPM, June 2004:38).

Direct Policies

India has taken some direct steps to encourage local manufacturing. For example, India has manipulated customs duties in favor of importing wind turbine components over importing complete machines. There is no customs duty on special bearings, gearboxes, yaw components and sensors for the manufacture of wind turbines, or on parts and raw materials used in the manufacture of rotor blades. There is a reduced customs duty on brake hydraulics, flexible coupling, brake calipers, wind turbine controllers and rotor blades for the manufacture of wind turbines, and the excise duty is exempted for parts used in the manufacture of electric generators (Rajsekhar et al., 1999).

[16] Suzlon's choice of Denmark for its international headquarters does not reflect an interest in entering the Danish market or in expanding to offshore wind technology development. In fact, Suzlon has stated that it has no plans to do either, and is primarily looking to the North American, European, Chinese and Australian markets. Placement of the international headquarters in Denmark is particularly strategic right now since many former workers for the leading Danish wind companies, Vestas and NEG Micon, have been laid off after streamlining in conjunction with the merger of the two companies (WPM, October 2004:25).

India has also developed a national certification program for wind turbines administered by the Ministry on Non-Conventional Energy Sources (MNES), based in large part on international testing and certification standards.

Indirect Policies
India has been an active supporter of wind development since the 1990s. In the 1990s, India's market experienced a significant boom as a result of various tax incentives, attractive buy-back rates, and some preferential loans. For example, 100% depreciation of wind equipment was allowed in the first year of project installation, and a 5-year tax holiday was allowed (Rajsekhar et al., 1999). The national Guidelines for Clearance of Wind Power Projects implemented in July 1995 (and further refined in June 1996) mandated that all State electricity boards and their nodal agencies make plans ensuring grid compatibility with planned wind developments, and that they seek Detailed Project Reports (DPRs) from independent consultants (for capacities above 1 MW) on all proposed wind development projects to verify project capital costs and proposed power generation against certified wind turbine power curves and wind data at the site, before granting approval for projects (Rajsekhar et al., 1999). The expectations for future market growth in the early-mid 1990s attracted a number of firms to the Indian market.

However, even with extensive government regulations pertaining to wind farm development, inaccurate resource data, poor installation practices and poor power plant performance led to a dramatic slowdown of installed capacity in the Indian market in the late 1990s and early 2000s (Rajsekhar et al., 1999). Policy drivers also became unstable during this period.

In recent years, the market has begun to re-establish itself. State governments in India are running concession programs, and have already earmarked 50 sites for wind farm development. In Gujarat the government has signed agreements with Suzlon, NEG Micon, Enercon and NEPC India to develop wind farms on a build-operate-transfer (B.O.T.) basis, with each manufacturer given land for the installation of between 200-400 MW in the Kutch, Jamnagar, Rajkot and Bhavnagar districts (WPM, March 2004:57). Additional policies established in certain provinces have helped to spur recent development.

Conclusions and Outlook for the Future
India may be poised for growth with Suzlon planning global expansion, but fundamental risks in the Indian market remain, making international manufacturers somewhat reluctant to invest. For example, the power grid has such severe reliability problems that day and night voltages differ. In addition, India's relatively poor infrastructure previously meant that transport and installation of megawatt scale wind power technology was impossible (WPM, June 2004:38).

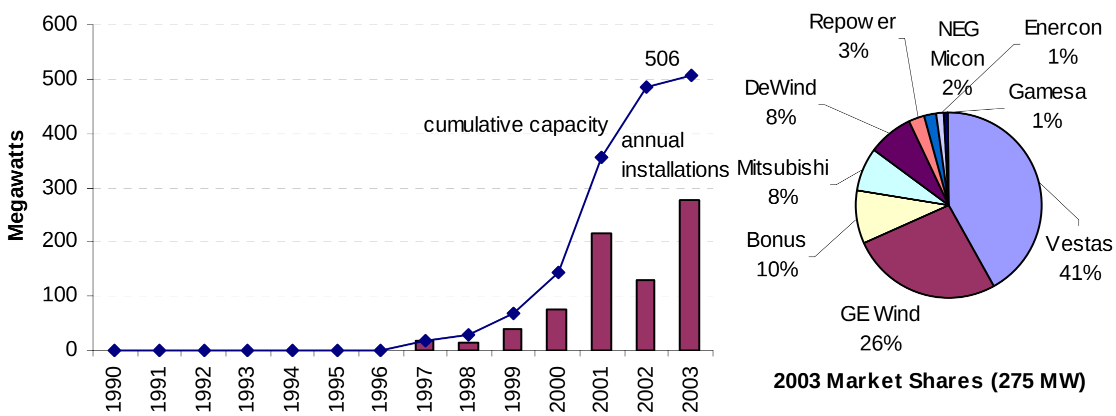
The early perception of growth prospects for India had led to the presence of local manufacturing of wind turbines by international companies, and more recently Indian companies. India's policy scheme, in particular the major tax advantages offered to manufacturers, helped to promote the industry throughout the 1990s. However, the current policy outlook is less clear, and wind power will likely be directly affected by the current restructuring of India's electric power industry. The Indian government continues to show it support for wind power and has set aggressive targets to bring 5,000 MW of new wind power capacity online by 2012 (WPM, March 2004:57).

6.10. Japan

Wind Industry Overview

Japan had 506 MW of wind power capacity installed by the end of 2003, 275 MW of which was installed in 2003 (Table 3). Mitsubishi is the leading Japanese turbine manufacturer, with 7.8% of Japanese market share and 2.6% of global market share in 2003. Over 92% of Mitsubishi's turbines in 2003 were either exported or manufactured overseas. Mitsubishi is involved in global industrial sectors including machinery, chemicals and metals as well as energy technology. The company's interest in manufacturing wind turbines originated in the late 1980s, then waned throughout the 1990s, but has been recently renewed with new turbine models under development. Denmark's Vestas dominated Japanese market share in 2003, manufacturing 42% of the turbines installed that year. Other companies selling turbines to Japan in 2003 included GE Wind with a 26% share, Bonus with a 9.5% share, DeWind with a 7.7% share, REpower with a 2.7% share, NEG Micon with a 2.3% share, Enercon with a 1.1% share, and Gamesa with a 0.9% share (Figure 11).

Figure 11. Japan's Cumulative and Annual Wind Power Capacity 1990-2003 and 2003 Market Participants



Direct Policies

Japan has not taken a particularly active role in encouraging local manufacturing. Japan's New Energy and Industrial Technology Development Organization (NEDO), however, does subsidize private companies for one-third of the turbine installation costs, and local governments for one-half of installation costs (IEA, 2004:1). NEDO also financed R&D support for wind technology beginning in the early 1990s with wind turbine system control technology development and a wind quality survey of nationwide wind resources (IEA, 2004:1). The New Sunshine Program further increased R&D for wind and wind resource surveys, and later for promoting the use of wind technology on remote islands. Government-sponsored R&D for wind technology was concluded in March 2003 after the government decided that the technology had reached maturity (IEA, 2004:1), though a total of about 100 million dollars had been invested by Japan from 1974-2001 (Figure 1). Japan's Ministry of Economy, Trade and Industry (METI) has promoted standardization and certification programs under its Integration of Japanese Industrial Standards (JIS) program and International Electrotechnical Commission (IEC) standards (IEA, 2004:1).

Indirect Policies

Japan's power companies began a voluntary agreement program with renewable energy generators in 1992 that included wind power. The government issued proposals to purchase the renewable electricity at the retail price at which it was sold to households under a 15-17 year fixed contract, essentially creating a feed-in tariff for wind (IEA, 2004:2). Japan's dense population and land limitations have led the government to explore offshore development, although no tangible plans have been set. A renewable portfolio standard has been introduced in Japan (the Special Measures Law Concerning the Use of New Energy by Electricity Retailers), setting the total contribution of renewables to primary energy at 3% by 2010 (IEA, 2004:2), and 1.35% of each retailer's electricity sales comes must come from renewables by 2010 (Nishio and Asano, 2003). The government has also set an official target to increase wind power capacity to 3,000 MW by 2010 (WPM, November 2003:52).

Conclusions and Outlook for the Future

The Japanese market is currently not large enough and is not showing enough prospects for growth to stimulate the interest of foreign manufacturers. Japan has not been very active in providing direct policies to promote the development of a local wind turbine manufacturing industry, but its local industrial strength has created a somewhat successful global competitor in Mitsubishi. Mitsubishi is continuing to advance its turbine technology, most recently installing a 2.4 MW turbine in Yokohama, Japan (WPM, September 2004:14). Mitsubishi's 1 MW turbines are currently being installed in several projects around the world, including in the US, Europe, India, Mexico and Peru, as well as Japan, and are often the technology of choice among Japanese developers (WPM, November 2003:52).

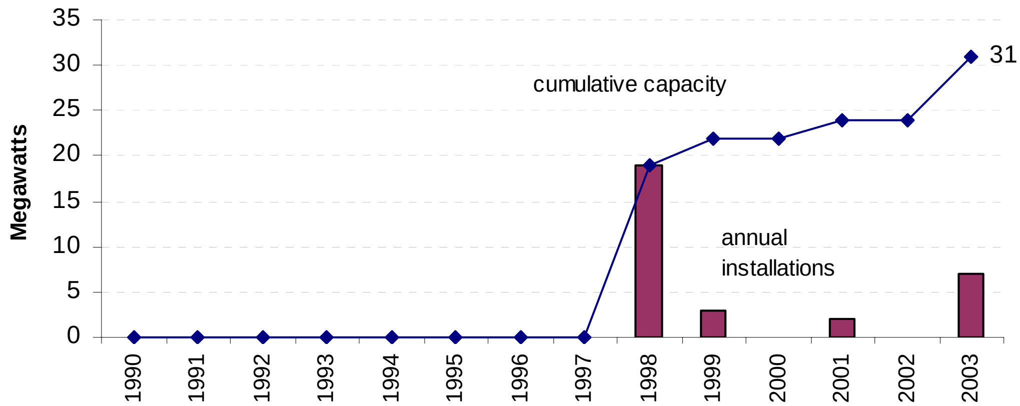
However, there are signs that the Japanese government's lack of support for wind power may be changing with its new initiatives to encourage renewable energy development. Mitsubishi has recognized its disadvantage in international wind markets due to its lack of a stable home market, but believes that as its home market develops, Mitsubishi will have better options to develop new products, and will be able to emerge as an important global player (WPM, November 2003:52).

6.11. Brazil

Wind Industry Overview

Brazil had a total installed wind power capacity of just 31 MW as of 2003 (Table 3), but anticipates quickly ramping up the utilization of wind power as it promotes a local manufacturing industry for wind power technology. Among companies already able to build turbines in Brazil is Wobben Windpower, controlled by Germany's Enercon, with manufacturing plants in the states of Sao Paulo and Ceara, and Fuhrmet Energy Brazil (WPM, May 2004:30). Despite the fact that NEG Micon had plans for a manufacturing facility in Brazil before its merger with Vestas, Vestas is not planning to follow through on these plans anytime soon, primarily because the Brazilian market has not developed as fast as expected. Spanish wind companies Enerfin and Gamesa both intend to establish wind turbine manufacturing in the Spanish state of Rio Grande do Sul (WPM, May 2004:30). GE Wind has already identified a partner in Brazil to manufacture rotor blades for its turbines for export, and may extend this operation to include turbine manufacturing (WPM, October 2004:32).

Figure 12. Brazil's Cumulative and Annual Wind Power Capacity 1990-2003



Direct Policies

The Brazilian government has pursued policies governing wind farm development that include stringent local content requirements, primarily through the recent Proinfa[17] legislation (the Incentive Program for Alternative Electric Generation Sources). Proinfa aims to increase the participation of Independent Power Producers (IPPs) in generating electricity for the national grid, and offers fixed price contracts for a mandatory purchase of 3,300 MW of renewables by 2006, split between wind, biomass and small scale hydro. Renewables projects will also have access to attractive loan terms (WPM, June 2004:21; October 2004:32).

Starting in January 2005, the Proinfa legislation requires 60% of the total cost of wind plant goods and services to be sourced in Brazil; only companies that can prove their ability to meet these targets can take part in the bidding process. In addition, from 2007 onwards, this percentage increases to 90% (DaSilva et al., 2005). Companies that already have manufacturing facilities in Brazil will therefore have a major advantage in obtaining these projects. However, legal battles have already broken out in Brazil as controversy has arisen over the legality of the selection of companies awarded the projects, and Windpower Monthly described Proinfa as "teetering on the edge of collapse" (WPM, August 2004:6).

Proinfa created an executive committee comprised of government agencies to oversee R&D in renewables and energy efficiency in Brazil, including the Ministry of Science and Technology, the Ministry of Mines and Energy, and the National Electricity Regulatory Agency. One of the goals of the R&D program is to increase the competitiveness of Brazil's manufacturing industries for the electricity sector. The program receives 1% of the net income of the utilities, which in 2001 totaled $27.6 million and for 2004 is estimated to be $41.3 million.

Indirect Policies

Brazil has abundant wind resources and views wind as a complimentary technology to hydropower on which it is dependent for over 90% of electricity generation. The twenty-year power purchase agreements for wind farms being signed by the national utility Eletrobrás at competitive prices under the Proinfa legislation described above are the first sign of a stable

[17] PROINFA stands for the "Programa de Incentivo a Fontes Alternativas."

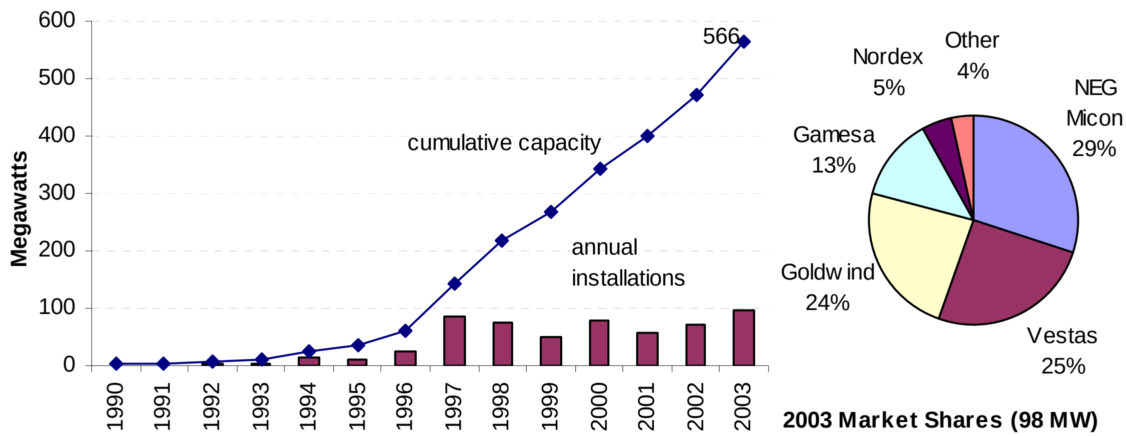
environment for wind power development in Brazil. The first Proinfa projects are slated to come online by December 2006. The second phase of Proinfa includes a target of 10% national electricity production from renewables over the next 20 years (Goldemberg et al., 2004).

Conclusions and Outlook for the Future
The outlook for wind development in Brazil is uncertain, as Proinfa is just getting underway. Successful tariffs for wind and long-term power purchase agreements are encouraging international manufacturers to explore options for local manufacturing in Brazil, and the Brazilian government is taking one of the most proactive roles in mandating local content requirements for wind turbine development. However, the policy environment for renewables in Brazil has historically been very unstable, so there is certainly concern among the wind industry that the current support for wind power could suddenly be reversed.

6.12. China

Wind Industry Overview
China had a total installed capacity of 566 MW at the end of 2003 (Table 3), with 98 MW constructed that year—the largest annual addition in China's history of wind development. The domestic market is divided among several manufacturers, which in 2003 broke down as follows: NEG Micon 30%, Vestas 25.3%, Goldwind 23.9%, Gamesa 12.7%, Nordex 4.5%, other 3.6% (Figure 13). Several other manufacturers are poised to enter the Chinese market, including GE Wind. The leading Chinese wind turbine manufacturer is Goldwind, which obtained its turbine technology originally from a technology transfer arrangement with REpower of Germany (formerly Jacobs Energie). Goldwind has yet to expand outside of China into international markets. There are several other Chinese companies developing large wind turbines, although none have sold their products commercially.

Figure 13. China's Cumulative and Annual Wind Power Capacity 1990-2003 and 2003 Market Participants



Direct Policies

China has taken several steps to encourage local manufacturing, including policies to encourage joint-ventures and technology transfers in large wind turbine technology, local content requirements, differential customs duties favoring domestic rather than overseas turbine assembly, and public R&D support.

In 1995 China's began its Ride the Wind Program that the State Development and Planning Commission (now the NDRC) initiated to promote a model of "demand created by the government, production by joint venture enterprise, and ordered competition in the market" (SDPC, 1996). 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 (Lew, 2000). Under this program, several international and Chinese companies capitalized on this requirement and formed joint venture companies for 600 kW and 660 kW wind generators. This program was supported by The State Economic and Trade Commission (SETC)'s National Debt Wind Power Program which used national debt with favorable interest subsidy conditions to build wind farms with locally manufactured turbines. By 2000, this program had established four demonstration projects with a total installed capacity of 73 MW (NREL, 2004). The Ride the Wind program experienced limited success, blamed on the fact that foreign companies were not able to choose their Chinese partners; rather they were selected by the Chinese government. 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; this is quite similar to what happened in the United States.

China is also experimenting with local content requirements in a variety of forms. Wind farm projects approved by the National Development and Reform Commission (NDRC) during the Ninth Five-Year Plan (1996-2000) required that wind turbine equipment purchased for these projects contain at least 40% locally-made components. In addition, the government has launched a Wind Concession program that includes local content requirements that have been growing more stringent over time. Since the program's inception in 2001, the government has invited international and domestic investors to develop large wind farms (ranging from 100-400 MW) through a tendering procedure aimed at bringing down the cost of wind-power generation. 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. The Hainan government, meanwhile, recently released a request for bids for a 300 MW project that encouraged the use of "technologically matured domestic turbines" (WPM, Oct 2004:32). It is clear that these local content requirements are causing foreign firms interested in selling wind turbines in China to develop a manufacturing strategy in China that will allow them to meet these requirements. Many companies are either establishing manufacturing facilities in China, or assembly facilities for components that would be contracted out to Chinese manufacturers.

In China there is currently no customs duty on wind turbines, but this has changed several times over the past few years. The earliest initiative can be traced back to a preferential policy about customs duty exemption for imported wind turbines valid from 1990-1995. As expectations of establishing a domestic wind turbine industry grew, China changed the customs duty regulations in 1996 so that there was a higher duty on imported complete turbines and a lower duty on imported components. In 1998, further differentiation between the two was made when components were exempted from VAT surtax and turbines were not. However, the latest amendment of custom duty regulation in 1998 exempted the tariff for wind turbine imports, but kept the 3% duty for importing major components, which has now reversed the incentive away from promoting localization and towards importing foreign turbines (Liu et al., 2002).

The Ministry of Science and Technology (MOST) has subsidized wind energy R&D expenditures at varied levels over time (Liu et al., 2002). 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). A prototype machine developed through this research was approved at the national level, and was used successfully at a wind farm. Chinese professional component manufacturers have produced key components of 600 kW machines including blades, gearboxes, generators, yawing systems, and control systems. In the 863 Wind Program, from 2001-2005 (the Tenth Five-Year Plan) MOST is supporting R&D programs to develop megawatt-size wind turbines, including technologies for variable pitch rotors and variable speed generators.

Indirect Policies

China has not yet developed a sizable or stable market for wind power, though efforts are under way to achieve this goal. The former Ministry of Electric Power issued the Regulation on the Management of Grid-Connected Wind Farms in 1994, mandating 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 repayment of loan and interest, plus a "reasonable" profit (Liu et al., 2002). This policy, however, was never widely accepted and applied, and has not been successful in dramatically increasing growth in the wind power market.

More recently, China has developed a series of government-run tenders known as Wind Concessions, described above. These tenders are leading to the development of larger wind farms in China, and may usher in a period of relative stability in the wind business. A national renewable energy law is also currently under review, and is expected to be implemented in 2005 and include a feed-in tariff as well as an expansion of the Wind Concessions. There are also policy efforts taking place at the provincial level: one province, Guangdong, recently implemented a feed-in tariff for wind projects in that province.

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% (NREL, 2004).

Conclusions and Outlook for Future

China's sizable wind resource potential, combined with amazing demand growth, has attracted the attention of many international wind companies. However, the relatively unstable policy environment for wind farm development in China is causing many to proceed with caution. Leaders like GE, Vestas, and Gamesa have announced plans to begin local manufacturing in China, but are proceeding slowly with these plans. China needs a more stable, sizable and profitable wind sector to catalyze the local manufacturing sector. The Chinese government's implementation of a national renewable energy law would be a crucial step in signaling to the international wind community that it is serious about promoting wind power development. However, the degree to which the law is able to encourage large capacity increases will depend on whether the central government follows the lead of the Guangdong Provincial Government and adopts a feed-in tariff mechanism. It is very likely that wind turbines will be locally manufactured in China in the near future; however, it is unclear whether Chinese manufacturing companies will be able to compete with the leading international manufacturers, even with stringent local content requirements.

7. Conclusions

Several key conclusions emerge from the data and policy experiences presented in the case studies above:

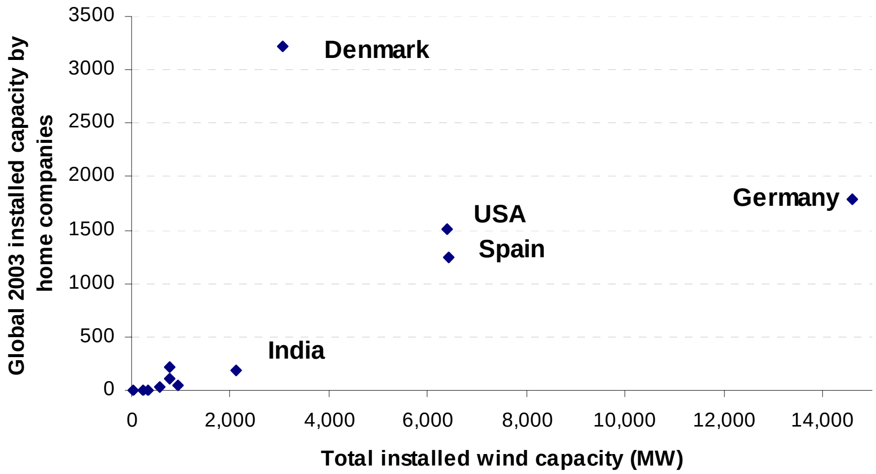
An attractive local market for wind power development is often a prerequisite to the robust development of a local manufacturing industry.

Wind turbine manufacturers usually get their start in their home country markets, as was clearly the case in Denmark, Germany, Spain, the US, and India (Table 3). A stable home market provides companies with the necessary testing ground to sort out their technology and manufacturing strategies and experiment with designs. In addition, a stable home market signals to a company that it has the long-term planning horizon necessary to allow it to invest in the future. Companies facing unstable markets are less willing to spend money on R&D and product development. Once greater technical maturity has been achieved within the local market, the company can transition to the global market and focus on exports and establishing foreign subsidiaries.

All leading turbine manufacturers are from countries with significant domestic wind power development, and most all have been very successful in their home markets. In 2003, Danish companies had 99% of home market share and have consequently expanded overseas where they had 29% market share. German companies had 48% home market share in 2003, and have been relatively successful overseas with potential for expansion beyond their 22% global market share. Spain has been very successful at home with 71% market share in 2003, and though its industry is young, Spanish companies are already expanding overseas with 15% market share. US companies have also been successful at home with 53% market share in 2003, and moderately successful abroad with potential for expansion from an 18% market share. Indian companies have 35% market share at home and are just beginning to expand abroad from a 2.2% global market share. Finally, Chinese manufacturers are doing well at home with a 24% market share in 2003, but the relatively new manufacturers have yet to expand abroad. Japan is the only country with a larger market share abroad than at home, but has not been particularly successful abroad with only 2.6% global market share in 2003, despite a relatively mature manufacturing industry.

Figure 14 shows clearly that the size of the home market is a key determinant of global success in wind turbine manufacturing. Moreover, as illustrated in Table 3, the top 5 countries in terms of installed capacity are also home to 9 of the top 10 wind companies globally. Wind turbine manufacturers located in these top five markets represented 77% (6,379 MW) of the total wind turbine manufacturing base in 2003 (8,344 MW). Market size is clearly crucial to supporting a domestic wind manufacturing industry.

Figure 14. Home Market Size and Global Market Share of Domestic Companies



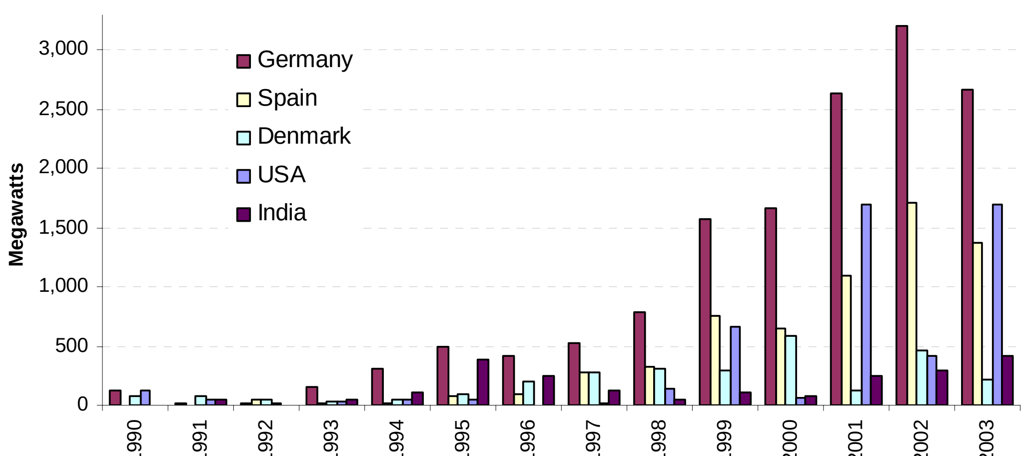
Source: BTM, 2004.

A local wind manufacturing industry must be supported by large, stable annual demand.

It is estimated that a minimum annual demand of 150-200 MW/year for 3 or more years is crucial to developing a nascent local manufacturing industry, while a more capable and aggressive local industry is likely to require a minimum of 500 MW a year (CanWEA, 2003).

As is seen in Figure 15 below, Germany has maintained a stable market of over 200 MW installed per year after 1994, while Denmark and Spain did so after 1997. The USA had an unstable market environment with installations of over 200 MW per year in 1998 and 1999 that then dropped in 2000. India's market has also been unstable with annual installations well over 200 MW for 1995 and 1996 that then dropped below 100 MW in the late 1990s.

Figure 15. Annual Capacity Installations in Countries with Leading Manufacturers in the 1990s



Indirect policies that create a sizable, stable environment for wind power have been crucial in both promoting wind power development and promoting a local turbine manufacturing industry.

Achieving a sizable, stable local market requires aggressive implementation of wind power support policies.

Denmark, Spain and Germany have built their local manufacturing industries through what have historically been stable and profitable feed-in tariff policies. The early US wind industry was also supported by a feed-in tariff.

Mandatory market shares for renewables have been implemented as Renewable Portfolio Standards (RPS) in several US States, as a national Mandatory Renewable Energy Target (MRET) in Australia, as a Renewables Obligation (RO) in the UK, and as the Special Measures Law in Japan. Since all programs have only been implemented recently, their impact on wind power development has been relatively small to date.

Government-run competitive bidding for wind concessions has been or is being used in Canada, the UK, India, Japan, China, and Brazil. In particular, Canada, China and Brazil's programs have resulted in significant new capacity additions in the past couple of years.

Several forms of tax incentives are being used to promote wind power development. Among the most successful include the US's Production Tax Credit, which is attributed as the primary policy mechanism governing wind development in the US, as signaled by almost no new capacity additions from the end of 2003 through mid-2004 when the credit had expired and was eventually renewed. China has a tax credit that decreases the VAT on electricity from wind.

Government loans and capital grants have been used by Denmark, Germany, the US, Australia, India, China and Brazil to support wind farm construction.

Table 5. Indirect Policy Measures and Notable Examples Where Used

Feed-in tariffs	Germany, Spain, Denmark, US States
Mandatory market shares	US States, UK, Australia, Japan
Resource concessions/bidding	UK, India, Japan, China, Brazil
Tax incentives	USA, China
Loans and capital grants	Denmark, Germany, US, Australia, India, China, Brazil

Policies that directly support local manufacturers can be crucial in countries where barriers to entry are high and competition with international leaders is difficult.

A variety of policy options exist to *directly* support local wind manufacturing, and several policy options have proven effective, as demonstrated in a number of countries.

Local content requirements and incentives, for example, are being used in the emerging wind markets of Spain, Canada, China, and Brazil. Spain's preferential polices for local manufacturing have helped Spanish manufactures like Gamesa grow in experience and begin to expand abroad, while simultaneously bringing international manufacturers into the Spanish market—not just to sell imported turbines but to manufacture their turbines locally—creating Spanish jobs and helping the Spanish economy.

Customs duties that support turbine manufacturing by favoring the import of components over full turbines have been used in Australia, India and China with some success.

Canada has implemented a tax credit on wages paid out to local labor forces in an attempt to encourage large wind turbine manufacturers to shift jobs to Canada. Spain's production tax credit on wind-powered electricity is granted only to turbines that meet local content requirements.

Export credit assistance or development aid loans tied to the use of domestic technology have been used particularly by Germany and Denmark, encouraging the dissemination of Danish and German technology around the world, particularly the developing world.

Quality certification and standardization programs have been used in Denmark, Germany, India and the USA. They were particularly valuable to Denmark in the early era of industry development when they essentially mandated the use of Danish-manufactured turbines as no other countries had manufacturers that could meet Danish standards.

R&D funding has been allocated to wind turbine technology development by every country in this study. The success of R&D programs for wind technology has been more related to how the funding was directed than the total quantity of funding. Although the US has put more money into R&D than any other country, an early emphasis on multi-megawatt turbines and funding directed into the aerospace industry are thought to have rendered US funding less effective in the early years of industry development. Denmark's R&D budget, although smaller in magnitude than some other countries, is thought to have been allocated more effectively among smaller wind companies developing varied sizes and designs of turbines. Demonstration funding, in particular, has been found to be particularly helpful in testing turbines prior to commercial sales.

Table 6. Direct Policy Measures and Notable Examples Where Used

Local content requirements & incentives	Spain, Canada, China, Brazil
Preferential customs duties	Australia, India, China
Tax incentives	Canada, Spain
Export credit assistance	Denmark, Germany
Certification	Denmark, Germany, USA, India
R&D	All

8. Recommendations for China

In its pursuit of a local wind turbine manufacturing industry, China can learn from the experiences of the other countries reviewed in this study. Based on the material presented above, we offer the following recommendations for China as it adopts policies to promote local manufacturing. The findings presented in this study are not comprehensive recommendations, but rather a starting ground for Energy Foundation grantees to build upon in future work.

Clarify national goals on localization

China has relied on technology transfer, through either joint-ventures and/or licensing arrangements with foreign firms, to acquire technology for large wind turbines. Although there is some evidence that a fully Chinese-manufactured commercial large wind turbine industry is getting off the ground, it is likely that in the near term Chinese manufacturers will have a hard time competing with foreign technology in terms of quality and reliability. However, Chinese firms may be able to compete in terms of price.

Many foreign firms have been disenchanted by experiences with joint ventures in the wind turbine industry in China that have not been successful, and therefore are hesitant to participate in further technology transfers in this manner. Therefore, companies looking to meet local content requirements are attempting to do so without any transfer of their intellectual property rights. Companies like Vestas have discussed plans to manufacture wind turbines in China, but have said they will only do so while maintaining 100% ownership of the subsidiary company. GE Wind also has discussed plans for manufacturing wind turbines in China, but plans to take a different strategy in which they certify local Chinese components manufacturers to produce components for GE turbines, then develop a facility at which they would assemble the components but do no manufacturing. GE also plans to establish an extensive sales and service presence in China and provide service to turbines covered under GE's warranty.

China therefore needs to determine whether it will be satisfied with the local manufacturing of wind turbines that may hire local Chinese labor and provide some local economic benefit, but will not result in the transfer of property rights, innovation knowledge or know-how surrounding the manufacturing of large wind turbines. This sort of "technology transfer" may contribute to the Chinese economy, but not to its industrial knowledge base.

Implement indirect policies to support aggressive and stable wind power capacity additions

Leading wind manufacturers come from countries that have historically maintained strong policy environments for wind development. A stable feed-in tariff has proven to be the most successful mechanism for promoting wind energy utilization to date. However, several policies may be effective if implemented carefully, including a mandatory market share or RPS, or government-run project auctions or concessions. What is clear is that the structure of a nation's policy framework will affect how the domestic wind industry will look, and how the development of wind power will proceed.

China's indirect policies to promote a domestic wind industry are proving moderately effective due to new policies implemented in 2003 and 2004. The government's five Wind Concession projects have resulted in the procurement of 800 MW of new wind capacity in 2003 and 2004. If completed, the concession projects alone will more than double China's existing wind power capacity. Concern has arisen that the tariffs agreed to under these concession projects are too low to make the projects economically viable, and it will take the successful implementation of these projects to dispel this rumor. Additionally, in the summer of 2004, Guangdong's provincial government issued a feed-in tariff for wind power set at 0.528 Yuan/kWh. This price was based on the estimated competitive cost of wind power in Guangdong by basing it on the winning bid for the concession project in Guangdong province.[18] These policies are acting to reduce the investment risk for wind farms and to clarify the regulations surrounding wind farm development in China, which are likely to result in an increase in installed capacity in the coming years.

More aggressive and stable national policies are likely to be required to more fully stimulate local manufacturing, however, and the time is ripe for China to consider the establishment of an attractive national feed-in tariff, as has been successfully implemented in other countries.

Implement direct policies to encourage local manufacturing

China can maximize its attractiveness for local manufacturing by establishing a combination of direct and indirect policies to support wind industry development.

Direct support for local manufacturing is possible through a number of avenues as described above, and have proven particularly beneficial in countries trying to compete with dominant industry players. The most effective policies are the ones that directly provide differential support to companies that are locally manufacturing their wind turbines, or that create strong incentives for companies to shift from importing their turbines to establishing a local manufacturing base.

Local content requirements are the most direct way to support the creation of a local manufacturing industry, and have proven to be an effective way to attract local manufacturing by foreign companies. Spain and Canada, for example, have both initiated local content requirements for recent wind projects, and are attracting foreign companies to manufacture locally. That said, a sizable local market is a pre-requisite to the effective use of this policy mechanism. Spain, for example, has enticed numerous foreign companies to manufacture locally, but this is likely due not only to stringent local content requirements but also to the market stability that a feed-in tariff provides. Canada has been able to attract local manufacturing again partly due to stringent local content and employment requirements, and partly due to extremely large project tenders that establish a sizable market.

Other policies that deserve consideration include:

- local content incentives, either in the form of cash or tax incentive,
- well-targeted customs duties that apply a higher tariff on complete turbines than on turbine components (China's existing policies in this regard are targeted poorly),
- other tax incentives targeted to local labor and materials used in wind manufacturing,

[18] The feed-in tariff in Guangdong was set at 0.01 Yuan/kWh above the tariff that won the Guangdong concession project in Huilai.

- export credit assistance (once a local industry is well established),
- R&D, and especially turbine demonstration support, and
- turbine quality standards and certification requirements.

Incentives should be directed not only at manufacturers of full wind systems but also to manufacturers of wind turbine components. Policymakers must also be aware of WTO rules that discourage protectionism.

Develop a plan for growing the local wind industry

In addition to the above recommendations, we believe that China must develop a coherent, short- and long-term plan for encouraging local manufacturing. In the near term, we recommend that additional research be conducted on the following topics:

- **Analyze China's historic attempts to support local wind manufacturing.** A review of previous policies that have attempted to support local wind technology manufacturing in China will provide additional insight on the factors leading to the success and failures of these programs, and provide useful lessons for future programs.

- **Assess the benefits of local manufacturing.** A comprehensive assessment of the potential economic, employment, and cost reduction benefits associated with different forms of local wind turbine manufacturing should be conducted.

- **Evaluate China's competitive advantages in wind turbine manufacturing.** Many governments, including Canada and Australia, are commissioning studies to determine their competitive advantages in wind turbine manufacturing. We recommend that China also begin such a study, as it will provide useful information to both the government and to companies considering the pursuit of local manufacturing in China. Local manufacturing in any country typically begins with the manufacturing of particular components that are difficult to import due to size and cost yet require minimal technical capacity, including steel towers, nacelle covers, and base frames. China has the capability to move well beyond this level of local manufacturing, but an identification of opportunities is required.

- **Develop detailed policy recommendations for consideration by the government.** This study has identified the importance of both direct and indirect policies to support the local manufacturing of large wind turbines. Policies that support a sizable, stable market for wind power, in conjunction with policies that provide incentives for wind power technology to be manufactured locally, are most likely to result in the establishment of an internationally competitive wind industry. Such policies are most likely to succeed when designed by the government in close consultation with representatives of the wind power industry. We therefore recommend that stakeholders in China develop a comprehensive set of recommendations for consideration by the Chinese government.

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