A Comparison of Wind Power Industry Development Strategies in Spain, India and China

Joanna I. Lewis[1]

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[1] Senior International Fellow, Pew Center on Global Climate Change. Tel: +1 703 516 4146. Email: lewisj@pewclimate.org.

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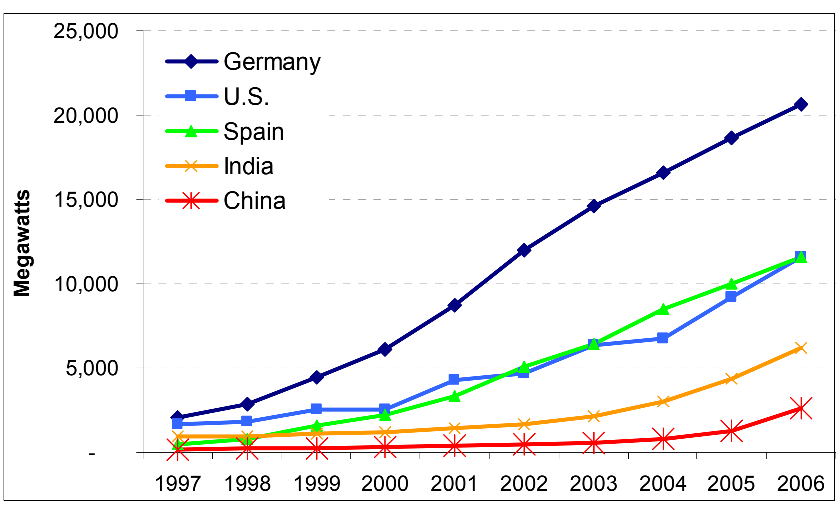
Summary

This paper compares the manner in which Gamesa (Spain), Suzlon (India) and Goldwind (China) became domestic leaders in their respective countries' wind industries. After a brief introduction to the global wind industry, the paper reviews the respective policy environments for wind energy in India, China, and Spain and how these policies have influenced the rise of a major domestic wind turbine manufacturer in each national context. It then examines and compares the manner in which Suzlon, Goldwind and Gamesa became domestic leaders in their respective countries' wind industries, with a focus on the acquisition of technology, technological know-how, and the associated intellectual property rights that allowed each company to become a leading wind turbine manufacturer in its own domestic market. These comparisons may be of interest to policy makers and technology developers within the Chinese context as Chinese wind turbine manufacturers strive to achieve similar technical capacity as their international counterparts.

1. Global Wind Industry Overview

In 2006, over 15 GW of new wind power capacity was installed worldwide, setting another annual growth record for the wind industry. Spain has the third largest installed wind capacity behind Germany and just behind the US. India, number four globally, currently leads the developing world both in installed wind capacity and in the manufacturing of utility-scale wind turbines. Spain is home to the second largest wind turbine manufacturing company in the world, Gamesa, and India to the fifth largest, Suzlon. China still lags these countries in terms of total wind capacity and manufacturing prowess, but in 2006 it ranked fifth (behind Germany, Spain, the US and India) in terms of annual capacity added that year, and currently stands at 2,588 in cumulative wind capacity. China's leading wind turbine manufacturer, Goldwind, entered the top 10 manufacturers list for the first time in 2006.

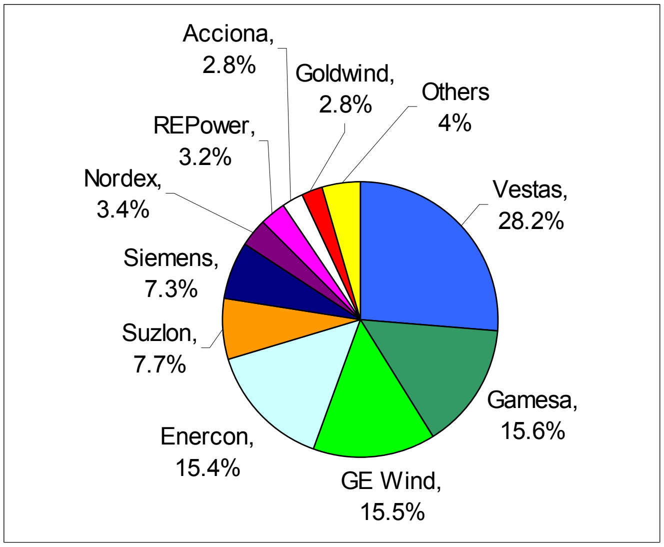
Figure 1. Wind Power Installations 1997-2006, Selected Countries



Source: BTM, 2006; Windpower Monthly, 2007.

Currently three quarters of global wind turbine sales come from only four turbine manufacturing companies: Vestas, GE, Enercon and Gamesa. Indian manufacturer, Suzlon, obtained 7.7 percent of global market share in 2006, while Chinese manufacturer, Goldwind, had 2.8 percent (Figure 2).

Figure 2. Global Market Share: Top 10 Wind Turbine Manufacturers (2006)



Note: 15,016 MW total capacity. Source: BTM, 2007. Note: The total shares sum to more than 100% due to discrepancies between supplier information and national installation figures.

Table 1. Largest Wind Markets and Domestic Wind Companies[2]

Country	Cumulative Wind Capacity (2006) (MW)	Leading Domestic Wind Companies (Global rank in 2006)	Percent of Installed Turbines Made by a Domestic Company (2006)
1. Germany	20,652	Enercon (#4), REpower (#8), Nordex (#7), Fuhrlander (#14), Siemens (formerly Bonus) (#6)[3]	55%
2. Spain	11,614	Gamesa (#2), Ecotecnia (#12), EHN/Ingetur (#11)	76%
3. US	11,575	GE Wind (#3)	37%
4. India	6,228	Suzlon (#5)	52%
5. Denmark	3,101	Vestas (#1)	100%
6. China	2,588	Goldwind (#10)	39%
7. Italy	2,118	None	0%
8. UK	1,967	None	0%
9. Portugal	1,716	None	0%
10. France	1,585	None	0%

Source: BTM, 2007; Wiser and Bolinger, 2007; company financial reports, and authors' calculations.

[2] The home country listed is based on the country in which the current ownership is primarily based, although many wind turbine manufacturing companies are increasingly global in their reach.
[3] Bonus, a Danish company, was purchased by Siemens, a German company, at the end of 2004, so the current company (Siemens) is listed as a German company.

2. India

India began wind development in the 1990s, and development has only begun to take off in the last few years. Although a relative newcomer to the wind industry compared with Denmark or the US, a combination of domestic policy support for wind power and the rise of a leading global wind turbine manufacturer have led India to become the country with the 4th largest installed wind power capacity in the world, and the wind energy leader in the developing world.

2.1. Policy Environment for Wind Energy

India has been an active supporter of wind development since the 1990s, and has a government ministry exclusively devoted to renewable energy promotion: the Ministry for Non-Conventional Energy Sources (MNES). However, India's policy support has been somewhat unstable over the years, which led to uneven wind development in the 1990s. Problems with inaccurate wind resource data, poor installation practices and poor power plant performance also slowed early wind power development in India.

Recent years have seen the market rebound, driven in part by more policy stability and more aggressive support mechanisms. India's Electricity Act of 2003, for example, requires all state-level energy regulatory commissions to encourage electricity distributors to procure a specified minimum percentage of power generation from renewable energy sources; as a result, the majority of renewable energy policy support in India has been left up to the states to implement. Many have aggressive renewable energy targets and policy support mechanisms in place; for example, the Karnataka Energy Regulatory Commission has stipulated a minimum of 5 percent and maximum of 10 percent of electricity from renewables, and the Madhya Pradesh Energy Commission has stipulated 0.5 percent of electricity from wind power by 2007. The state government of Maharashtra has implemented a fixed tariff price for wind electricity, guaranteeing a long term contract for wind power producers at a fixed price that declines over time (i.e., a "feed-in tariff"). Maharashtra has also imposed a small, per unit charge on commercial and industrial users to be used in support of non-conventional energy projects. In Gujarat, the government has signed agreements with Suzlon, NEG Micon (now Vestas), 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).

Table 2. India's Wind Power Capacity by Province (2006)

Province	Installations (MW)	Total Capacity (MW)
Tamil Nadu	324	3,216
Maharashtra	282	1,284
Karnataka	161	746
Rajasthan	83	441
Gujarat	63	401
Andhra Pradesh	0.6	122
Madhya Pradesh	15	55
Kerala	0	2
	928.6	6,267

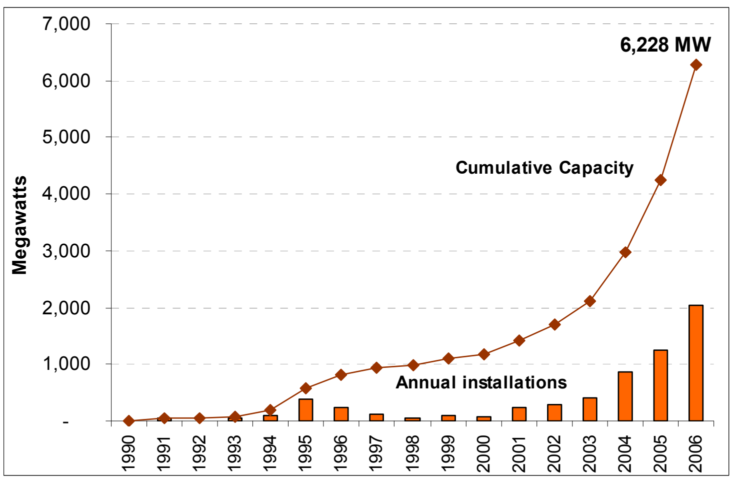
Source: WPM, March 2007:42.

Early wind policy in India included the National Guidelines for Clearance of Wind Power Projects implemented in July 1995 (and further refined in June 1996) which mandated that all state electricity boards take the necessary measures to ensure grid compatibility with planned wind developments. Early financial incentives were offered as well, with 100 percent depreciation of wind equipment allowed in the first year of project installation, along with a 5-year tax holiday (Rajsekhar et al., 1999).

More recent Indian polices have intentionally encouraged local wind turbine manufacturing. For example, the government has manipulated customs and excise duties in favor of importing wind turbine components over importing complete machines. India has also developed a national certification program for wind turbines administered by MNES, based in large part on international testing and certification standards, to boost the development of domestic turbine manufacturers.

Indian policy support has encouraged substantial wind development in India in recent years. In 2005, India became the country with the fourth largest wind power capacity in the world behind Germany, Spain and the US, surpassing Denmark. By 2006 India had reached 6,228 MW of installations, surpassing its long held target of 5,000 MW of wind capacity by 2012 several years early (WPM, March 2006:44). India's wind installations since 1990 are illustrated in Figure 3.

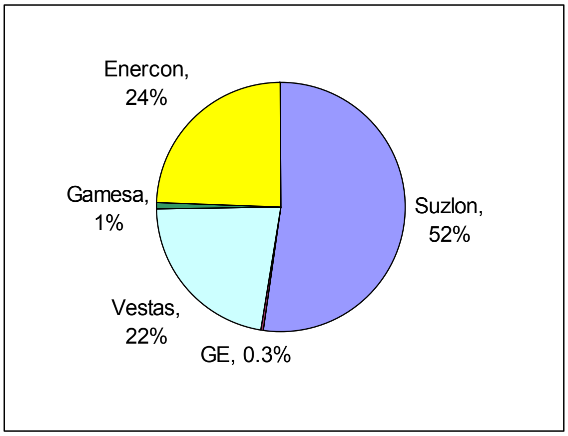
Figure 3. Installed Wind Power Capacity in India, 1990-2006



2.2. India's Leading Wind Turbine Manufacturer: Suzlon

Suzlon, an Indian-owned company, emerged on the global scene in the past decade, and is proving itself to be a worthy competitor among the more established wind turbine manufacturers. As of 2006 it had captured 7.7 percent of market share in global wind turbine sales—a modest share, but a share that has been increasing annually. Even more impressive, however, is the company's success in its home market. Suzlon is currently the leading manufacturer of wind turbines for the Indian market, holding 52 percent of market share in India. Suzlon's success has made India the developing country leader in advanced wind turbine technology.

Figure 4. Indian Market Shares, 2006



Note: 1,778 MW total capacity. Source: BTM, 2007.

Suzlon is owned by a family that diversified into the wind energy business from the textile industry, incorporating the company in 1995. Within five years Suzlon had made the list of top ten wind companies, and it 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). In September 2005, Suzlon went through an initial pubic offer in which requests to purchase its equity shares were reportedly five times oversubscribed.

Not just an equipment supplier, Suzlon is also a full wind farm project developer and operator. Its varied services are offered by its associated company subsidiaries, which have also been established to cover specific regional markets. Suzlon's wholly-owned subsidiaries include technological development centers in Germany and the Netherlands, a rotor blade manufacturing company (Suzlon Energy B.V) in the Netherlands, a US market subsidiary (SWECO), and an Australian market subsidiary (Suzlon Energy Australia Pty Limited). In August 2004, Suzlon Energy A/S, a wholly-owned subsidiary, was created to supervise Suzlon's international marketing activities. A representative office in Beijing and manufacturing facility in Tianjin have also been set up in China to expand Suzlon's presence in the Chinese market.

Suzlon maintains that it still views India as its key market, but is actively exploring growth opportunities overseas. Suzlon has plans for extensive international expansion in the next few years, with targeted markets including North America, Europe, China and Australia. Suzlon's wind turbines are already being exported to the US, Europe and several developing countries (WPM, March 2004:57). In 2004 Suzlon completed its first US project, a 24 MW wind farm in Minnesota.

In 2004, Suzlon 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). Placement of the international headquarters in Denmark was particularly strategic since, in 2004, many former workers for the leading Danish wind companies, Vestas and NEG Micon, had recently been laid off after streamlining in conjunction with the merger of the two companies. The Group headquarters is still located in Pune, India, and the Global Management Center is located in Amsterdam, Holland.

Wind turbine technology expertise was obtained by Suzlon in a variety of ways. In 1995, it entered into a technical collaboration agreement with a German company, Sudwind GmbH Windkrafttanlagen, and subsequently an agreement with Sudwind Energiesysteme GmbH (Sudwind) which took over the former company in 1996. The new agreement was for Sudwind to share technical know-how relating to 270 kW, 300 kW, 350 kW, 600 kW and 750 kW wind turbines, in return for royalty payments for each wind turbine sold over the course of five years from the starting date of the agreement, September 30, 1996 (Red Herring, 2005). In 2001, Suzlon obtained a license to manufacture rotor blades from the company Aerpac B.V, and entered into an agreement with Enron Wind Rotor Production B.V. in which Suzlon made a one-time payment to acquire the necessary moulds, production line, and technical support to produce another model of rotor blades in India.

Suzlon currently offers wind turbines that range in size from 350 kW to 2.1 MW.[4] The company's manufacturing strategy has been to build upon the licensing agreements described above with their own research and development, and to manufacture as many wind turbine components as possible in house. Suzlon believes that increasing its in-house manufacturing capabilities will help them to lower wind turbine costs by giving them greater control over the supply chain, and enable quicker and more efficient assembly and faster delivery times to customers (Red Herring, 2005). This strategy of developing integrated manufacturing capability is particularly aimed at supporting high growth regions, including India, China and the US. It allows them to respond to local demand and not have to rely on a supply chain of components suppliers to ensure turbine orders, and also allows them to cut logistics and transaction costs since fewer parties are involved along the chain. In particular, Suzlon's integrated wind turbine manufacturing facility in Tianjin, China; and rotor blade manufacturing facility in the Pipestone, United States are examples of Suzlon's strategy to support high growth regions with dedicated delivery capability.

Suzlon's manufacturing capabilities include rotor blades for the larger turbines (1 MW and larger), tubular towers, control panels and nacelle covers. In 2006, Suzlon purchased Hansen, the second largest gearbox manufacturer in the world, expanding Suzlon's access to gearbox technology. This deal marked the second largest foreign corporate takeover by an Indian company in any industry. Some components not manufactured in-house, including blades for some of the smaller turbine models, and a few minor components, but recent expansion of gearbox and generator manufacturing means that Suzlon's supply chain is becoming more and more comprehensive. In 2005 Suzlon began manufacturing generators through a 74.9 percent owned subsidiary, Suzlon Generators, which is a joint venture with Elin EBG Motoren GmbH of Austria. Suzlon also has an arrangement with Winergy AG, the leading gearbox supplier in India, which allows for the use of domestically manufactured gearboxes while it continues to work to advance its own technology. Most recently, in May 2007, Suzlon acquired German manufacturer REpower for approximately €1 billion.

Research and development activities at Suzlon are currently focusing on the design and development of new wind turbine models (focusing on a gearless 1.25 MW, and 1.5 MW, and 2.1 MW capacity models), upgrading current models, and advancing rotor blade technology to improve efficiency. Its research center based in the Netherlands is located there to specifically take advantage of Dutch expertise in aerodynamic rotor blade design and material sciences, while the German site is taking advantage of German wind turbine engineering capabilities, specifically looking at gearbox prototypes (Red Herring, 2005).

The majority of Suzlon's manufacturing facilities are still located in India. Suzlon believes this gives them increased access to capital, and to low manufacturing and labor costs, giving them an edge over competitors manufacturing turbines in higher cost regions such as Western Europe. Within India, facilities are sited closest to states that the company believes offer the best wind energy development potential. However, Suzlon has been expanding its manufacturing presence around the world. Suzlon's operations in Belgium include cooperation with gearbox manufacturer Hansen Transmissions to produce megawatt-range gearboxes.

[4] Models include 350 kW, 950 kW, 1 MW, 1.25 MW, and 2.1 MW turbines.

Recently Suzlon established a rotor blade manufacturing facility in Pipestone, Minnesota in the United States to reduce transportation and delivery costs and increase its role in the US market. Suzlon also has recently established a manufacturing facility in Tianjin, China, recognizing China as another key growth market with opportunities for manufacturing low cost components. The facility has an annual manufacturing capacity of 600 MW (Suzlon Website, 2007). However, production costs are reportedly still lower at the Indian facility than at the Chinese facility due to lower labor costs.

3. Spain

Spain, like India, began wind power development in the 1990s, and has experienced substantial capacity additions over the last decade. Another relative latecomer to the development of domestic wind technology expertise, 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. Wind comprises about nine percent of Spain's total electricity production— the highest after Denmark's 20 percent.

3.1. Policy Environment for Wind Energy

Spain has fostered a relatively supportive policy environment for wind power development, and has used policies to directly support Spanish wind turbine manufacturers. Spanish government agencies have mandated the incorporation of local content in wind turbines installed in Spain in many contexts. Several of Spain's autonomous regional governments have used local content requirements to attract wind turbine manufacturers to their regions in an attempt to boost industrial development and economic growth. Such provinces include Navarra, Galicia, Castile and Leon and Valencia, many of which have insisted on local assembly and manufacture of turbines and components before granting development concessions (WPM, October 2004:6). Spain represents a particularly aggressive use of such policies to support local wind turbine manufacturers, and the success of Gamesa and other manufacturers is very likely a result of such policy support.

Table 3. Spain's Wind Power Capacity by Region (2005)

Region	Capacity (MW)	Region	Capacity (MW)
A Coruna	755.1	Jaen	21.1
Alava	26.9	Leon	55.7
Albacete	1002.3	Lugo	962.9
Almeria	13.2	Murcia	48.9
Asturias	145.9	Navarra	827.4
Avila	110.8	Palencia	148.8
Baleares	3.6	Pontevedra	109
Burgos	399.2	Rioja	346.8
Cadiz	236.2	Segovia	14.5
Ciudad Real	76	Soria	473.4
Cuenca	480.6	Tarragona	93.8
Gerona	0.5	Teruel	62.7
Granada	54.1	Toledo	52.7
Guadalajara	38.8	Valencia	20.4

Guipuzcoa	32.3	Vizcaya	25.5
Huelva	14.4	Zamora	320.6
Huesca	1182.3	Zaragoza	953.9

Source: Graber, 2006.

Aside from local content requirements, other incentives for local manufacturing have also been sporadically employed within the provinces. The Spanish government also provides some support for R&D in wind technology under the Research Centre for Energy, Environment and Technology (CIEMAT), the main public R&D organization in wind energy. Spanish private wind companies invest heavily in R&D, estimated at about 11 percent of their gross value added, which is above average for other sectors and companies in Spain (IEA, 2004).

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. This year, however, the government announced that it would cut payments for wind production by more than half due to reports that wind profits were extremely high (WPM Jan 2007).

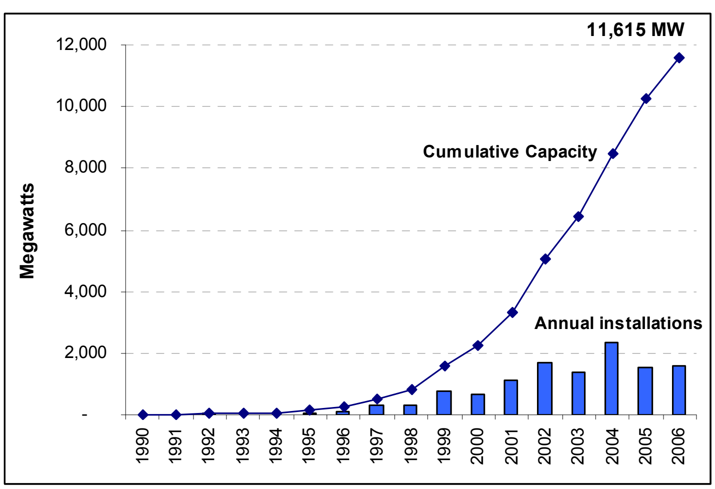
Government-led wind concessions are also widely used in Spain. Five wind concessions totaling 3,200 MW were granted to project developers through a public tender process. These concession projects help to support new transmission capacity, since the financing of power lines is a requirement of the concession projects.

Spain has also adopted the European target of 12 percent 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. More recently this target was increased to 20 GW by 2010, but it is unclear if this will be met if development levels off at 1,550 MW per year as is being projected by the national wind association in Spain (AEE) (WPM, March 2007). Wind projects further benefit by the deferral of tax payments on earnings for 15 years (WPM, February 2001:20).

The Spanish government is currently establishing regulations for the development of offshore wind power; there is an estimated 3,000 MW of immediately viable offshore potential, much off the southern part of the Iberian Peninsula.

Spain had a total installed wind power capacity of 11,615 MW at the end of 2006, 1,587 MW of which were installed that year. This marked a growth rate of just 13 percent over 2005, a substantial slowdown from the earlier part of the decade.

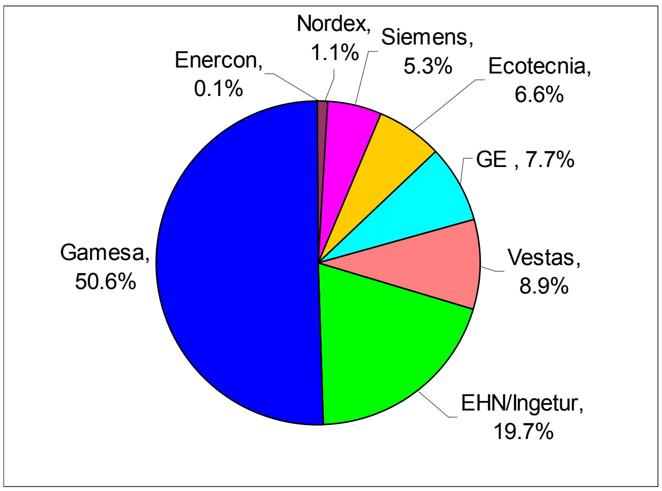
Figure 5. Installed Wind Power Capacity in Spain, 1990-2006



3.2. Spain's Leading Wind Turbine Manufacturer: Gamesa

Spanish turbine manufacturer Gamesa had the largest market share in Spain of any manufacturer in 2006, with half the market, followed by another major Spanish manufacturer, EHN/Ingetur, with about 20 percent, Vestas with 9 percent, GE with just under 8 percent, Ecotecnia with 6.6% and Siemens with 5.3%. Gamesa also had about 16 percent of global market share in 2006 (BTM, 2007).

Figure 6. Spanish Market Shares, 2006



Note: Shares represent 1,900 MW total capacity.[5] Source: BTM, 2007.

Gamesa, like Suzlon, is a vertically-integrated wind turbine technology supplier, developing a full wind turbine technology supply chain in-house. Current manufacturing capabilities blades, root joints, blade moulds, gearboxes, generators, converters and towers, besides assembling the wind turbines. Gamesa offers a wind turbines ranging in size from 850 kW to 2.0 MW. Gamesa has 15 manufacturing facilities around the world that make turbines and/or blades, including 3 new factories that opened in 2006 in the US, Spain and China. Gamesa has supplied wind turbines in the US, Italy, France, Portugal, Germany, China, Japan, India and Latin America. It has subsidiaries in Germany and the US, sales offices in Italy, Greece, Portugal, France, the UK and Brazil, and cooperation agreements with local companies in Gamesa's newer markets, including Japan, India, China and Australia.

Gamesa's primary markets are within Europe, the US and China. In 2006, 65 percent of Gamesa's sales were to Europe, of which 40 percent were within Spain. 12 percent of sales were to the US market, and 10 percent were within the Chinese market.

Gamesa's key technology acquisition that led to its becoming a leading global wind turbine manufacturer began in 1994 with its joint venture with Vestas. Grupo Auxiliar Metalurgico SA (Gamesa's parent company) was founded in 1976 by Tornusa, a private investment company. Financial backing for the company comes from the group IBV, a joint venture between Spain's second largest utility, Iberdrola, and the financial institution Banco Bilboa Vizcaya Argentaria. In the 1980s, IBV took over 91 percent of the Gamesa Group, leaving Tornusa with 9 percent.

[5] Reported turbine shipments may be higher than installed capacity for 2006 since not all turbines are installed in the same year.

The Spanish market became particularly lucrative in the mid 1990s when big utilities started to place large orders for wind farms to benefit from government incentives. The Gamesa-Vestas joint venture was formed in 1994 as a way for Vestas to manufacture turbines in Spain, allowing it 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). The joint venture, Gamesa Eólica, consisted of Gamesa Energía (51 percent), Vestas (40 percent) and the industrial holding company of Navarra's regional government, Sodena (9 percent). By 1997 Gamesa Eólica controlled 70 percent of the Spanish wind turbine market. The joint venture with Vestas landed Gamesa "exclusive rights to manufacture, assemble and sell Vestas technology in Spain."

Gamesa Eólica's own R&D department is continually developing and innovating upon the technology it has inherited from Vestas. For example, in 1997 Gamesa Eólica introduced the Ingecon variable speed system to its turbines, which, the company claims, increases nominal capacity by approximately six percent and was therefore an added improvement on the Vestas design. The system has been widely applied to Gamesa Eólicas biggest seller, the 660 kW G47 turbine, based on the Vestas V47.

In November 2001 Gamesa Eólica reached a deal with Vestas to buy out its share of the company, and maintain the intellectual property rights to continue to utilize and build upon Vestas' technology in the Spanish, and world, market. The split between the two companies resulted in Vestas relinquishing its 40 percent in Gamesa Eólica to the Gamesa group for €287 million, and began the phasing out of the technology transfer agreement between the two companies.

The decision to split was likely due to conflicts between the two companies that arose in part due to the Vestas policy of being a turbine supplier only, while Gamesa also operates as a project developer through Gamesa Energía. As Gamesa Energia continued to grow and wanted to use Gamesa turbines, there was a need for Gamesa Eólica to be able to expand beyond the geographical confines of its technology-transfer agreement with Vestas. The original technology transfer agreement limited Gamesa Eólica's market mainly to the Iberian Peninsula and some Latin American countries, while Vestas remained free to supply the rest of the world. Following the separation deal, Gamesa Eólica acquired the right to sell anywhere in the world. It also retained its technology transfer agreement with Vestas for the two 850 kW models until the end of 2002 and for the G66-1.65 MW and V80-2 MW machines until the end of 2003. However, Gamesa is free to continue to sell all five models, from the 600 kW up to the 2 MW units in any country for an unlimited period despite the official end of the agreement, which basically just ends Vestas' technological support to the joint venture.

In early 2002 Gamesa Eolica also reached a deal with Germany's REpower Systems to manufacture and market its 1.5 MW turbine. In 2003 Gamesa acquired Spanish turbine manufacturer Made, which held 14 percent of Spanish market share in 2003, increasing their global market share (WPM, January, 2002:24).

Gamesa supplied 2,250 MW of capacity in 2006, up 26 percent from its volume in 2005 (but installed a total of 2,402 MW). It reported total sales of 2.4 billion euros in 2006, up 36 percent from 2005. The company has an objective of 15 percent annual growth from 2006-2008. 64 percent of 2006 sales were of the 2 MW machines, and the rest were for their 850 kW turbines.

4. China

Although China still lags many countries in terms of total wind power installations, its recent growth rates have far exceeded the world average. An increasingly strong policy environment and a growing local manufacturing base contributed to China's more than doubling of its wind power capacity in 2006.

Table 4. China's Wind Power Capacity by Province (2006)

Province	Installations (MW)	Total Capacity (MW)
Inner Mongolia	165.74	508.89
Hebei	108.25	325.75
Jilin	109.36	252.71
Liaoning	127.46	232.26
Guangdong	140.54	208.49
Xinjiang	181.41	206.61
Heilongjiang	57.35	161.15
Ningxia	112.95	159.45
Shandong	83.85	144.60
Gansu	52.20	127.75
Jiangsu	0	108.00
Fujian	58.75	88.75
Zhejiang	34.15	35.65
Shanghai	24.40	24.40
Hainan	8.70	8.70
Hong Kong	0.80	0.80
Total	*1265.91*	*2593.96*

Source: WPM, March 2007.

4.1. Policy Environment for Wind Energy

The first major policy to specifically support utility-scale wind power in China came in 1994 when the Chinese government, led by what was then the Ministry of Electric Power, released "Provisions for Grid-Connected Wind Farm Management." The Provisions mandated that grid operators facilitate interconnection of wind farms, and set a purchase 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). In addition, the Provisions stipulated that any incremental cost of wind power over the average cost of conventional electricity be borne by the entire grid. This cost-plus-profit formula persisted in China for several years, encouraging wind development in certain provinces but reportedly leading to huge subsidies in many instances where the profit margin was set relatively high. In 2002, the Ministry of Finance and the State Duty Bureau implemented a new tax policy that reduced the Value-Added Tax for wind generation from 17 to 8.5 percent (NREL, 2004).

More recently, China has developed a series of government-run tenders known as Wind Concessions for government-selected sites that are auctioned off through a competitive bidding process among potential developers. The primary goal of the wind concession program, from the government's perspective, is to steadily ramp up new wind power capacity at the lowest possible cost while maintaining control over development decisions. After years of high wind electricity tariffs, the government hoped that introducing a competitive bidding process for wind farm development would reveal the true market price of wind power in China. Additional program goals include promoting the technology transfer of advanced wind energy technology, and increasing local manufacturing of wind energy systems and technology components (Wind Concession Group, 2003). A condition was placed on the developers of the concession projects that 70 percent of the turbines used must be made in China. Approximately 4,000 MW of new wind power capacity is expected to be installed through the concession process by 2010.

These wind concessions became the model used in China's 2005 National Renewable Energy Law when subsequent power pricing regulations were released in 2006. These regulations stipulated that concession-based pricing be used for the majority of wind power development in China, although in some cases negotiated feed-in tariff or other fixed price contracts are being agreed to for discrete projects. Guangdong province had set a provincial feed-in tariff for wind power prior to the passage of the renewable energy law, and there have been discussions of moving to a feed-in model rather than the concession model due to market instability and reportedly below-market prices being bid by domestic developers to win concession contracts.

Wind farm projects 50 MW and over must gain approval by the central government. This has prompted many developers to build 49 MW wind farms to avoid this approval process. The tariff structure used for these projects appears to be guided by the concession tariffs in the regions, and these projects still must meet the 70 percent local content requirement for the wind turbine technology used.

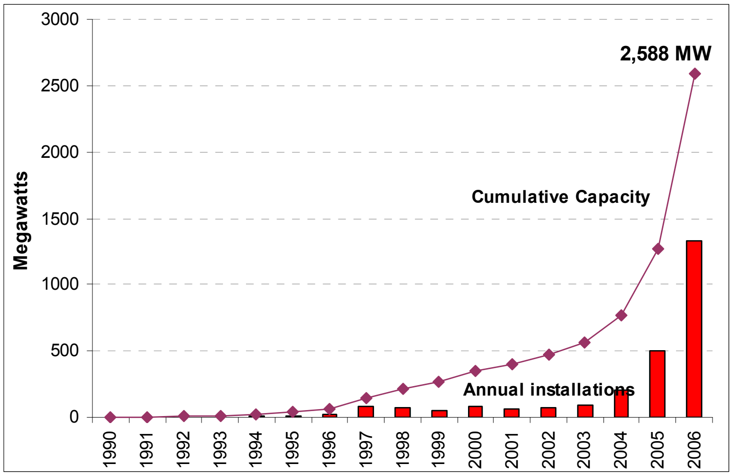
China has taken several additional steps to directly encourage local wind turbine manufacturing, including policies that encourage joint-ventures and technology transfers in large wind turbine technology, policies that mandate locally-made wind turbines, differential customs duties favoring domestic rather than overseas turbine assembly, and public R&D support. The Ministry of Science and Technology (MOST) has subsidized wind energy R&D expenditures at varied levels over time, beginning most notably in 1996 with the establishment of a renewable energy fund (MOST et al., 2002; Liu et al., 2002). MOST supported the development of megawatt-size wind turbines, including technologies for variable pitch rotors and variable speed generators, as part of the "863 Wind Program" under the Tenth Five-Year Plan (2001-2005).

In 1997 the SDPC began its "Ride the Wind Program" in order to promote a model of "demand created by the government, production by joint venture enterprise, and ordered competition in the market" (MOST et al., 2002). The technology transfers carried out through this program started with a 20 percent local content requirement with the goal of an increase to 80 percent as learning on the Chinese side progressed (Lew, 2000). The Ride the Wind program experienced limited success, perhaps due to the fact that foreign companies were not able to choose their Chinese partners— instead 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 manufacturing wind turbines.

The Chinese government has also experimented with reducing customs duties on imported wind turbines or components over the years. In the late 1990s, several components were tax-exempt or faced lower customs duties than complete wind turbines, in an attempt to encourage locally manufactured machines.

China's target of 1000 MW of wind by the year 2000 was not met, which members of the wind industry blamed on unclear approval procedures and unrealistic local content requirements (Feifel, 2001). However, recent changes in policy signals, particularly related to the national renewable energy law, have contributed to much more sizable growth over the past couple years, as illustrated in Figure 4. At 2.5 GW in 2006, however, the country still has a long way to go to meet its national target of 30 GW of wind power by 2020.

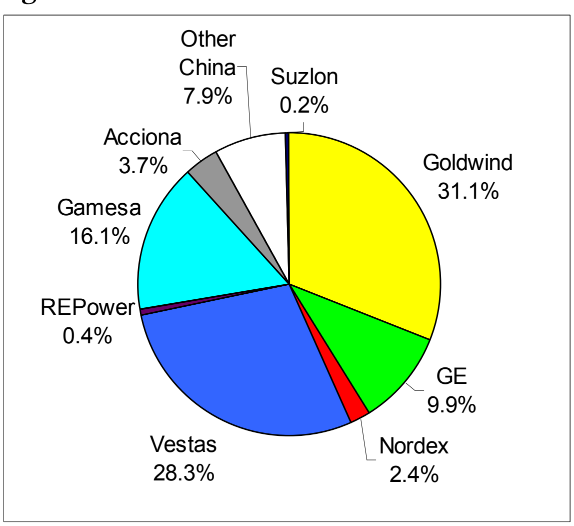
Figure 7. Installed Wind Power Capacity in China, 1990-2006



4.2. China's Leading Wind Turbine Manufacturer: Goldwind

Goldwind (*Jinfeng*) has recently emerged as the leading Chinese wind turbine manufacturer. A Chinese company, Goldwind currently holds 2.8 percent percent of market share in global wind turbine sales, reaching the top 10 for the first time in 2006. Within China it captured 31 percent of sales in 2006 (BTM, 2007). The company is rapidly expanding production, and has been benefiting from Chinese government policies that selectively promote the utilization of domestically-manufactured wind turbines in its wind farm projects (described in the previous section). In 2006, Goldwind installed 442 MW—by far its largest annual installation to date. Goldwind has, thus far, only supplied the Chinese market, and has not yet exported any turbines outside of China.

Figure 8. Goldwind's Chinese Market Shares, 2006



Note: 1,337 MW total capacity. Source: BTM, 2007; WPM, March 2007.

Xinjiang Goldwind Science and Technology Company Limited (Goldwind) is a subsidiary of the Xinjiang Wind Energy Company (XWEC) and was established in 1998. It is based in Urumqi in Xinjiang Province in Northwest China, the first site of large-scale wind power in China. Goldwind, a fully Chinese-owned company, is also 55 percent State-owned, and receives research and development funds from the Xinjiang Science and Technology Commission.

Goldwind sells turbines in the 250 kW, 600 kW and 750 kW size classes, and more recently is supplying a 1.2 MW turbine. Goldwind first obtained its wind turbine technology through purchasing a license from Jacobs, a small German wind turbine manufacturer which has since been purchased by REpower, to manufacture 600 kW wind turbines. The license is paid as a 10,000 DM (~ €5,000) royalty per machine produced, and reportedly included component specifications and assembly of turbines, but not how to design a turbine (Brown, 2002). Subsequently, Goldwind also obtained a license from REpower for its 750 kW turbine, and a license from German company Vensys Energiesysteme GmbH for a gearless 1.2 MW turbine. When Vensys developed a low wind speed version with a larger 64m/211-ft diameter rotor that increased output to 1.5 MW, Goldwind acquired the license for that turbine as well and is currently working with Vensys to produce 2.0 MW and 2.5 MW turbines with a view to offshore applications.

Goldwind has produced more than 100 of its 600 kW wind turbines for use in China. In 1998, XWEC's turbines contained 33 percent local content, and by the next year the share of locally manufactured materials had increased to 72 percent. The highest local content it has achieved has been estimated at 78 percent; this excludes blades and a few other small parts. It was estimated that once China has the capability to manufacture blades, at least 96 percent of wind turbines could be manufactured locally.[6] At least two companies have begun to exclusively manufacture turbine blades in China: Baoding and LM Glasfiber; several international turbine manufacturers (including Suzlon) have as well. Goldwind reportedly now uses locally manufactured generators, gearboxes, control systems, blades, yawing systems, hubs and towers for its turbines, purchasing several of its components from domestic suppliers (Yu and Wu, 2004). Quality and reliability among domestic suppliers is still a problem, particularly for key components such as rotor blades, gearboxes, generators, yaw systems and electric control systems. A domestic technology certification program being implemented by the Chinese government hopes to increase in quality of locally-made components, and help to boost the image of Chinese-made turbines, which are still thought to be less reliable than foreign-made turbines. Goldwind's 600 kW turbine was certified under the ISO 9001 quality certification system in September 2000, and is thought to be one of the most reliable Chinese made models available.

Since 1996, Goldwind has pursued a business model that allows it to implement modern foreign technologies while promoting its own technological advancement, with the goal of creating new ideas and eventually gaining benefit from its own products and proprietary results of research and development (Yu and Wu, 2004). Goldwind believes strongly that holding trademarks and property rights improves "progressive production engineering" as well as "sales of the products without geographical boundaries (Yu and Wu, 2004)." Goldwind recognizes that patents in particular have been used in the wind industry to defend market share; a famous example is the US patent for variable speed turbine technology acquired by GE after its purchase of Enron Wind, serving to limit competition in the US wind turbine market.[7] Perhaps hoping to use a similar strategy in the Chinese

[6] Local content is generally calculated according to cost, therefore 78% local content represents domestically produced components totaling 78% of the wind turbine cost.

[7] 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

marketplace, and recognizing its role as the leader in wind turbine innovation in China, Goldwind is ensuring that it registers for patents for all newly developed products as soon as possible. It is also playing a watchdog role to ensure that other domestic companies do not attempt to register for similar patents.

In addition to its license arrangements, Goldwind works to improve its technical capacity by sending its employees abroad to obtain advanced training. Goldwind reports that two-thirds of its staff has already attended events for technical exchange or further training by foreign companies or institutes, and several high-level managers have been sent abroad for MBA programs. In addition, as Goldwind expands it is reforming its stock ownership policies to allow employees to be shareholders, hoping to further encourage employee commitment by giving them a share of the company's future profit and assets.

Goldwind received a high-profile order to supply one of the first two government wind concession projects, the Huilai project in Guangdong province, at the end of 2003. The concession tenders highlighted the fact that Goldwind could offer turbines for about 25 percent less than the price that was being offered by the European manufacturers, making them particularly attractive to developers trying to win the concession projects by bidding the lowest possible tariff price. Goldwind's selection for the 2003 Guangdong project—and the fact that it was selected over several foreign turbine manufacturers—was a key turning point in the company's market credibility and has resulted in increased publicity for the company.

Goldwind has taken several strategic investors to raise capital, including a number of venture capital firms. In addition, Goldwind announced in April 2006 that it planned an initial public offering, with reports speculating that after the Suzlon IPO performed very well, as did the IPO of China's leading solar equipment manufacturer Suntech Power in December 2005, that Goldwind hoped to follow suit (LeeMaster, 2006). However, despite reports over the past year that Goldwind would be doing a US-based IPO, or a Hong Kong based IPO, it reportedly has decided against a US IPO and plans instead to just list in China (Leung, 2006; Hua, 2007).

Goldwind is likely to continue to lead the Chinese market in coming years. It currently has orders worth 9 billion CNY and recently signed a long term strategic agreement with LM Glasfiber's China division to supply blades for its 1.5 MW turbines over 6 years, as well as to develop blades for its next generation of turbines 2 MW and above for both onshore and offshore applications (WPM, March 2007). Although Goldwind is yet to export turbines outside of China it is reportedly considering export markets, though it likely will be able to rely on the expansive Chinese market for years to come. The company has a goal of moving up to the 8th largest global producer of wind turbines by 2010.

5. Wind Power Development in India, China and Spain Compared

5.1. Domestic Policy Context

India, China and Spain all have excellent wind resources, and strong, long-term government commitments to promote wind energy development. All three countries have been promoting wind energy for over a decade through a variety of policy mechanisms. Some of the early support mechanisms in China and India in particular led to market

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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 an early US turbine manufacturer, US Windpower. Since purchasing Enron in 2002, GE has filed similar patent infringement suits in Europe and Canada, and recently in China.

instability as developers were faced with regulatory uncertainty, particularly with respect to pricing structures for wind power. In the early years of wind development in both China and India, difficulties also resulted from a lack of good wind resource data, and a lack of information about technology performance stemming from little to no national certification and testing. However, policy reforms in both countries and national legislation to promote renewable energy generally has led to a series of regional renewable energy development targets in India, national targets in China, and additional financial support mechanisms for wind power in particular.

Spain is the only country of the three that has a feed-in tariff policy for wind power at the national level, although several key provinces in India have feed-in tariffs, and one province in China has experimented with a feed-in tariff despite a national trend to rely on concession-based projects and competitive bidding to set tariff prices. Despite indications from the Chinese government that it would implement such a policy nation wide, when the implementing regulations for the renewable energy law were released in early 2006, the pricing structure for wind power relied significantly on a competitive bidding model rather than a fixed-price, subsidy model (WPM, February 2006:25). Many studies have cited feed-in tariffs as the most effective policy mechanism for promoting a wind power development due to the stability and regulatory certainty it provides (Sijm et al., 2002, Lewis and Wiser, 2007).

Key differences in the policy support mechanisms used by Spain and China versus India surround both Spain and China's recent reliance on local content requirements to support their respective local wind turbine manufacturing industries. Within China, although such policies encourage foreign-owned companies to shift their manufacturing to China, the primary beneficiary of this policy to date has been Goldwind—the only turbine manufacturer that could meet the local content requirements before the other companies could. Although all countries have manipulated customs duties and related taxes in order to promote the use of domestically manufactured wind turbines or components, India has generally been much more hands-off than Spain and China in promoting local wind turbine manufacturing, having yet to mandate the use of local content in domestically-installed wind turbines. India's local manufacturing industry seems to have emerged naturally as companies shifted their facilities to India to meet the local market demand. China has not experienced the same magnitude of annual capacity additions as India, and is still several thousand megawatts behind India in terms of total installed capacity. It is likely that once the Chinese market takes off and turbine suppliers see the same annual demand that they experienced in India, local manufacturing will continue to shift into China.

The Spanish experience appears to demonstrate the results of an effective combination of direct and indirect wind manufacturing incentives, in the form of both local content requirements and stable feed-in tariffs, which has attracted the interest of leading global turbine manufacturers. 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 contributed to 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.

5.2. Technology Development

An examination of Suzlon, Goldwind and Gamesa's technology development strategies again illustrates some similarities, as well as distinct differences. There are a suite of options available to a company looking to enter the wind industry, including technology imports from abroad, majority or minority ownership of local joint ventures, licensing arrangements, acquiring local companies, or building up a network of local components suppliers. The choice of a technology strategy will depend on the unique domestic policy requirements within each country, particularly localization requirements. Each of the three companies examined in this paper opted to pursue licensing arrangements with established wind turbine technology companies. Only Gamesa established a joint venture with an established market leader, as opposed to "second-tier" turbine manufacturing companies, meaning companies that comprise less than 5 percent of the global market (and often much less).

India's licensing arrangements with Sudwind, Aerpac and Enron Wind provided it with the necessary base of technical knowledge needed to enter the wind turbine manufacturing business. Building on the knowledge gained through international technology transfers in the form of licenses, Suzlon also formed many overseas subsidiaries. It did this jointly with foreign-owned companies, either to manufacturer a specific component such as its gearbox company in Austria, or to undertake collaborative R&D such as its Netherlands-based blade design center, and its Germany-based gearbox research center. Suzlon also sited its international headquarters in Denmark—the origin of the utility-scale wind turbine industry.

Suzlon differs from Goldwind in that it has not primarily contained its technological learning and innovation networks to India, in the way that Goldwind has. Goldwind does report to send employees abroad for training, but has not established global innovation networks equivalent to Suzlon's, having no overseas offices or subsidiaries. Goldwind has conducted minimal R&D with its technology partner REpower in German wind turbine test facilities. In addition, Suzlon has gained significant technical know-how through its acquisitions of foreign companies, including leading gearbox manufacturer, Hansen.

While looking overseas for technical know-how in wind turbine manufacturing, Suzlon did not neglect to build up its Indian manufacturing base. Although it conducts R&D abroad, it relies primarily on domestically-made components, most of which it makes itself based on experience gained through its overseas research efforts. As the largest Indian-owned wind turbine manufacturer in India, Suzlon has access to local networks that foreign companies lack. It has been able to build its Indian supply chain through a network of subsidiaries, allowing it to maintain control of the intellectual property associated with its turbine designs.

Goldwind is also looking to build up a domestic supply chain based in China; however, it is already competing with international firms with substantial China-based supply chains—such as GE Energy's expansive network of suppliers for its hydro and gas turbine businesses. Although Suzlon also faces competition from foreign wind companies manufacturing turbines in India, such as Vestas and Enercon, it has been able to maintain its role as the sales leader in the Indian market. Gamesa has an extensive R&D program that has allowed it to innovate and build up on the design it originally acquired from Vestas.

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

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 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 transferred 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.

It is worth noting that the technology obtained from these smaller technology suppliers may not necessarily be inferior to that provided by the larger manufacturing companies, however certainly their operation experience is substantially less.

5.3. Global Expansion and Technology Status

Although Suzlon and Goldwind were established approximately a year apart, Suzlon is far ahead in terms of its international expansion, having exported its turbines abroad to the US and various other countries. Spain, although behind Germany and the US in terms of average turbine size and wind manufacturing experience, is well ahead of India and China, due in part to Gamesa's ability to partner early on with Vestas and obtain a license for advanced wind turbine technology. Although Gamesa was initially restricted to the Spanish market, it was subsequently permitted to expand.

Despite ambitious plans to continue to expand globally, Suzlon still manufactures most of its wind turbines in India, and India comprises the majority of its annual turbine sales. Goldwind has yet to export its wind turbines made in China to other countries. Although it has indicated an interest in exploring overseas opportunities, at its current size it appears that the Chinese domestic market is sufficient to fulfill its capacity for annual turbine orders.

Currently Indian and Chinese wind turbine manufacturers are producing turbines that are smaller on average than those produced by their foreign competitors. Figure 9 illustrates both the size trends in annual turbine installations over the past 5 years, and the relationship between turbine size and technical experience in the wind turbine manufacturing business.

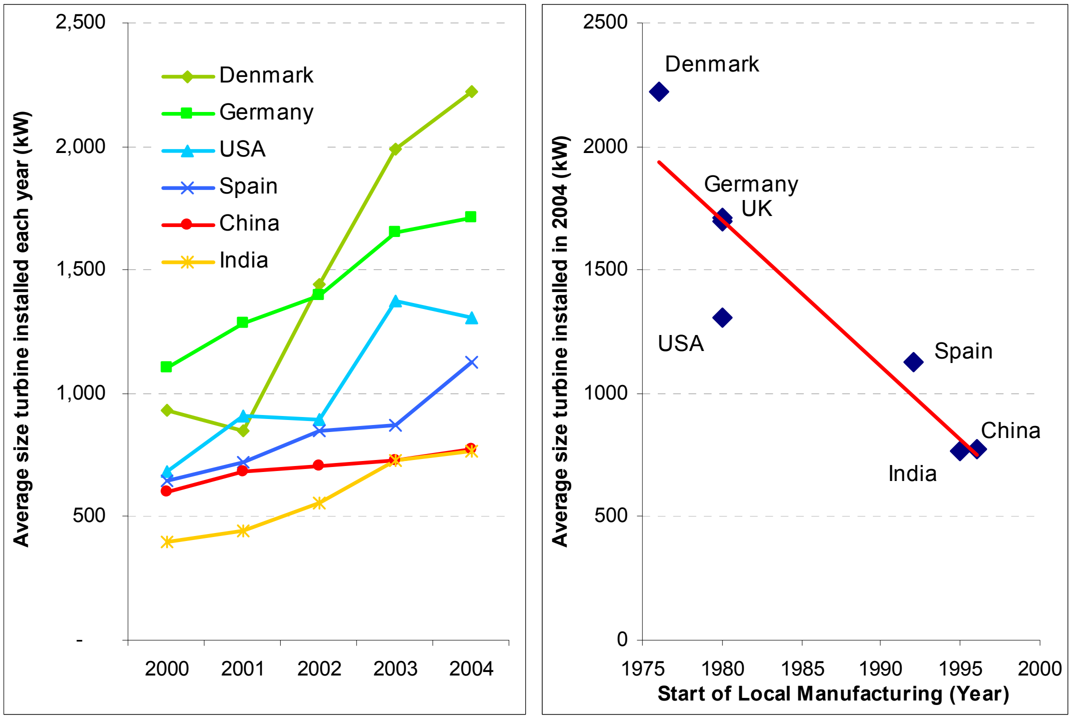
The first graph illustrates the trend towards increasing turbine size around the world. Larger turbines are not only more efficient, but installing fewer turbines to achieve the same power capacity can save money in installation costs.[8] The graphs illustrating average size of turbines installed includes imported turbines, locally made turbines by foreign companies, and locally made turbines by local companies. This somewhat confounds the relationship between the manufacturing experience of the country and the size of turbines being installed there, but a trend is still evident. Denmark was the leading country in wind turbine manufacturing and for many years led the world in terms of total installed wind power capacity, and is today only installing the most advanced, largest turbines. Germany, the UK and the US entered the industry soon after Denmark, and are also installing primarily advanced, megawatt-sized turbines. Spain entered the industry a few years later, and has just recently passed the megawatt mark in its average turbine installation size.

India and China began manufacturing wind turbines just a year apart. The difference in average turbine size illustrated in the first graph is due to the early success of Suzlon and to India's greater reliance on domestically-manufactured turbines at an earlier stage, while China relied primarily on imported turbines in the early years of its wind development, and therefore installed larger turbines on average. Recently, as the share of Chinese-made

[8] However, economies of scale with manufacturing a larger quantity of the same turbine type could potentially outweigh cost disadvantages due to turbine size.

turbines has increased, the average turbine size in China and India has become roughly equivalent; the average turbine size was 771 kW in China and 767 kW in India in 2004. In 2006 the average turbine sizes in China and India were 931 kW and 926 kW respectively (BTM, 2007).

Figure 9. Manufacturing Experience and Average Turbine Size



Source: BTM, 2005-2007; Lewis, 2005.

There is clearly a smaller average turbine size in emerging markets due to the fact that similar models for technology development are being used around the world—as was illustrated in the discussion of Suzlon and Goldwind. Both companies began their own R&D by obtaining transfers of older technology, and have been supplementing the knowledge gained through licensing arrangements with their own research and development. When pursuing licensing arrangements with more advanced companies, the recipient company may be limited to the transfer of a somewhat outdated turbine model. Alternatively, even if state-of-the-art technology is obtained (e.g. a 600 kW turbine was quite advanced when it was obtained by Suzlon and Goldwind in the mid-1990s), it still may take the recipient company several years to be able to develop the technical capacity to locally manufacture the technology obtained in the license. The obvious exception to this rule was Gamesa obtaining Vestas' license, but as discussed, this is a model that is unlikely to be repeated.

Despite the fact that China and India are producing smaller turbines than its competitors, this does not mean the turbines being produced are necessarily inferior. Smaller turbine sizes are still highly useful in some markets, particularly where infrastructure to erect the turbines is limited, or topography is challenging.

If Indian and Chinese manufacturers are able to capture significant cost savings by manufacturing turbines locally, there would be excellent potential for both locations to serve as manufacturing bases for regional export. Both Suzlon and Goldwind believe that they are able to beat the prices being offered by their foreign competitors by locally sourcing their turbines. As foreign companies move towards local manufacturing of wind turbines, it is likely they will realize cost savings through use of local labor and materials. Currently, the overall scarcity of wind turbines worldwide has meant that this potential price differential may not be playing as important a role as it may in a more competitive market.

6. Conclusions

India, China and Spain have excellent wind resources, and the promise of years and years of wind turbine sales has kept overseas turbine manufacturers closely involved in all three markets. However, fundamental risks in the Indian and Chinese markets remain, making international manufacturers somewhat reluctant to invest. For example, the Indian power grid has such severe reliability problems that day and night voltages differ. In addition, India's relatively undeveloped national infrastructure meant that transport and installation of megawatt-scale wind power technology was impossible until recently (WPM, June 2004:38). Fundamental power sector problems face China as well. Despite constant discussions of a national, interconnected power grid, China still relies on often unconnected, regional grids that vary in quality and reliability throughout the country. China's booming economic development in its eastern coastal regions around Guangdong and Shanghai has resulted in blackouts, causing supply disruptions and boom and bust cycles in planning for power sector capacity additions in provinces that at times have been supportive to wind development. In addition, both countries have been undergoing power sector reforms of varying degrees, and the impact of such reforms on renewable energy is still somewhat uncertain. Spain, in comparison, has also been a somewhat threatening location for foreign turbine manufacturers to compete due to the advantages that the current policy structure gives to domestic manufacturers.

The institutional and other barriers present in large, developing countries such as China and India certainly challenge any simplistic notions of energy leapfrogging. However, as an examination of wind turbine development in these countries has shown, substantial technical advances are indeed possible in relatively short amounts of time. It took both China and India less than ten years to go from having companies with no wind turbine manufacturing experience other than the license they had obtained from an overseas company, to companies capable of manufacturing complete wind turbine systems with completely or almost completely locally made components. This was done within the constraints of national and international intellectual property law. Suzlon's growth model in particular highlights an increasingly popular model of innovation practices for transnational firms. Suzlon's expansive international innovation networks allow it to stay abreast of wind technology innovations around the world that it can then incorporate into its own designs through its extensive research and development facilities. It has developed this network of global innovation subsidiaries, while maintaining control of enough intellectual property rights to remain at the forefront of wind turbine manufacture and sales around the globe.

The experience of Gamesa in forming a joint venture with the leading wind turbine manufacturer, Vestas, illustrates a technology development strategy which is unlikely to be replicable by a Chinese or Indian wind turbine manufacturer, since few 10 top manufacturers would likely be willing to license their technology to emerging companies in these markets where local companies have a competitive edge due to lower costs. Most of the licensing agreements being reached in the wind industry today are comprised of the larger companies either acquiring licenses or purchasing outright the smaller wind technology companies.

The future of China's wind industry is still somewhat uncertain, but it is likely that Chinese-made turbines will enter the global marketplace in the coming years. Although Chinese firms have yet to export their turbines overseas, exports are likely to be forthcoming, particularly if Goldwind is able to successfully follow Suzlon's model. So far, it appears that it is following a quite similar model, at least in terms of technology development. While both companies pursued similar licensing arrangements to acquire basic technical knowledge, what is lacking from Goldwind's technology development model is Suzlon's network of strategically-positioned global subsidiaries contributing to its base of industry knowledge and technical capacity. Goldwind is also at risk of being prevented from exporting its turbines outside of China since it currently relies on its REpower license to produce the majority of its wind turbines (its models under 1 MW). Suzlon purchased REpower this year, and now has the ability to control Goldwind's export of its turbines. Goldwind is in negotiations to purchase Vensys, the company holding the licenses to its turbines over 1 MW, which would prevent similar restrictions being placed upon the turbines that are likely to comprise the majority of its future sales.

Also lacking from Goldwind's development strategy is a factor somewhat out of its control—a domestic policy environment that supports sizable and stable annual wind power capacity additions. A reliance on wind concessions has led to some uncertainty about pricing policies throughout the country, particularly as the idea of implementing a feed-in tariff structure has yet to be abandoned in policy circles.

This investigation of how the dominant, locally owned wind turbine companies of India, China, and Spain acquired their ability to manufacture wind turbines provides a look at how countries obtain the necessary technical capacity to make successful international transfers possible. Such insights are crucial to facilitating international technology transfers, which will be an important component of any technological leapfrogging strategy to achieve lower greenhouse gas emissions trajectories in the developing world.

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References

Brown, Carol-Ann. 2002. *Commercialising Wind Power in China: The Policy Challenge.* Ph.D. Dissertation, Department of Geography and the Environment and the Environmental Change Institute, University of Oxford.

BTM Consult ApS. 2004-2007. *International Wind Energy Development, World Market Update*, March.

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

Graber, Cynthia. 2005. "Wind Power in Spain." *MIT Technology Review.* Available at: http://www.technologyreview.com/microsites/spain/wind/docs/TR_Windpower_Spain.pdf

Hua, Judy. 2007. "China's Goldwind blows off U.S. IPO, stays at home." Jun 11, 2007. Available at: http://uk.reuters.com/article/oilRpt/idUKHKG15266620070611?pageNumber=3

IEA. 2004. International Energy Agency (IEA). *Renewable Energy: Market and Policy Trends in IEA countries.* Paris: IEA/OECD.

LeeMaster, Tim. 2006. "Wind turbine maker plans US$200m overseas listing." *The Standard*, online version (April 19).

Leung, Alison. "China's Goldwind wants US share float." June 20, 2006. Available at: http://www.boston.com/news/world/asia/articles/2006/06/20/china_wind_power_plant_maker_wants_us_ipo/

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

Lewis, Joanna I. and Ryan H. Wiser. 2007. "Fostering a Renewable Energy Technology Industry: An International Comparison of Wind Industry Policy Support Mechanisms." *Energy Policy* 35 (2007) 1844–1857.

Liu Wen-Qiang, Lin Gan, Xi-Liang Zhang. 2002. "Cost-Competitive Incentives for Wind Energy Development in China: Institutional Dynamics and Policy Changes." *Energy Policy* 30, 753–765.

Meyer, Sebastian. 2006. "China Wind Concession Projects Awarded: Update and Roundup." Azure International, September 15.

Ministry of Science and Technology (MOST), State Development Planning Commission (SDPC), State Economic and Trade Commission. 2002. *Evaluation of Policies Designed to Promote the Commercialization of Wind Power Technology in China.* Energy Foundation China Sustainable Energy Program. May 15. Available: http://www.efchina.org/documents/WindPowerTech-complete.pdf

NREL. 2004. Fact Sheet on Grid Connected Wind Energy in China. Available at: http://www.nrel.gov/docs/fy04osti/35789.pdf

Rajsekhar, B., Van Hulle, F., Jansen, J. 1999. "Indian Wind Energy Programme: Performance and Future Directions." *Energy Policy* 27, 669-678.

Red Herring. 2005. Prospectus: Suzlon Energy Limited. (September 12). Available http://www.sebi.gov.in/dp/suz.pdf

Shi, Pengfei. 2006. "2003-2005 China Wind Concession Project Information." China Wind Energy Association.

Sijm, J. 2002. "The Performance of Feed-in Tariffs to Promote Renewable Electricity in

European Countries." The Energy Centre of the Netherlands, ECN-C—02-083, (November).

Wind Concession Synthesis and Policy Research Discussion Group (*Fengdian Texu Quanzong he Zhengce Yanjiu Keti Zhu*). 2003. *Wind Concession Policy Framework and Utilization Methodology Research (Fengdian Texuquan Zhengce Kuangjia he Yunzuo Fangshi Yanjiu*). July.

Windpower Monthly (WPM). February 2000:18. "Spanish utility places largest order ever." Denmark: Windpower Monthly News Magazine A/S.

Windpower Monthly (WPM). February 2001:20. "Spanish turbines for utility project." Denmark: Windpower Monthly News Magazine A/S.

Windpower Monthly (WPM). March 2004:57. "New law drives return to market growth – India on fast forward." Denmark: Windpower Monthly News Magazine A/S.

Windpower Monthly (WPM). June 2004:38."Ready to think big in India." Denmark: Windpower Monthly News Magazine A/S.

Windpower Monthly (WPM). October 2004:6. Michael McGovern. "Spain gets it together." Denmark: Windpower Monthly News Magazine A/S.

Windpower Monthly (WPM). October 2004:25. "Denmark picked for global headquarters." Torgny Moller and Gail Rajgor. Denmark: Windpower Monthly News Magazine A/S.

Windpower Monthly (WPM). February 2006:25. "China changes tack and goes for tender system -- premium fixed tariff definitively dropped by government." Denmark: Windpower Monthly News Magazine A/S.

Windpower Monthly (WPM). March 2006:44 "New national policy and grid investment – India close to 2012 wind target." Denmark: Windpower Monthly News Magazine A/S.

Windpower Monthly (WPM). "Looking set to pass 7500 MW." March 2007:42. Denmark: Windpower Monthly News Magazine A/S.

Windpower Monthly (WPM). March 2007:37. "China milestone reached." Denmark: Windpower Monthly News Magazine A/S

Windpower Monthly (WPM). March 2007. "2007 Wind Market Global Status." Denmark: Windpower Monthly News Magazine A/S.

Wiser, Ryan and Mark Bolinger. 2007. "Annual Report on US Wind Power Installation, Cost and Performance Trends: 2006." US Department of Energy.

Yu, W. M. and Wu, G. 2004. "The Development of China's Wind Turbine Manufacturing Industry and the Strategy of Goldwind Co." Proceedings of the World Wind Energy Congress, Beijing, China (October 31-November 4).