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GRID-CONNECTED RENEWABLE ENERGY:

WIND POWER TECHNOLOGIES

Slide 1

Grid-Connected Renewable Energy: Wind Power Technologies

Wind Power

- **The Resource**
- Wind Technology
- Global Status and Costs
- Wind Technology Manufacturing
- Policies Promoting Wind Development
- Project Development Issues
- Benefits of Wind Power
- Challenges to Wind Power Development
- Best Practices

Slide 2

Presentation Contents / The Resource

This module provides information on grid-connected wind power generation and consists of the following sections:

Section One – discusses the availability of wind and how it may be used

Section Two – examines wind technology issues

Section Three – examines the global status of wind power generation and investment costs

Section Four – looks at trends in the manufacturing of wind turbines and strategies to build local manufacturing industries

Section Five – explores the impact of various policies on wind power development

Section Six – discusses business models and project development sequencing

Section Seven – looks at the energy, environmental, and job creation benefits of wind power development

Section Eight – addresses key challenges confronting wind power developers, including resource variability, grid integration, and transmission costs

Section Nine – Provides best practices for enabling the development of wind power

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OVERVIEW

Wind technology is:

- Commercially viable and cost-competitive in many locations
- The fastest growing renewable power source in the world
- Emissions-free
- Not susceptible to fuel price volatility
- Suitable for community-based development
- Being deployed successfully by developing countries, some of whom are also leaders in wind turbine manufacturing

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Overview

This presentation offers a discussion of the current status of large, grid-connected wind energy, its benefits, constraints to development, as well as strategies for mitigating negative impacts and overcoming barriers to investment.

Why Wind?

Wind technology is now commercially viable and cost-competitive in many locations. Wind power accounted for 42% of new capacity additions in the United States (second only to natural gas for the fourth year running) and for 36% of new installations in Europe in 2008. Around the world, 80 countries are using wind power on a commercial basis. It is the fastest growing renewable power source in the world. There is extensive global experience with using policies to promote wind energy, and many different types of policies have proven successful in different national contexts.

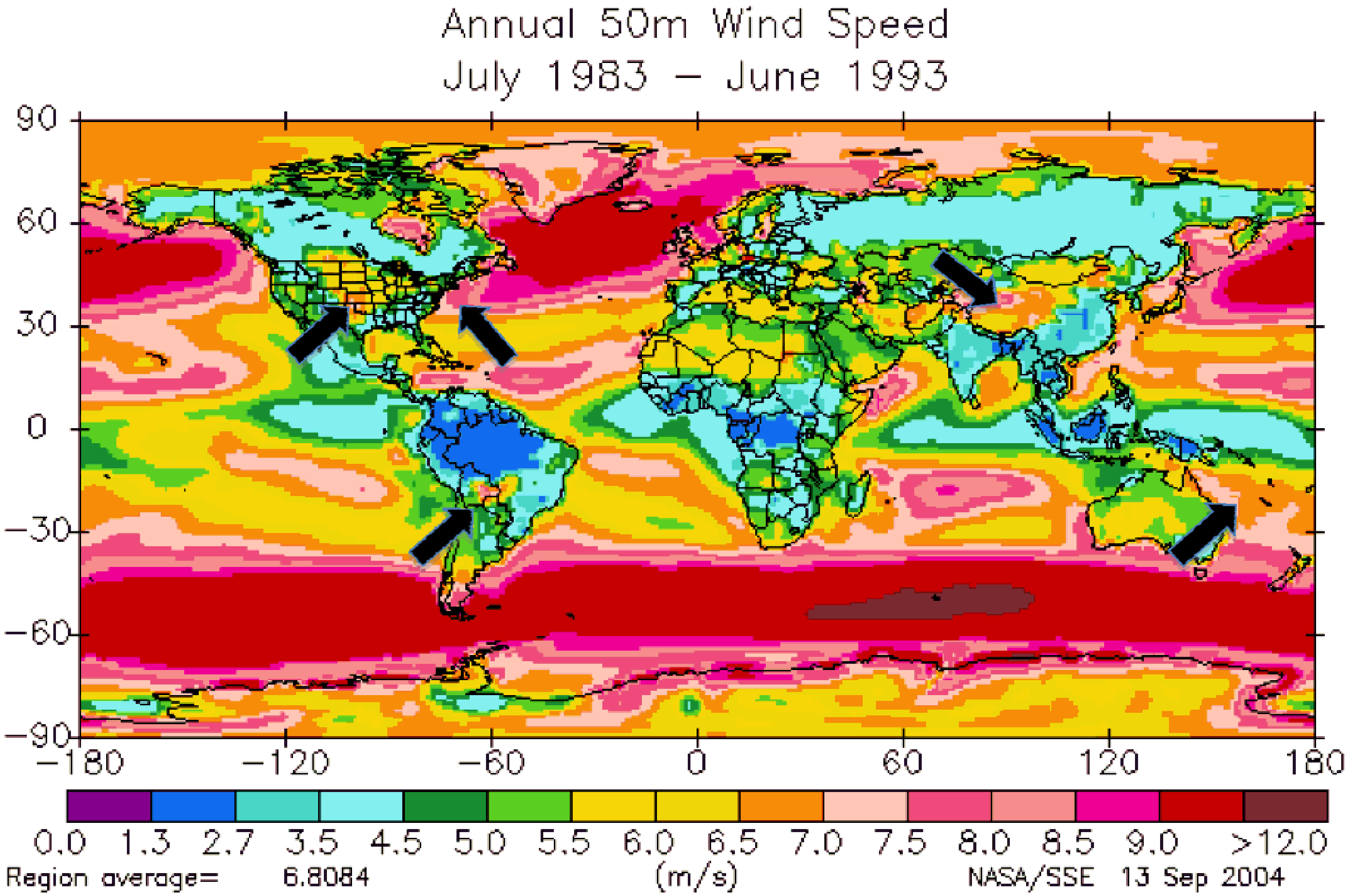
Wind offers many benefits over traditional forms of energy, including being emissions-free, and not susceptible to fuel price volatility. Along with traditional financing methods, community-based wind development holds promise for many developing countries. Many developing countries are now leading the way in wind development globally.

References

- Worldwatch Institute – Wind Power Increase in 2008 Exceeds 10-year Average Growth Rate

Photo credit: Joanna Lewis, 2004.

GLOBAL WIND RESOURCES



Arrows highlight coastal and mid-continental plains regions with high average wind speeds

Source: http://www.ocean.udel.edu/WindPower/ResourceMap/SSE_Methodology.pdf

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Global Wind Resources

This map is an illustration of year-round, average winds around the world, as derived from 10 years of GEOS-1 satellite data. Satellite data are the only global-scale wind data available, but are less accurate than wind speed data measured on land since they are indirect. Looking at the map, a rough guideline is that wind speeds of 7 meters/second (m/s) and faster are economically worth exploiting today even in higher-cost offshore locations (orange, pink, red and brown). In many areas, especially on land, the 6 m/s areas are already economically viable (yellow). The largest wind resources are above the oceans and mid-continental plains of each of the major continents. The coastal ocean locations are of special interest, because they have strong winds and they are close to most of the world's population and electric use. To get a better idea of whether coastal resources are exploitable for wind power, ocean depth also needs to be taken into consideration, since this will substantially affect the cost of a potential project.

It should be noted that there are many small areas with good wind resources that cannot be seen on these global-scale maps, but would show up with a higher resolution picture. It is therefore important to obtain locally specific wind resources prior to assessing wind potential. Often the local meteorological agency within a country has access to national-level wind resource data. Site-specific measurements should be taken, however, prior to the design of a wind farm, and may be necessary to obtain project financing.

References

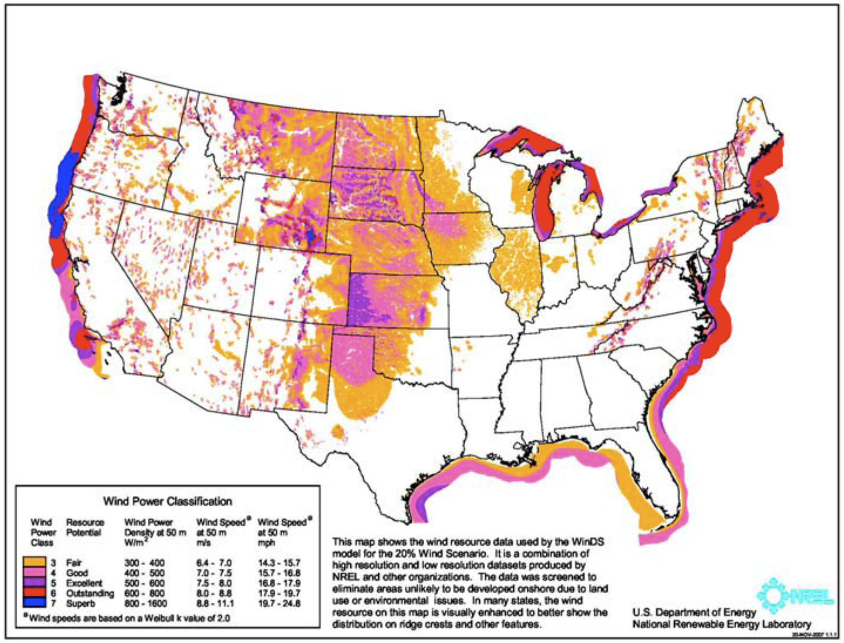
Full documentation on how these wind speeds are calculated can be found in:

- 204. NASA – Surface Meteorology and Solar Energy: Methodology
- 287. Univ. of Delaware – Mapping the Global Wind Power Resource

ASSESSING RESOURCE VIABILITY

Resources must be considered along with:

- Access to land transportation
- Construction infrastructure
- Accessibility of terrain (or water depth if offshore)
- Competing uses



Wind Power Classification

	Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m²	Wind Speed* at 50 m m/s	Wind Speed* at 50 m mph
🟧	3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
🟪	4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
🟪	5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
🟥	6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
🟦	7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

*Wind speeds are based on a Weibull k value of 2.0

This map shows the wind resource data used by the WinDS model for the 20% Wind Scenario. It is a combination of high resolution and low resolution datasets produced by NREL and other organizations. The data was screened to eliminate areas unlikely to be developed onshore due to land use or environmental issues. In many states, the wind resource on this map is visually enhanced to better show the distribution on ridge crests and other features.

U.S. Department of Energy
National Renewable Energy Laboratory

US Onshore and Offshore Wind Resource Potential at 50m

Source: DOE, 2008, Figure 2-1.

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Assessing Whether a Site is Viable for Wind Power

Initial wind resource measurements can help to identify areas to target for wind resource development. For example, this map shows US wind resource potential at 50 m both on land and offshore. It clearly illustrates that the best wind resource potential in the United States is in the Midwestern plains, and the eastern and southern coastlines. However, several other factors must also be considered to assess the viability of these locations for wind power development.

Onshore Viability Considerations

Land transportation constraints can be a limiting factor for installing wind turbines on land. Prospective wind development sites need access to cost-effective road transportation that can provide large trailers carrying very heavy loads (a cargo weight of about 42,000 lbs) access to wind farm sites. Large loads may require utility and law enforcement assistance along the roadways. Road dimension limits have the most impact on the base diameter of wind turbine towers. Rail transportation is even more dimensionally limited by tunnel and overpass widths and heights. Overall widths should remain within 3.4 m, and heights are limited to 4.0 m. Transportation weights are less of an issue in rail transportation, with gross vehicle weight limits of up to 360,000 lbs.

Construction infrastructure must be able to support wind farm construction once turbines arrive at the construction site. Constraints to the physical installation pose other practical limits on turbine size. For example, a 1.5 MW turbine typically is installed on an 80 meter tower, requiring a very large crane. Crane requirements are quite stringent because of the large size of the turbine nacelle, the mass and the height, and required extension of the boom. As the height of the lift to install the rotor and nacelle on the tower increases, the number of available cranes with the capability to make this lift is fairly limited. This is a particular problem in developing countries where large cranes may not be available. In addition, cranes with large lifting capacities may be difficult to transport and require large crews.

Accessibility of terrain is an important factor when assessing a potential site. Operating large cranes in rough or complex, hilly terrain may require repeated disassembly to travel between turbine sites, which can be time consuming and labor intensive.

Offshore Viability Considerations

Additional considerations that must be taken into account when assessing the viability of offshore wind development include water depth, and competing uses such as tourism, shipping, or marine conservation. For example, in the United States, there are several offshore areas in New England and Long Island that are attractive based on current wind technology and economics, as they have wind speeds over 7.5 m/s and water depths under 21 m. However, competing uses may constrain the extent of their ultimate development.

References

- US wind resource map on p. 24, figure 2-1
- 205. DOE – 20% Wind Energy by 2030

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Wind Technology

WIND TECHNOLOGY: TURBINES

- **Small (0-10 kW)**
  - Homes (grid-connected)
  - Farms
  - Remote applications (battery charging, water pumping, telecom sites)
- **Intermediate (10-500 kW)**
  - Village power
  - Hybrid systems
  - Distributed power
- **Large (500 kW – 6 MW)**
  - Central station wind farms
  - Distributed power
  - Offshore wind generation stations
  - 5-6 MW prototypes in development

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Wind Technology: Turbine Sizes and Applications

Wind power technology comes in a wide range of sizes suitable for a broad range of applications.

Small wind turbines are turbines up to 10 kW in size. They are used to power individual homes, and are typically grid-connected, though in some cases are connected to a battery system or a hybrid system (for example, with solar photovoltaics). They are often used on small farms as well. Another use is for small, off-grid applications such as battery charging stations, water pumping, or telecom sites.

Intermediate-sized turbines are typically 10 kW-500 kW in size. They are used to power small villages, often in conjunction with hybrid systems relying on solar or diesel generators in remote areas. They can also be used to provide distributed power that is connected to the grid.

Large wind turbines range from 500 kW – 6 MW (currently, 5-6 MW prototypes are in development). These turbines typically are used in commercial, utility-scale wind farm applications for centralized power, but can also be used for distributed power in smaller quantities. Large wind turbines are also being used in offshore wind farms. Offshore sites tend to utilize the largest turbines, due to the costs associated with installation per turbine.

Photo credits: Karl Rabago

References

- 235. Rabago – Big Power

WIND TURBINE EVOLUTION

Source: DOE

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Wind Technology: Evolution of Commercial Large-Scale Wind Turbines

1970s

Until the early 1970s, wind energy filled a small market niche, supplying mechanical power for grinding grain and pumping water, as well as electricity for rural battery charging. The windmills of 1950 differed very little from the primitive devices from which they were derived. Increased RD&D in the latter half of the 20th century, however, greatly improved the technology.

1980s

According to the US Department of Energy, the first wind farm was built in December 1980 by U.S. Windpower on Crotched Mountain in southern New Hampshire. It consisted of 20 wind turbines rated at 30 kilowatts each. However, the project was a failure due to an overestimated wind resource, and mechanical problems with the turbines. U.S. Windpower, which later changed its name to Kenetech, subsequently developed wind farms in California, improved its designs, and for a brief period of time became the world's largest turbine manufacturer and wind farm developer.

The wind turbines of the 1980s were generally structurally stiff, 3-bladed, upwind yaw-driven machines. They operated at either constant speed or 2 speeds, had fiberglass blades, geared transmission, an induction generator, and a steel truss or tube tower.

In the 1980s, the practical approach of using low-cost parts from agricultural and boat-building industries to produce the first wind turbines resulted in machinery that usually worked, but was heavy, high-maintenance, and grid-unfriendly. Little was known about structural loads caused by turbulence, which led to the frequent and early failure of critical parts, such as yaw drives. Additionally, the small-diameter machines were deployed in the California wind corridors, mostly in densely packed arrays that were not aesthetically pleasing in such a rural setting. These densely packed arrays also often blocked the wind from neighboring turbines, producing a great deal of turbulence for the downwind machines. As a result, reliability and availability suffered.

1990s

Wind turbines of the 1990s had some of the same characteristics of the earlier machines, with some technical improvement. They were still generally structurally stiff, but now operated at both variable speed and constant speed, used special airfoils, were stall regulated and pitch controlled, used planetary transmission and an induction generator, and their larger size reduced the cost of energy.

Recognizing the problems associated with the turbine technology of the 1980s, wind operators and manufacturers have worked to develop better machines with each new generation of designs. Drag-based devices and simple lift-based designs gave way to experimentally designed and tested rotor blades, many with full-span pitch control. Blades that had once been made of sail or sheet metal progressed through wood to advanced fiberglass composites. The direct current (DC) alternator gave way to the grid-synchronized induction generator, which has now been replaced by variable-speed designs employing high-speed solid-state switches and advanced power electronics. Designs moved from mechanical cams and linkages that feathered or furled a machine to high-speed digital controls.

2000 and beyond

The wind turbines of the 21st century continue to be scaled to larger sizes, and utilize advanced blade materials and manufacturing, low speed direct-drive generators, high-efficiency and custom power electronics, and feedback control of drive train and rotor loads. The new models are structurally more flexible, and possess features to reduce operation and maintenance costs.

Many RD&D advances have contributed to changes in wind power technology. A 50 kW machine, considered large in 1980, is now dwarfed by the 1.5 MW to 2.5 MW machines being routinely installed today. Airfoils that are now tested in wind tunnels are designed for insensitivity to surface roughness and dirt. Increased understanding of aeroelastic loads and the ability to incorporate this knowledge into finite element models and structural dynamics codes make the machines of today stronger, more flexible, and lighter. Simpler design improvements that have been incorporated into today’s turbines include increasing the height of the towers to take advantage of higher wind speeds found at higher altitudes, and increasing the size of the turbines to minimize the costs of materials. While size increases have been the trend over the past few decades, land-based turbine size is not expected to grow as dramatically in the future as it has in the past. Larger sizes are physically possible; however, the logistical constraints of transporting the components via highways and of obtaining cranes large enough to lift the components present a major economic barrier that is difficult to overcome. Many turbine designers do not expect the rotors of land-based turbines to become much larger than about 100 m in diameter, with corresponding power outputs of about 3 MW to 5 MW. Turbine sizes in the 5-6 MW range are currently in the prototype phase. For offshore turbines, larger sizes are more economic due to the costs associated with installing each turbine and the challenge of accessing the turbines for maintenance.

References

- 205. DOE – 20% Wind Energy by 2030
- 288. DOE – Historic Wind Development in New England: The Age of PURPA Spawns the “Wind Farm”
- 302. TelosNet – Illustrated History of Wind Power Development

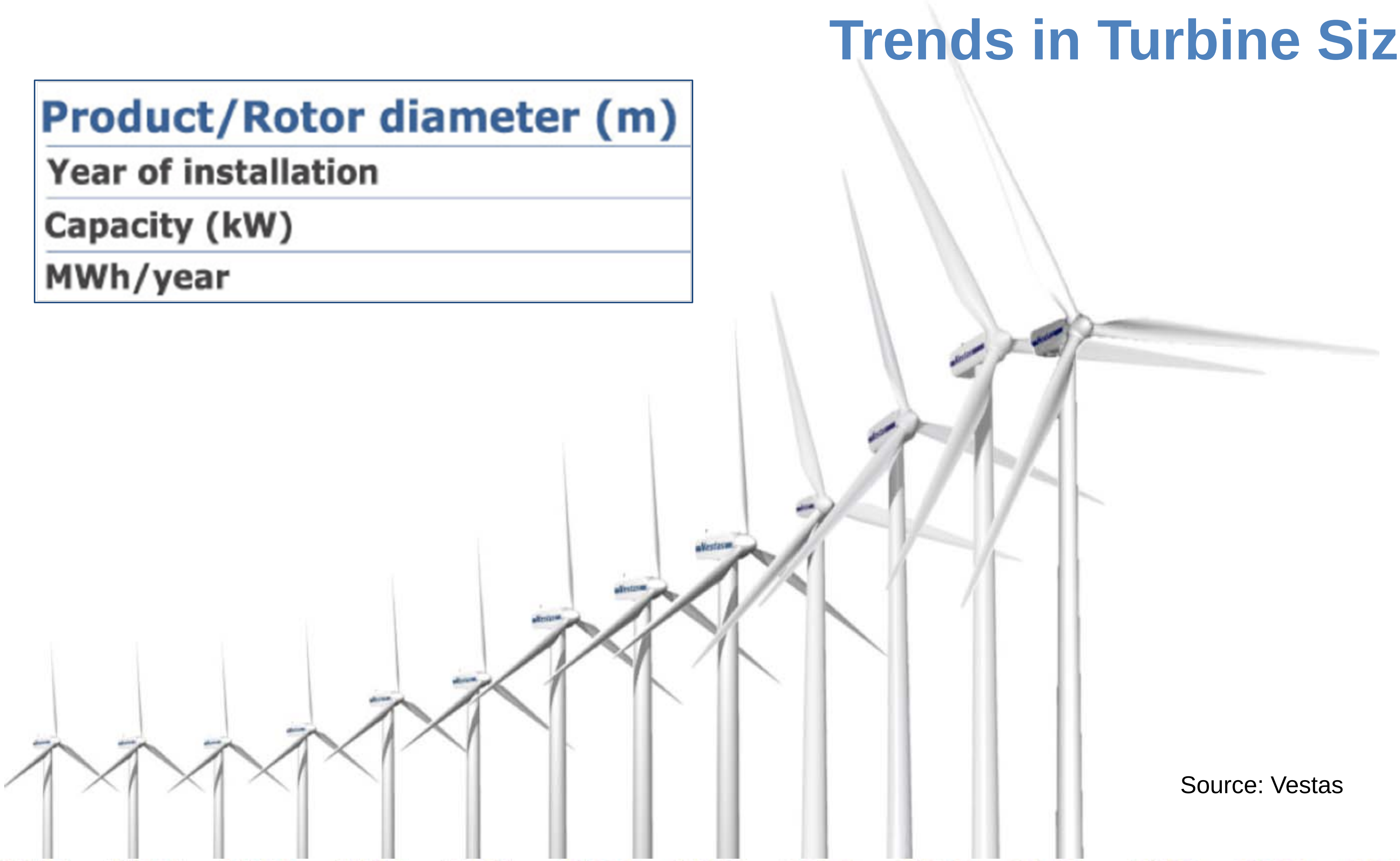
Trends in Turbine Size

Product/Rotor diameter (m)

Year of installation

Capacity (kW)

MWh/year



Source: Vestas

V15	V17	V19	V20	V25	V27	V39	V44	V47	V52	V66	V80	V90
1981	1984	1986	1987	1988	1989	1991	1995	1997	2000	1999	2000	2002
55	75	90	100	200	225	500	600	660	850	1750	2000	3000
217	265	301	346	481	647	1304	1581	1947	2530	4705	6768	9152

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Manufacturer Trends: Vestas

Danish company Vestas is currently the leading manufacturer of wind turbines in terms of sales volume, and was one of the first companies to develop commercial-scale wind turbines back in 1981. Since that time, their turbines have been installed all over the world, and their technology has evolved from a 55 kW machine with 15 m rotor blades, to a 3 MW machine with 90 m rotor blades. The rotor diameter is now 6 times bigger and the capacity is more than 50 times higher. The enhanced capacity comes mainly from the much bigger rotor area, but also reflects improved technology.

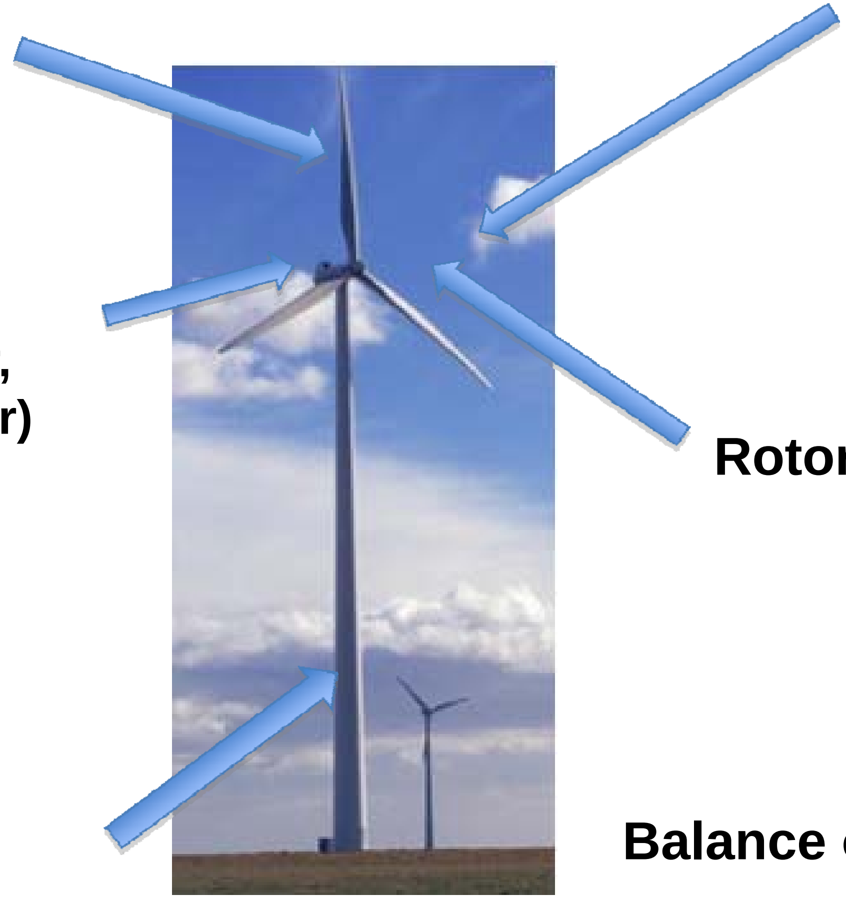
This chart illustrates turbine size in terms of rated capacity in kilowatts, along with annual power production in megawatt hours per year. Annual power production is estimated assuming the following parameters: a wind speed measurement at 40 m in height, an average wind speed of 7 m/s, c = 2.0, air-mass density = 1.225 kg/m^3, wind shear 0.15.

The tower heights on the turbine models illustrated in the slide are as follows:

- V44: 40 m
- V47: 45 m
- V52: 50 m
- V66: 67 m
- V80: 78 m
- V90: 80 m

Diagram from Vestas, 2003.

WIND TECHNOLOGY: COMPONENTS



Blades

Controls

The Drivetrain
(Gearbox, Generator,
and Power Converter)

Rotor

The Tower

Balance of Station

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Wind Technology: Status of Components

Blades

As wind turbines grow in size, so do their blades – from about 8 m long in 1980 to more than 40 m for many land-based commercial systems and more than 60 m for offshore applications today. New blade designs are more aerodynamic, use lighter materials, and reduce sensitivity to environmental factors. There is still much room for improvement, particularly in the area of dynamic load control and cost reduction.

The Drivetrain (Gearbox, Generator, and Power Converter)

Generating electricity from the wind places an unusual set of requirements on electrical systems. Wind systems can afford inefficiencies at high power, but they require maximum efficiency at low power – just the opposite of almost all other electrical applications in existence. The long-term reliability of the current generation of megawatt-scale drivetrains has not yet been fully verified with long-term, real-world operating experience. There is a broad consensus that wind turbine drivetrain technology will evolve significantly in the next several years to reduce weight and cost and improve reliability.

The Tower

The tower configuration used almost exclusively in turbines today is a steel monopole on a concrete foundation that is custom designed for the local site conditions. Generally, a turbine will be placed on a 60-80 m tower, but 100 m towers are being used more frequently. Efforts to develop advanced tower configurations that are less costly and more easily transported and installed are ongoing.

Controls

Today’s controllers integrate signals from dozens of sensors to control rotor speed, blade pitch angle, generator torque, and power conversion voltage and phase. In variable-speed models, the control system regulates the rotor speed to obtain peak efficiency in fluctuating winds by continuously updating the rotor speed and generator loading to maximize power and reduce drivetrain transient torque loads. Research into the use of advanced control methods to reduce turbulence-induced loads and increase energy capture is an active area of work.

Rotor

The job of the rotor is to operate at the absolute highest efficiency possible between cut-in and rated wind speeds, to hold the power transmitted to the drivetrain at the rated power when wind speeds exceed it, and to stop the machine in extreme winds. Modern utility-scale wind turbines generally extract about 50% of the energy in the air stream below the rated wind speed, compared to the maximum energy that a device can theoretically extract of 59% (“The Betz Limit”).

Balance of Station

The balance of the wind farm station consists of turbine foundations, the electrical collection system, power-conditioning equipment, supervisory control and data acquisition (SCADA) systems, access and service roads, maintenance buildings, service equipment, and engineering permits. Balance-of-station components contribute about 20% to the installed cost of a wind plant.

References

- 205. DOE – 20% Wind Energy by 2030

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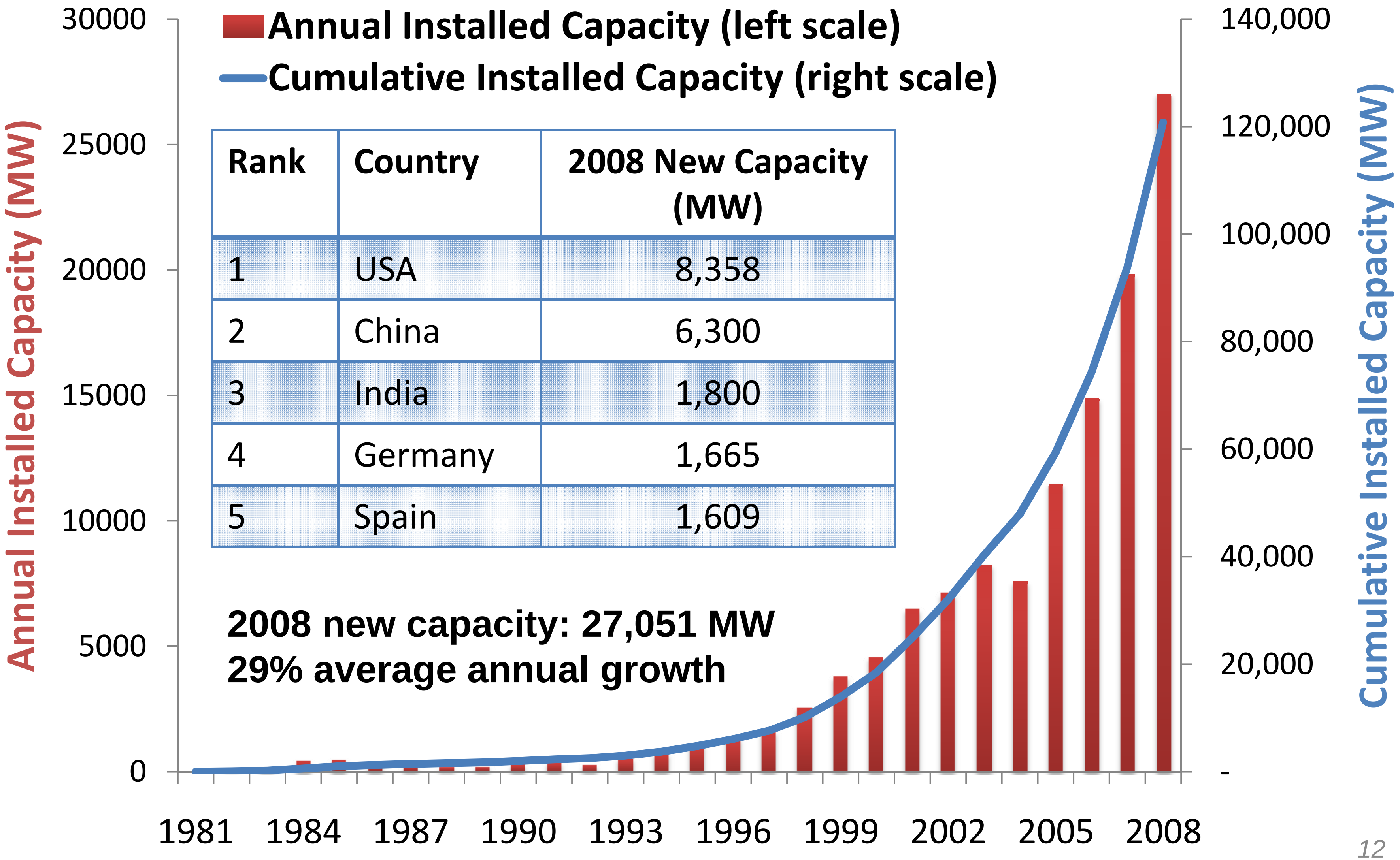
Global Status and Costs

GLOBAL EXPERIENCE: INSTALLED CAPACITY



Rank	Country	2008 New Capacity (MW)
1	USA	8,358
2	China	6,300
3	India	1,800
4	Germany	1,665
5	Spain	1,609

2008 new capacity: 27,051 MW
29% average annual growth

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Global Experience: Installed Capacity

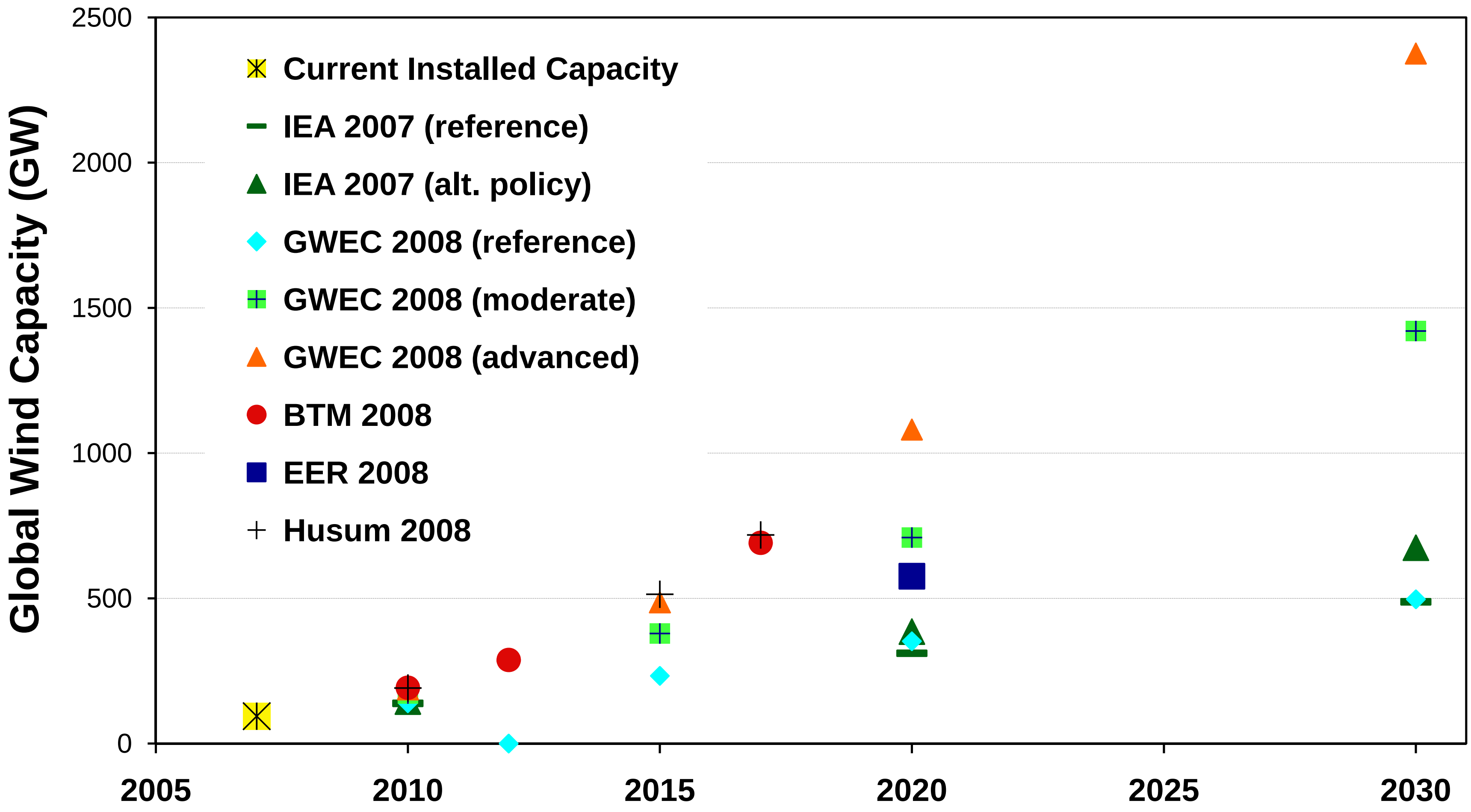
At the end of 2008, total global installed wind power capacity totaled 120.798 GW. The top five countries in terms of new installations in 2008 were the United States with 8,358 MW, followed by China with 6,300 MW, India with 1,800 MW, Germany with 1,665 MW, and Spain with 1,609 MW. While the top five countries were the same in 2007, China has moved up from the number 3 spot to the number 2 spot, and Spain has dropped from number 3 to number 5. India has also moved up from the number 4 spot to number 3. Projections show the United States and China continuing to dominate future wind power growth in coming years. While Denmark no longer makes the top five, it still gets the largest share of its electricity from wind power of any country – about 20% – even though almost no new *onshore* wind farms are being built there.

Offshore wind capacity accounts for almost 1,170 megawatts worldwide, roughly 1.2% of the 94,100 megawatts of installed capacity at the end of 2007. While this is a small share of the total, it is up from less than 0.3% in 2000. Denmark is the leader in the development of offshore wind capacity with 426 megawatts of installed offshore wind power capacity, followed by the United Kingdom, Sweden, the Netherlands, and Finland. In 2008, the United Kingdom is expected to overtake Denmark for the top spot and Germany is poised to move into the top five. With more than 1,200 megawatts presently under construction worldwide, primarily in Europe, offshore wind capacity is expected to more than double by the end of 2009.

References

- 206. Global Wind Energy Council – Global Wind Energy Outlook 2008
- 289. Earth Policy Institute – Global Wind Power Capacity Reaches 100,000 Megawatts

GLOBAL PROJECTIONS



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Global Experience: Projections for Future Growth

The range of projections for wind power utilization in the coming decades varies widely. Some of the most aggressive scenarios have been developed by the Global Wind Energy Council. Their “advanced” scenario forecasts 2,375 GW of wind in 2030 – that equates to 5,939 TWh of wind electricity. Other scenarios are more moderate. For example, the International Energy Agency’s (IEA) alternative policy scenario (the most aggressive scenario in the 2008 World Energy Outlook) forecasts 674.3 GW in 2030; this is just above their reference case forecast of 488 GW. Projections vary with assumptions about economic growth, as well as policy support – including the likelihood of carbon regulation driving wind power development.

References

- 211. Husum – WindEnergy Study 2008: Assessment of the Wind Energy Market Until 2017
- 212. GWEC – Global Wind 2007 Report
- 254. EER – Wind Turbine Industry Steps Up to Global Demand

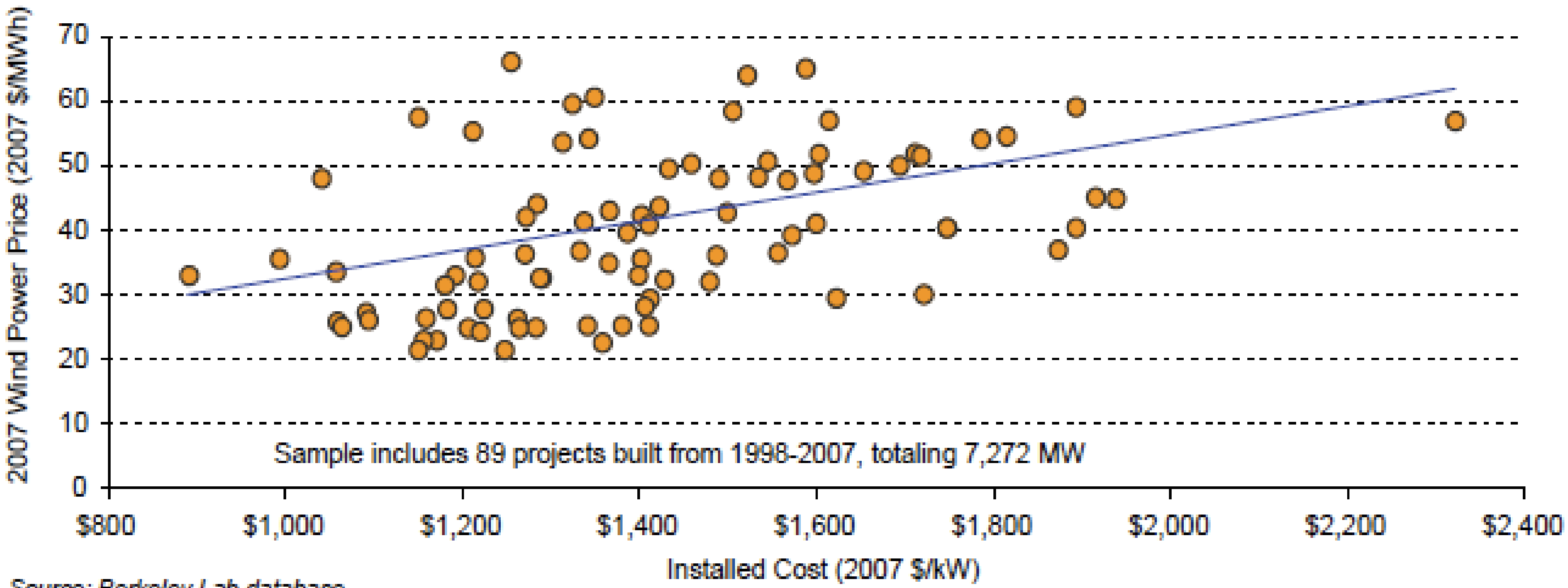
Further Reading

- BTM Consult. 2008. “International Wind Energy Development: World Market Update 2007.” Ringkobing, Denmark: BTM Consult.

GLOBAL EXPERIENCE: COSTS

- Installed capital cost: $1500-$2500/kW onshore; $2400-$5000/kW offshore
- Wind power price: $0.03 – 0.06/kWh

Wind Power Price as a Function of Installed Project Costs



Source: Berkeley Lab database.

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Global Experience: Costs

Several factors influence the cost per kilowatt hour of wind electricity, including capacity factor, cost of turbine technology, and policy incentives.

Installed Capital Cost

Current installed capital cost of wind power is $2,000/kW installed (a range of $1.500-$2,500/kW). Offshore installed capital cost is $2,400-$5,000/kW. Because offshore wind energy tends to take advantage of extensive land-based experience and mature offshore oil and gas practices, offshore cost reductions are not expected to be as great as land-based reductions spanning the past two decades.

The Cost of Wind Electricity Today (Cost vs. Price)

The cost of wind-generated electricity has dropped dramatically since 1980, when the first utility-scale wind plants began operating in California. Since 2003, however, wind energy prices in many countries have increased. Price here reflects the wholesale power price that the purchaser of electricity would pay to the wind farm owner. In the US in 2006, the price paid for electricity generated in large wind farms was between 3.0 and 6.5 ¢/kilowatt-hour (kWh), with an average near 5 ¢/kWh (1¢/kWh = $10/megawatt-hour [MWh]). This price included the benefit of the federal production tax credit (PTC), state incentives, and revenue from the sale of any renewable energy credits.

Wind energy prices have increased since 2002 for the following reasons:

- Shortages of turbines and components, resulting from the dramatic recent growth of the wind industry in the United States and Europe
- The weakening US dollar relative to the euro (many major turbine components are imported from Europe, and there are relatively few wind turbine component manufacturers in the United States)
- A significant rise in material costs (such as steel and copper) and transportation fuels over the last three years
- The on-again, off-again cycle of the wind energy PTC in the United States (uncertainty hinders investment in new turbine production facilities and encourages hurried and expensive production, transportation, and installation of projects when the tax credit is available).

Increases in wind power costs in some cases could result in higher power prices being passed on to the consumer, depending upon the structure of the electricity sector in a given location. However, in the US, for example, even higher wind prices haven’t dampened wind power development given the increased risk of building fossil-fuel power plants in the face of impending carbon regulation.

Capacity Factors

In most countries, capacity factors for wind turbines have increased with operating experience. In the US, wind turbines that began operating commercially before 1998 have an average capacity factor of about 22%. The turbines that began commercial operation after 1998, in the same resource area, show an increasing capacity factor trend, reaching 36% in 2004 and 2005. However, capacity factors are also a function of the wind speed, so a wind turbine installed in a poorer resource area will have a lower capacity factor than will that same turbine installed in a superior wind resource area.

Learning Curves

Progressing along the design and manufacturing learning curve allows engineers to develop technology improvements and reduce capital costs. The more engineers and manufacturers learn by conducting effective RD&D and producing greater volumes of wind energy equipment, the more proficient and efficient the industry becomes. The learning curve is often measured by calculating the progress ratio, defined as the ratio of the cost after doubling cumulative production to the cost before doubling. Results show that progress ratio estimates were approximately the same for Denmark (91%), Germany (94%), and Spain (91%).

In addition, stable policy environments for renewable energy development could also lower costs. Increased RD&D efforts can also lower costs. The increased globalization of manufacturing is discussed on the following slide.

References

- 174. FERC – Standard Interconnection Agreements for Wind Generators
- 205. DOE – 20% Wind Energy by 2030
- 208. LBNL – Wiser, Ryan & Mark Bolinger, Annual Report on US Wind Power Installation, Cost and Performance Trends: 2007

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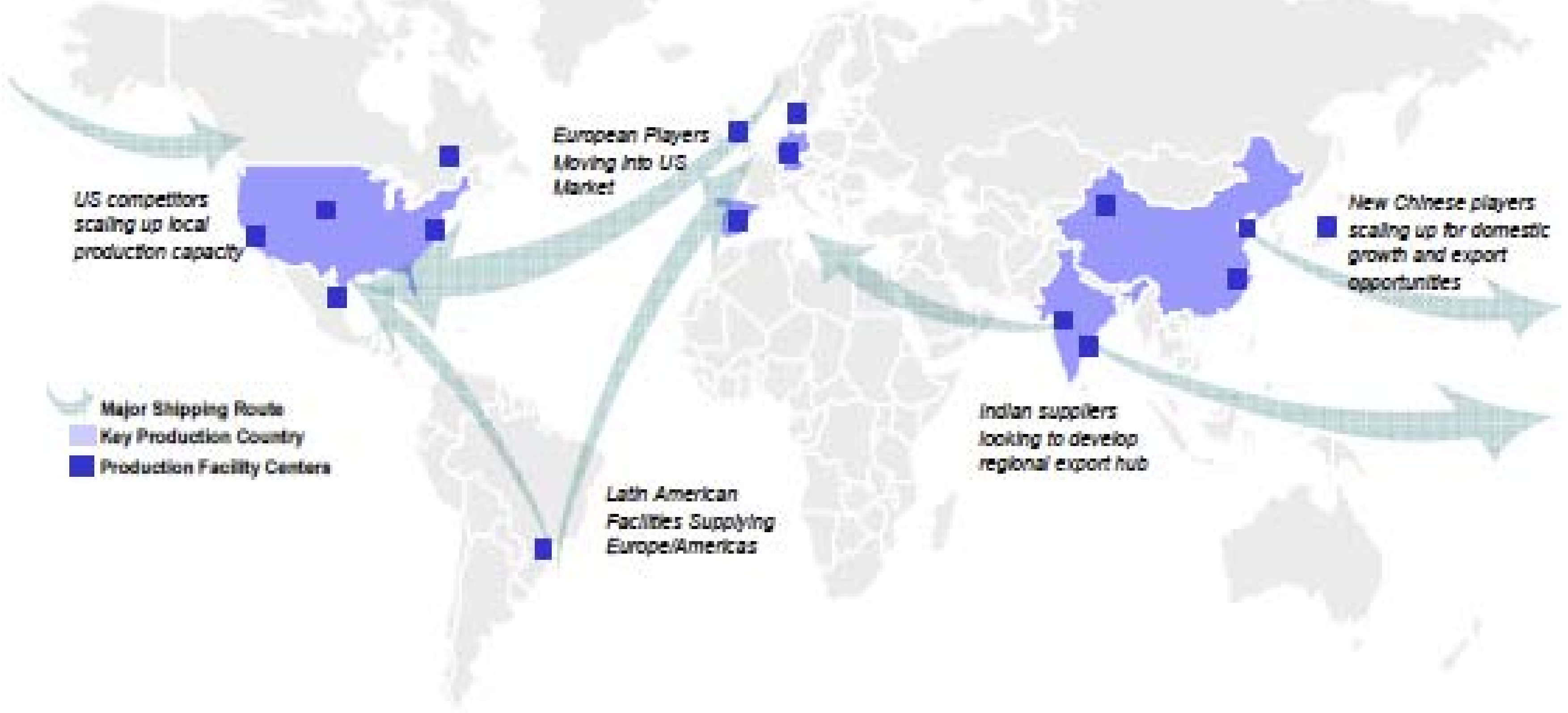
Wind Technology Manufacturing

GLOBALIZATION OF MANUFACTURING

The globalization of wind turbine manufacturing—and the emergence of China and India as manufacturing bases for the world—will drive cost reductions and could expand access to wind power technology throughout the developing world



Source: Emerging Energy Research

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Globalization of Manufacturing

Expected future reductions in wind energy costs would come partly from expected investment in the expansion of manufacturing volume in the wind industry. In particular, the entry of developing country turbine manufacturers in China and India will likely drive technology cost reductions due both to increased manufacturing scale, and to lower labor and material costs. Wind turbines being manufactured in China are reportedly already 30-60% less expensive than those being manufactured in Europe and the United States.

While China and India are becoming hubs of wind turbine manufacturing, Latin America is entering the global supply chain as well. European technology leaders are increasingly entering the US market. While very few Chinese wind turbines are currently being exported outside of China, this will likely change in the next 5 years. Indian manufacturer Suzlon already is manufacturing its turbines in the United States.

References

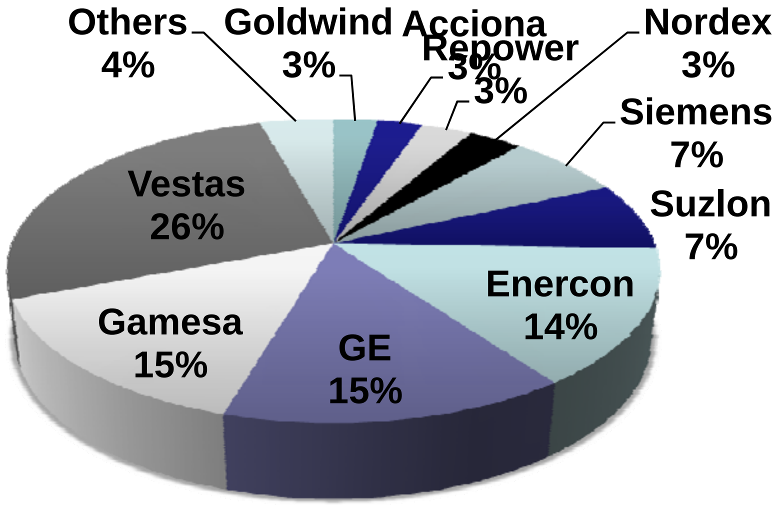
- 254. EER – Wind Turbine Industry Steps Up to Global Demand

TURBINE MANUFACTURING TRENDS

Leading turbine manufacturers typically come from countries with large domestic markets

Rank	Country	Manufacturers
1	USA	GE
2	Spain	Gamesa, Ecotecnia, EHN
3	China	Goldwind, Sinovel, DEC
4	India	Suzlon
5	Germany	Enercon, Repower, Nordex, Fuhrlander

2006 market shares by manufacturer



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Global Experience: Leading Wind Turbine Manufacturers

Many of the most successful wind turbine manufacturers globally come from countries with large domestic wind power markets. There are many reasons for this, but it is clear that companies are able to thrive when they have a stable, sizable wind power market that is supported by domestic policy incentives. While Denmark's manufacturers were pioneers in the beginning of the wind industry, back when Denmark was also a leading wind market, its manufacturers were able to thrive by scaling and testing their technology locally. Later, Germany's manufacturers were supported by the domestic feed-in tariff program (EEG) in the German market. Recently, strong policy environments in the United States, Spain, and China have led to the emergence of successful wind turbine manufacturers in those countries. While GE is a relatively recent entrant into the wind business, it benefited from purchasing several smaller firms that had much of the early US experience with wind technology development, including Enron Wind. Spain's largest manufacturer, Gamesa, benefited from a joint venture with Vestas. China's firms have primarily benefited from licensing agreements with smaller German firms.

The slide lists the countries home to the leading wind turbine manufacturers (in terms of sales capacity) for 2006, as well as global market shares for that year.

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ATTRACTING WIND TECHNOLOGY MANUFACTURING

Specific considerations

- Local technical capacity (skilled labor)
- Infrastructure (cranes, transmission lines)
- Access to technology and IPR

Models of Technology Transfer Used in Spain, India, and China

	Gamesa	Suzlon	Goldwind
Technology acquisition	Joint venture; company buy-outs	Licenses; company acquisitions/mergers	Licenses
R&D	Aggressive in-house R&D program	Internationally dispersed R&D centers	Primarily China-based R&D
Supply chain	Vertically integrated	Vertically integrated	Obtain components from local suppliers

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Developing Countries and Wind Technology Manufacturing

There are many policy mechanisms that can be used to promote the utilization of wind power, but wind power utilization does not necessarily lead to or require the development of a local wind technology manufacturing industry, or the localization of wind turbine manufacturing. Instead, wind power technology is often imported from abroad until a large enough domestic demand for wind power has been established to support local manufacturing.

Even if localization of wind technology manufacturing is achieved, either for components or for entire wind systems, such localization can take multiple forms. Leading foreign wind turbine manufacturers may simply decide to establish a local manufacturing presence in which certain components or entire turbines are manufactured in the local market. On the other end of the spectrum, wind technology may be developed entirely locally, through local innovation or research and development initiated by a domestic firm itself, or in combination with other domestic research organizations. An intermediate strategy is for wind turbine technology to be acquired by a local firm through the transfer of that technology from overseas firms that have already developed advanced wind turbine technology, often through a licensing agreement. 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 property rights necessary 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 permission to make or use a patented article for a limited period or in limited territory. A technology transfer may or may not include technological know-how associated with the development of the technology itself, despite the fact that the physical transfer of technology alone 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. For example, a purchase of a license to produce one model of wind turbine will likely be less valuable than an arrangement that also includes on-site training of the workers in the purchasing company by the transferring company.

A local wind industry may aspire to manufacture complete wind turbine systems, to manufacture certain components and import others, or perhaps just to serve as an assembly base for wind turbine components imported from abroad. Each of these basic approaches to and forms of localization implies different degrees of local manufacturing and technology ownership, and each may require a distinct and targeted set of policy measures. Countries may also move from one model to another over time as local technological capabilities expand. As developing countries decide on a strategy for wind technology acquisition, there are several options that can be considered. One is to import the turbines from abroad. Another is to set up facilities to locally manufacture the turbines. This may have added job benefits but will require much more local technical capacity. In this case, there are different models of technology transfer that may be employed, including licensing or joint ventures.

The technology transfer models used to bring wind power technology to Spain, India, and China, are illustrated in the table on the slide. We know that in each country, at least one model was ultimately successful, since Spain, India, and China are all top 5 countries in terms of installed wind power capacity. However, the models used differed across countries, and there is no “one size fits all” technology transfer model. While the joint venture model worked for Spanish company Gamesa, its partner – Vestas – is unlikely to ever form a joint venture again, particularly in a developing country, because it ultimately created a major global competitor for itself by giving Gamesa the rights to use its technology. China and India have therefore primarily relied on licensing technology from more advanced wind companies, primarily in Europe. More recently, successful companies such as Goldwind and Suzlon have been able to acquire majority ownership of companies that hold technical knowledge that they need.

There are specific considerations for developing countries for wind power development. The first is access to local technical capacity, in particular skilled labor that is especially important for the O&M of the wind farm. The second is access to infrastructure including tall enough cranes, land transportation, and access, as well as proximity to transmission lines (which can be more of a challenge in developing countries with less electricity infrastructure or lower electrification rates.)

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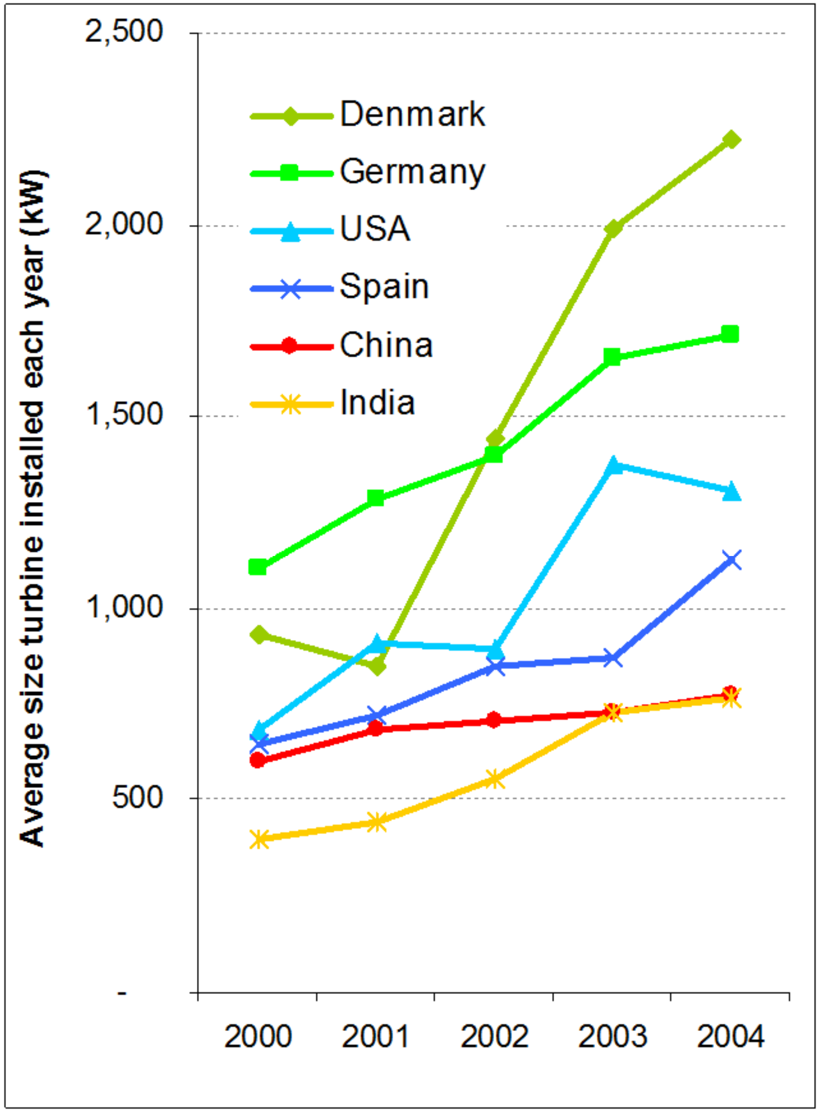
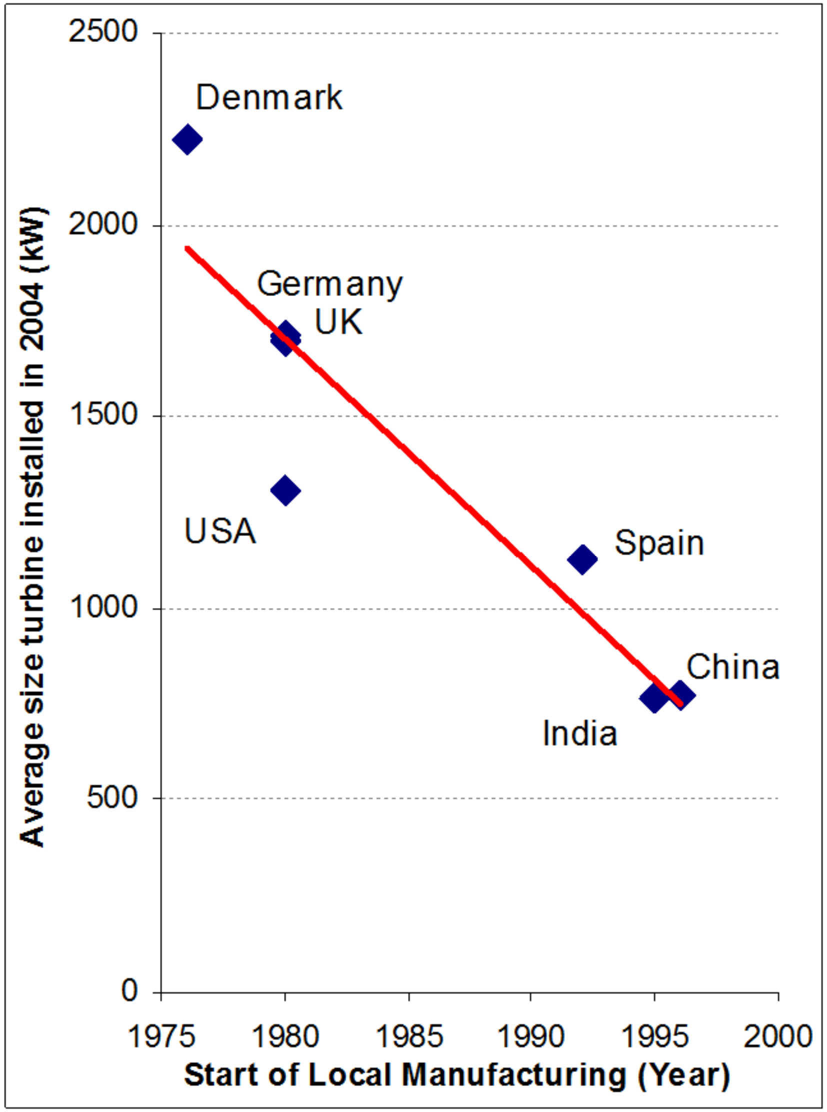
MANUFACTURING EXPERIENCE AND TURBINE SIZE





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Developing Countries and Wind: Manufacturing Experience and Turbine Size

These charts illustrate how as experience in developing wind farms increases, so does average turbine size. The chart on the left illustrates the average size of turbines being installed each year in the world's largest wind markets, and illustrates a clear evolution from smaller (500-600 kW) to larger (2+ MW) turbines. In addition, developing country turbine sizes tend to lag the sizes in industrialized countries, because as developing countries that newly enter the manufacturing industry use their own turbines, they usually begin with smaller turbine sizes. As experience increases, turbine size also increases. The graph on the right illustrates the evolution of the wind industry in terms of countries to enter the wind turbine manufacturing business. India and China are the most recent entrants, and as of 2004 were still installing much smaller turbines on average than Denmark, Germany, the United States, and the UK. Spain, also a late comer, was installing smaller turbines than its European counterparts. Since 2004, however, the average turbine size in these countries has increased and is now over 1 MW.

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- The Resource
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- Project Development Issues
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Policies Promoting Wind Development

POLICIES TO PROMOTE WIND POWER

Policies to support deployment

- Feed-in tariffs
- Mandatory renewable energy targets (portfolio standards)
- Government auctions or resource concessions
- Financial incentives (loans, wire charges)
- Developer tax incentives
- Green power markets

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Policies to Promote Wind Power

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. 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. (More detail on all of these policies can be found in the Overview Module).

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. The advantage of this approach, as opposed to the tax credit style of incentives more familiar to US business, is that it gives a renewable energy producer the ability to project business growth outwards over a number of years.

Germany, Denmark, and Spain have been the most successful countries at creating sizable, stable markets for wind power; all three of these countries also have a history of stable and profitable feed-in tariff policies to promote wind power development. The early US wind industry was also supported by a feed-in tariff in the state of California, though this policy was not stable for a lengthy period. The Netherlands, Japan, Brazil, and some Indian states and Chinese provinces have also experimented with feed-in tariffs, with varying levels of success.

Mandatory renewable energy targets – These 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.

These policies have been implemented as Renewable Portfolio Standards (RPS) in 29 US states, plus the District of Columbia; 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. Similar policies are also beginning to be developed in several Canadian provinces. Since nearly all of these programs have been implemented only recently, their impact on wind power development has so far been relatively modest. Wind power development in the United States has been tied in part to the implementation of state Renewable Portfolio Standards, however, and the market for wind in the UK is also beginning to expand. Other countries that have also recently developed mandatory renewable energy purchase obligations include Sweden, Italy, Poland, and Belgium.

In the United States, over 50% of the non-hydro renewable capacity additions from 1998 through 2007 occurred in states with RPS programs (˜8,900 MW), and 93% of these additions came from wind power.

Concerns have been raised about the competitive mechanisms created by these policies. In addition, the possible long-term political uncertainty that can surround the targets and their design may create market uncertainty and lower overall industry profitability, thereby fostering an environment that offers less incentive for wind localization. A determination of how common this problem is must await further experience with the policy mechanism.

Government auctions or resource concessions – Another way for governments to facilitate wind development is to run competitive auctions for wind projects or resource tenders for prime wind sites, accompanied by benefits like long-term power purchase agreements. However, government tendering programs of this type have historically not provided long-term market stability or profitability, due in part to the often uncertain or long lead times between tenders and the fierce competition among project developers to win the competitive process.

The UK's Non-Fossil Fuel Obligation, which provided periodic tenders for renewable energy generation during the 1990s, is the most commonly cited example of government-run bidding processes. Ultimately, policymakers found that these tenders were not sufficiently certain and the contracts not sufficiently profitable to draw much manufacturing interest to the country. In addition to the UK, government-run competitive bidding for wind projects has been or is being used in Canada, India, Japan, some US states, China, and most recently in Jordan and other countries with emerging wind sectors.

In China, the wind power concessions have met with only moderate success. Reports of gaming the bidding process through the submission of unreasonably low tariffs that are later renegotiated after the developer was granted the project have threatened the outlook for the concession program, as well as the competitiveness and stability of the market. The Chinese government appears to be moving toward a concession-guided feed-in tariff program, in which concession prices end up setting the feed-in tariff levels for a specific site or province.

Financial incentives – Financial incentives of various forms, whether based on electrical production or capital investment, and whether paid as a direct cash incentive or as a favorable loan program, can also be used to encourage renewable energy development. 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 also be used. Without a long-term power purchase agreement, however, this policy mechanism has been found generally to 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 for 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.

One of the most successful tax incentives in terms of contributing to installed capacity is the US's Production Tax Credit (PTC). Though the PTC has certainly been effective at promoting wind installations, its on-again, off-again nature has resulted in a very unstable market for wind farm investment in the United States. In the 1990s, India's market was also driven in large part by various tax incentives, including 100% depreciation of wind equipment in the first year of project installation, as well as a 5-year tax holiday. China has VAT reductions and income tax exemptions on electricity from wind, and a number of other countries have also used or continue to use a variety of tax-based incentives.

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 in developing countries typically is rather limited.

Photo credit: Joanna Lewis

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POLICIES TO PROMOTE LOCAL MANUFACTURING

Policies to support local wind industry development

- Local content requirements
- Preference or incentives for local content
- Favorable customs duties
- Industry tax incentives
- Export credit assistance
- Certification and testing programs
- Research, development and demonstration programs

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Policies to Support Local Wind Industry Development

In addition to the policies on the previous slide, countries increasingly are using some of the direct policy measures identified below to encourage local manufacturing.

Local content requirements – One direct way to promote the development of a local wind manufacturing industry is to require 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.

Local content requirements are currently being used in the wind markets of Spain, Canada, Brazil, and China. Spanish government agencies have long mandated the incorporation of local content in wind turbines installed on Spanish soil; the creation of Gamesa in 1995 can be traced in part to these policies. Even today, local content requirements are still being demanded 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 of wind power has created 4,000 jobs. Other regions, including Castile and Leon, Galicia and Valencia, insist on local assembly and manufacture of turbines and components before granting development concessions. The Spanish government has clearly played a pro-active role in kick-starting the domestic wind industry, and the success of Gamesa and other manufacturers is very likely related to these policies.

At least one provincial government in Canada – Quebec – is pursuing aggressive local content requirements in conjunction with wind farms developed in its region. In May 2003, Hydro-Quebec issued a call for tenders for 1,000 MW of wind for delivery between 2006 and 2012, with a local content requirement. This 1,000 MW call was twice the size initially planned by the utility, but it was doubled by the Quebec government with the hope of contributing to the economic revival of the Gaspe Peninsula.

The Brazilian government has also pursued policies governing wind farm development that include stringent local content requirements, primarily through the recent Proinfa legislation (the Incentive Program for Alternative Electric Generation Sources) that offers fixed-price electricity purchase contracts to selected wind projects. Starting in January 2005, the Proinfa legislation required 60% of the total cost of wind plant goods and services to be sourced in Brazil; only companies that could prove their ability to meet these targets were to be allowed to take part in the project selection process. After 2007, the percentage increased to 90%.

China also has been using local content requirements in a variety of policy forms. China's 1997 "Ride the Wind Program" established two Sino-foreign joint venture enterprises to manufacture wind turbines domestically; the turbines manufactured by these enterprises under technology transfer arrangements started with a 20% local content requirement, with the goal of an increase to 80% as learning on the Chinese side progressed. China's recent large government wind tenders, referred to as wind concessions, have a local content requirement that has been increased to 70% from an initial 50% requirement when the concession program began in 2003. Local content is also required to obtain approval of most other wind projects in the country, with the requirement recently increased from 40% to 70%.

It should be noted that such local content requirements potentially could foster international trade disputes. The World Trade Organization (WTO) explicitly restricts preferential treatment of domestic products over foreign products. Chinese local content requirements, in particular, have recently been met with frustration by foreign-owned wind turbine manufacturers. Many countries' current and proposed wind industry policies concerning import tariffs, technology transfer, local content, and domestic subsidies could become the subject of trade disputes if other WTO member countries believe these practices violate current WTO agreements. Local content requirements for wind turbine technology are perhaps most clearly at risk of being the subject of an international trade dispute, but since many international wind turbine manufacturers are already in the process of meeting these local content requirements and have not yet brought such a challenge, a dispute is perhaps unlikely in the near term. Proposed Chinese local intellectual property requirements for wind turbine technology may pose the greatest risk of catalyzing a trade dispute since they would likely exclude foreign firms from the Chinese wind power market to a far greater extent than current and past requirements.

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 providing subsidies on wind power generated with locally made machines.

Favorable customs duties – Another way to create incentives for local manufacturing is through the treatment 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.

For example, Germany's 100MW/250MW program provided a 10-year federal generation subsidy for projects that helped to raise the technical standard of German wind technology, and over two-thirds of the total project funding for this subsidy went to projects using German-built turbines.

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. Export credit assistance or development aid loans tied to the use of domestic wind power technology have been used by many countries, but most extensively by Germany and Denmark, encouraging the dissemination of Danish and German technology, particularly in the developing world. For example, the Danish International Development Agency (DANIDA) has offered direct grants and project development loans to qualified importing countries for the purchase of Danish turbines.

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.

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; quality certification and standardization programs have since been used in Denmark, Germany, Japan, India, the USA, and elsewhere, and are under development in China. They were particularly valuable to Denmark in the early era of industry development when they essentially mandated the use of Danish-manufactured turbines, since stringent regulations on turbines that could be installed in Denmark made it very difficult for outside manufacturers to enter the market.

Research, development, and demonstration (RD&D) 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 can play a crucial role in testing the performance and reliability of new domestic wind technology before those turbines go into commercial production.

Although the United States has put more money into wind power R&D than any other country, an early emphasis on multi-megawatt turbines and funding directed into the aerospace industry are thought (in retrospect) to have rendered US funding less effective in the early years of industry development than the Danish program (the same has been said about early German and Dutch R&D programs). 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 in the initial years of industry development.

Photo credit: Joanna Lewis

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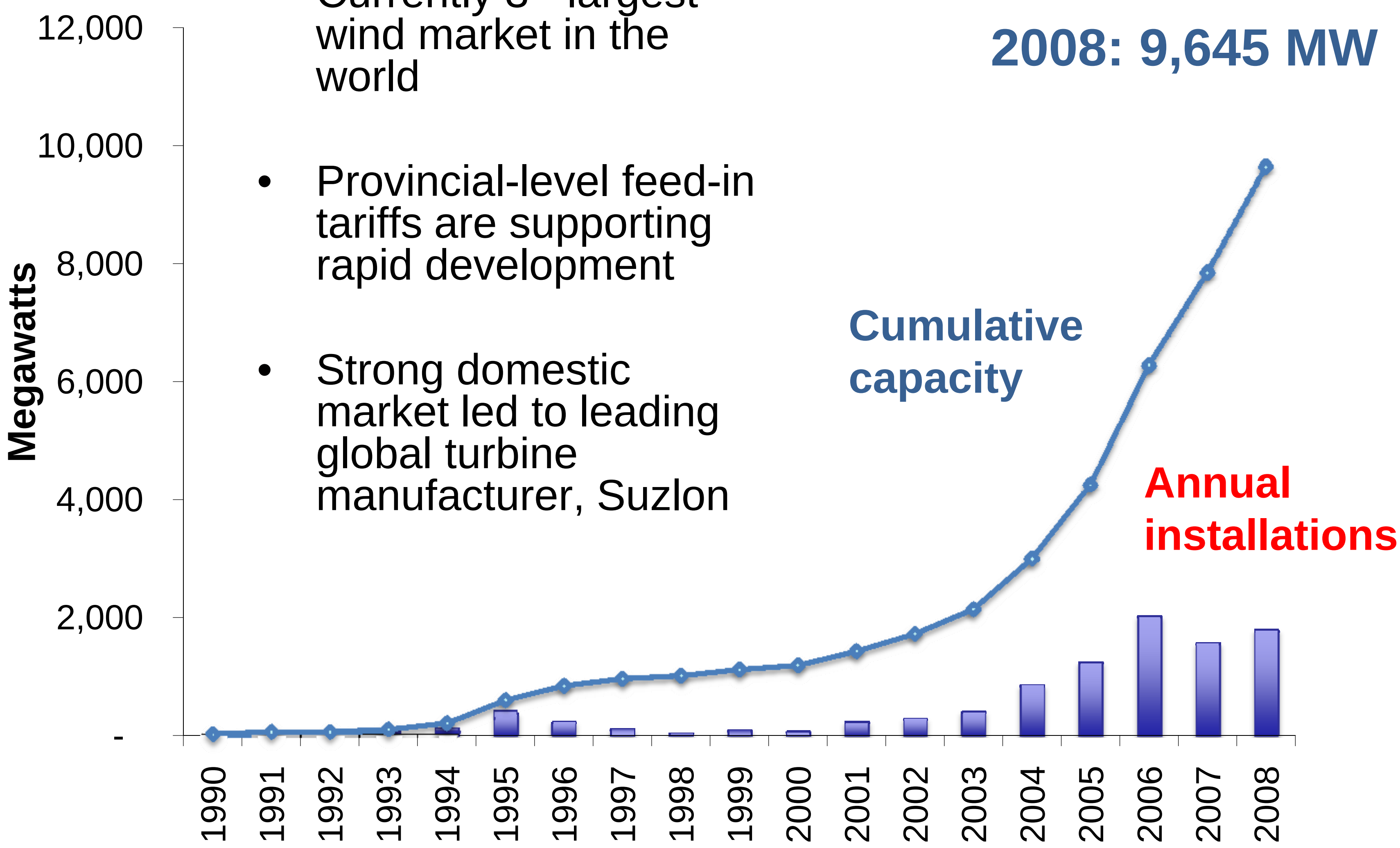
- Provincial-level feed-in tariffs are supporting rapid development
- Strong domestic market led to leading global turbine manufacturer, Suzlon



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Policy Experience Case Study: India

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% and maximum of 10% of electricity from renewables, and the Madhya Pradesh Energy Commission has stipulated 0.5% 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.

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. The Indian government is considering passing a national renewable energy law that would consolidate and normalize various state programs.

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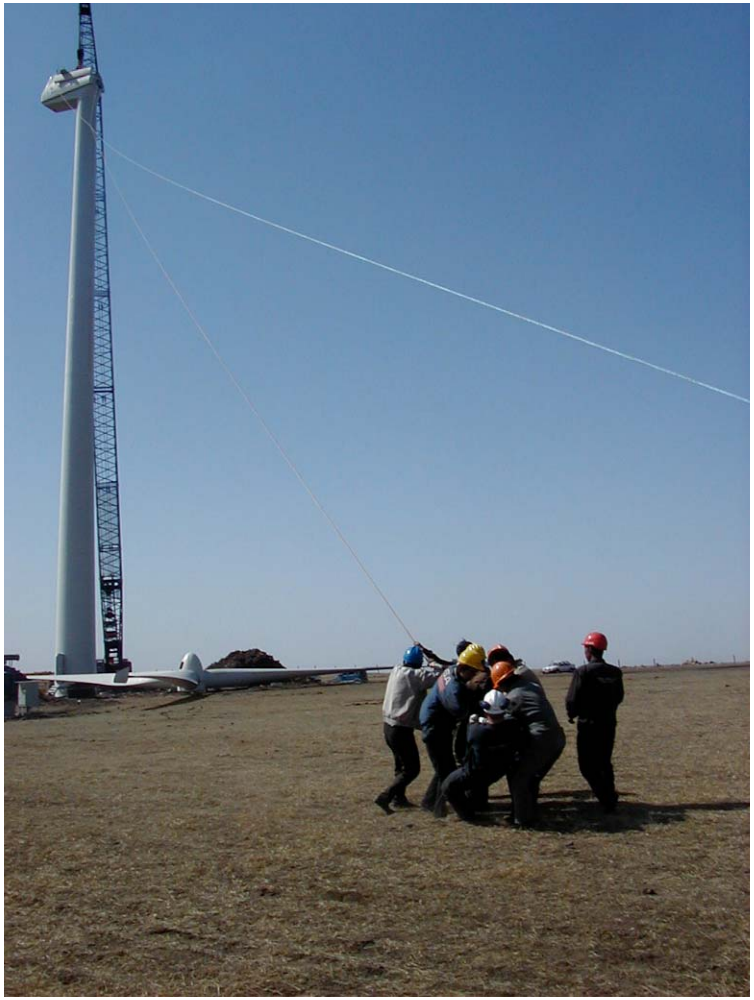
Project Development Issues

PROJECT DEVELOPMENT ISSUES: OWNERSHIP MODELS

Investment Models

- Utility owned
- IPP
- Cooperative ownership
  - Flip structure
  - On-site or sole ownership



Benefits to community involvement in ownership:

- Avoids NIMBY concerns
- Promotes education and awareness of electricity issues at local level
- Promotes better conservation practices

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Models of Financing

Most wind power generation is owned and developed either by utilities on a turnkey basis or by independent power producers (for more details, see the Overview Module). A growing body of literature suggests that the community can be both a motivating and limiting factor to the successful implementation of wind energy. As evidence of the importance of community support of wind, one should note that as of 2007, almost a quarter of global utility-scale, grid-connected wind generation capacity was owned not by utilities, but by individuals or wind cooperatives. Encouraged by the success of community wind projects, governments the world over have been quick to provide economic inducements to promote the proliferation and evolution of community wind.

Cooperative Ownership or “Multiple Local Owner Model”

In this model, one or more farmers solicit sufficient equity investment to support the project from among the local farming community. An example of this model has been employed in the Midwind Projects in Minnesota. In this case, limited liability companies (LLCs) were formed, allowing investors to buy shares for as little as $5,000 per share. The LLC obtains debt from a local bank or from a state-sponsored energy loan program. The project sells power to a utility through a negotiated long-term power purchase agreement, and investors split the income and tax benefits proportionally, according to their level of investment in the project. Barriers to this model will vary according to the country in which it is used, but US barriers have included transaction costs associated with “securities” investment regulation.

The “cooperative” model has been most widely used in Denmark, as Danish law encourages mutual ownership of wind turbines (fællesmølle) by exempting owners from taxes on the portion of the wind generation that offsets a household’s domestic electricity consumption. A wind coop would then buy a wind turbine, site it to greatest advantage, sell the electricity to the utility, and share the revenues among its members. This enabled a group to buy the most cost-effective turbine available, even though it may have generated more electricity than any individual member needed. The term cooperative is used loosely. In the Danish context, many cooperative ventures were assembled as limited liability companies-investment coops in response to the vagaries of Danish law and tax policy. Danish wind turbine cooperatives have had a profound effect on the development of wind energy. Until 1995, most wind turbines in Denmark were installed cooperatively. About 5% of the population now own a stake in a windmill guild.

Flip Structure Model

In this model (which is specific to the United States, where the production tax credit is a valuable driver of wind development), farmers bring in a corporate, tax-motivated equity partner that is easily able to absorb the tax credits. This approach is being used in Minnesota. In the Minnesota example, the local farmer/landowner (“local partner”) initially contributes as little as 1% of the equity in the LLC, with the corporate partner contributing up to 99%. During the first 10 years of the project, all cash flows and tax benefits from the project are divided among the corporate and local partners, proportional to their level of investment in the LLC (e.g., 99% to 1%). At the end of 10 years (once the PTC is no longer available), or potentially later if the corporate partner requires more income to meet a return hurdle, ownership in the LLC “flips” to 99% local, 1% corporate. At the time of the flip the corporate partner typically has the option either to maintain its 1% ownership position for the remaining life of the project, or else sell its 1% interest to the local partner at fair market value. Since there is virtually no economic difference between these two options, given the size of the share in question (i.e., 1%), the corporate partner is perhaps more likely to stay in the project, if only to demonstrate to the IRS the long-term nature of its investment, and that it was not simply seeking a tax shelter. Either way, after the flip the local partner – having contributed only 1% of project equity at inception – essentially owns a debt-free, utility-scale wind project that should continue to operate and generate substantial income for at least another decade.

Another “flip” model was used in Wisconsin by John Deere, a corporation that has voiced its willingness to partner with farmers in wind project flip structures. John Deere has chosen to enter this market not only because it is financially attractive, but also because its involvement will increase the prosperity of rural America, its core client base. Farmers earning income from successful wind projects have more money with which to buy tractors. In this Minnesota-style flip structure, multiple local investors (rather than a single farmer or landowner) provide debt (rather than equity) financing to the wind project. As described in the plan, a group of local investors with limited or no tax credit appetite pool enough capital (through sales of $5,000 shares) into an LLC to cover 20% of the total costs of a 3 MW wind project. The LLC “loans” this amount to a tax-motivated corporate investor, who in turn contributes another 30% of total project costs in the form of equity, and borrows the remaining 50% from a commercial lender, resulting in a 70:30 debt/equity ratio for the project as a whole. The corporate investor owns 100% of the project for the first 10 years and benefits from the federal PTC and accelerated depreciation, as well as revenue from the sale of power and renewable energy credits (RECs). At the same time, it services the project’s debt, repaying the entire 10-year commercial loan, as well as interest – but not principal – on the loan from the local LLC. At the end of the tenth year, with its minimum return hurdle met, the corporate investor simply drops out of the project, retaining the LLC’s loan principal as payment for the project. At this point, the local LLC assumes 100% ownership of the project, which is now free of debt, and therefore quite profitable.

On-Site Project Model or Sole Ownership Model

In this model a wind project is developed on-site and the power generated is used directly by the farm, instead of being sold to a utility. This model must involve a large end-use electricity consumer (e.g., a large farm operation) financing and interconnecting a utility-scale wind turbine on its side of the meter to supply on-site power and thereby displace power purchased from the utility. A wind project that offsets the full retail rate a customer pays for electricity may provide the highest value to its owners. This is because retail rates for commercial customers such as farmers typically average around 7¢/kWh – well above the 3-4¢/kWh that a wind project might earn by selling its power on the wholesale market.

Taxable business entities such as farmers, however, face a rather unique barrier to on-site wind development (or any type of on-site generation): the electricity bill savings that result from the project are, in effect, taxable, since they reduce the amount of utility payments that the owner can deduct as a business expense. Partly for this reason, most on-site utility-scale wind projects installed to date in the United States have been owned by tax-exempt large electricity users, such as schools.

Key barriers to this model include the fact that demand charge is based on the customer’s peak demand measured during a specified period each month. If the wind is not blowing during that period, then on-site wind generation will not reduce peak demand. In such a situation, if demand charges account for half of the farmer’s electricity bill, then the per-kWh savings from the wind turbine will only be half of the full retail rate. Conversely, a standby charge is based on any shortfall of actual demand below “normal” or contractual demand, and is intended to compensate the utility for continually “standing by” ready to serve in the event that on-site demand for power exceeds the on-site supply of power. In other words, a standby charge allows the utility to recover its fixed costs (e.g., transmission and distribution costs, reserve costs) of standing ready to serve self-generating customers. Whereas demand charges erode the value of on-site wind generation if the wind generation does not reduce peak demand, standby charges work in reverse, reducing the value of on-site generation if the wind turbine does reduce peak demand. In either case, the generator will not earn the full retail electricity rate for power produced.

Note that while community wind models have been primarily used in Europe and the United States, they are beginning to be experimented with in the developing world as well. Models of wind development that directly involve and benefit local communities have been shown to be particularly important in small island nations, where the wind farm is in very close proximity to small island communities.

Photo credit: Joanna Lewis

References

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- 215. LBNL – Community Wind Support Schemes in Europe and their Relevance to the United States
- 301. Badgley – Community Development through Wind Energy: Lessons from Wind Developments in Remote and Small Island Nations

PROJECT DEVELOPMENT FLOW

Common steps & sequence for wind project development (minimum 2-3 years)

- Resource assessment
- Transmission needs
- Secure land rights (e.g., lease agreement)
- Determine turbine manufacturer
- Economic assessment
- Power purchase agreement
- Secure financing
- Siting and feasibility considerations
- Zoning and permitting
- O&M agreements
- Construction

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Project Development

Common steps and the sequence for wind project development can be summarized as follows:

Resource assessment: Most developers want at least two years of site-specific wind data, on top of any general wind data and metrological data that can be used to predict the power output from the potential wind farm site. Usually the developers collect this information themselves. In some cases, however, the government will collect this data in an attempt to spur wind development at a particular site (for example, the Chinese government did this for its wind concessions). Note that resource assessment can be taking place while the other steps are in process, such as securing land rights and permitting.

Transmission needs: A developer will need to assess transmission availability, and negotiate any needed extensions with the grid owner/utility, or in some cases the government will intervene. In a situation where new lines will need to be constructed, this can take a long time to negotiate, though this will vary from place to place.

Secure land rights (e.g., lease agreement): The rules governing this will be very site specific.

Determine turbine manufacturer: Typically the developer selects the wind turbine manufacturer. For some projects, however, the selection of a certain type of manufacturer (e.g., one meeting a certain local content requirement, or utilizing equipment of a certain turbine size) will aid in the project contract being awarded to the developer. Large-scale developers sometimes use “frame agreements” with turbine suppliers, allowing them to secure the turbines well in advance of specific site identification to improve pricing, with specific designations made prior to delivery.

Economic assessment: The developer will determine the overall economics of the project, including usually the cost of generating electricity on a levelized basis. This is then used to inform PPA negotiations.

Power purchase agreement: The project developer must negotiate the power purchase agreement with whomever will be buying the electricity, unless the developer is also the electricity provider. Depending on how many actors are involved and the policy environment for wind power, this can be one of the more time-consuming elements of developing a wind project.

Secure financing: The developer may initially take out a construction loan until the project becomes operational, at which time it may shift to a long-term loan. Depending on the economic climate this can be a smooth or a very difficult, time-consuming process. Securing of financing is usually contingent on having already negotiated a PPA.

Siting and feasibility considerations: Overall siting considerations will be very site specific.

Zoning and permitting: Depending on the location of the wind project, the zoning or permitting process can take a lot of time. This will depend on how rigorous environmental impact assessment or other regulations are in the country or site of the wind project.

O&M agreement: In some case O&M is performed by the wind turbine manufacturer, and in some cases this is contracted out to a specialty firm.

Construction: Actual construction of a wind farm is rather fast, perhaps around six months, depending on the total size. Large projects are typically divided up into segments (perhaps of 50 – 100 MW) so that the first phase can be brought online while the second phase is still being completed.

Overall, it could take two to three years to construct an average wind farm from start to finish.

Photo credit: Joanna Lewis

References

- 221. Yarano and Brusven – Basics of a Power Purchase Agreement: Sample Power Purchase Agreement (PPA)
- 223. AWEA – Wind Energy Siting Handbook
- 224. The Community Wind Development Handbook
- 225. Sample Wind Project Calculator (excel spreadsheet)
- 236. Promotion of Renewable Energy in Sri Lanka: Future Directions

PROJECT DEVELOPMENT ISSUES: RISK MITIGATION

Perceived risks

- Direct risks
  - Increasing O&M costs
  - Poor performance
  - Poor wind plant array efficiency
- Indirect risks
  - Increased cost of insurance and financing
  - Slowing or stopping development
  - Loss of public support

Risk mitigation options

- Certification
- Full-scale testing
- Performance monitoring and O&M

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Financing Wind Power: Risks that Impact Revenue

There are both direct and indirect perceived risks that can impact wind project revenue. Direct risks are caused by:

Increasing O&M costs – There is mounting evidence that O&M costs are increasing as wind farms age. Most of these costs are associated with unplanned maintenance or components wearing out before the end of their intended design lives. Some failures can be traced to poor manufacturing or installation quality. Others are caused by design errors, many of which are caused by weaknesses in the technology's state of the art. The numbers and costs of component failures have increased with time, and the risk to the operators grows accordingly. For a new machine, O&M costs might have an average share over the lifetime of the turbine of about 20-25% of total levelized cost per kWh produced.

Poor availability driven by low reliability – Energy is not generated while components are being repaired or replaced. Although a single failure of a critical component stops production from only one turbine, such losses can mount up to significant sums of lost revenue.

Poor wind plant array efficiency – If turbines are placed too close together, their wakes interact, which can cause the downwind turbines to perform poorly. But if they are placed too far apart, land and plant maintenance costs increase.

Although the wind industry has achieved high levels of wind plant availability and reliability, unpredictable or unreliable performance would threaten the credibility of this emerging technology in the eyes of financial institutions and utilities. The consequences of real or perceived reliability problems would extend beyond the direct cost to the plant owners. These indirect risks that have consequences for the continued growth of investment in wind could include:

Increased cost of insurance and financing: Low interest rates and long-term loans are critical to financing power plants that are loaded with upfront capital costs. Each financial institution will assess the risk of investing in wind energy and charge according to those risks. If wind power loses credibility, these insurance and financing costs could increase.

Slowing or stopping development: Lost confidence contributed to the halt of development in the United States in the late 1980s through the early 1990s. Development did not start again until the robust European market supported the technology improvements necessary to reestablish confidence in reliable European turbines. As a result, the current industry is dominated by European wind turbine companies. Active technical supporters of RD&D must anticipate and resolve problems before they threaten industry development.

Loss of public support: If wind power installations do not operate continuously and reliably, the public might be easily convinced that wind is not a viable source of energy. The public's confidence in the technology is crucial. Without public support, partnerships working toward a new wind industry future cannot be successful.

Note that a 20-year lifetime is the general figure assumed in estimating levelized costs.

There are also options available to help mitigate the risks associated with a wind project. These include:

- **Certification** – third-party technical audits of technology design and performance
- **Full-Scale Testing** – test facilities that mimic harsh field conditions and long-term operation
- **Performance Monitoring and O&M** – strategic monitoring on-site to facilitate targeting of problems early

Photo credit: Joanna Lewis

References

- 205. DOE – 20% Wind Energy by 2030
- 217. AWEA – IEC Wind Turbine Standards

Wind Power

- The Resource
- Wind Technology
- Global Status and Costs
- Wind Technology Manufacturing
- Policies Promoting Wind Development
- Project Development Issues
- **Benefits of Wind Power**
- Challenges to Wind Power Development
- Best Practices

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Benefits of Wind Power

WIND POWER BENEFITS

- Lower carbon emissions
- Reduced prices for fossil fuels
- Additional price stability
- Environmental quality improvements
- Reduced water consumption
- Rural economic development
- Technology and manufacturing investments
- New employment opportunities

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Wind Power Benefits

The next section of the presentation elaborates on technology-specific benefits of wind power, including lower carbon emissions, environmental improvement, reduced water consumption, rural economic development, technology and manufacturing investments, and new jobs in wind (but job losses in fossil industries).

Other benefits to wind energy not elaborated here include reduced prices for fossil fuels that could come from decreased marginal demand, and additional price stability due to the fact that wind power is not tied to volatile fossil fuel prices.

Photo credit: Joanna Lewis

References

- 205. DOE – 20% Wind Energy by 2030

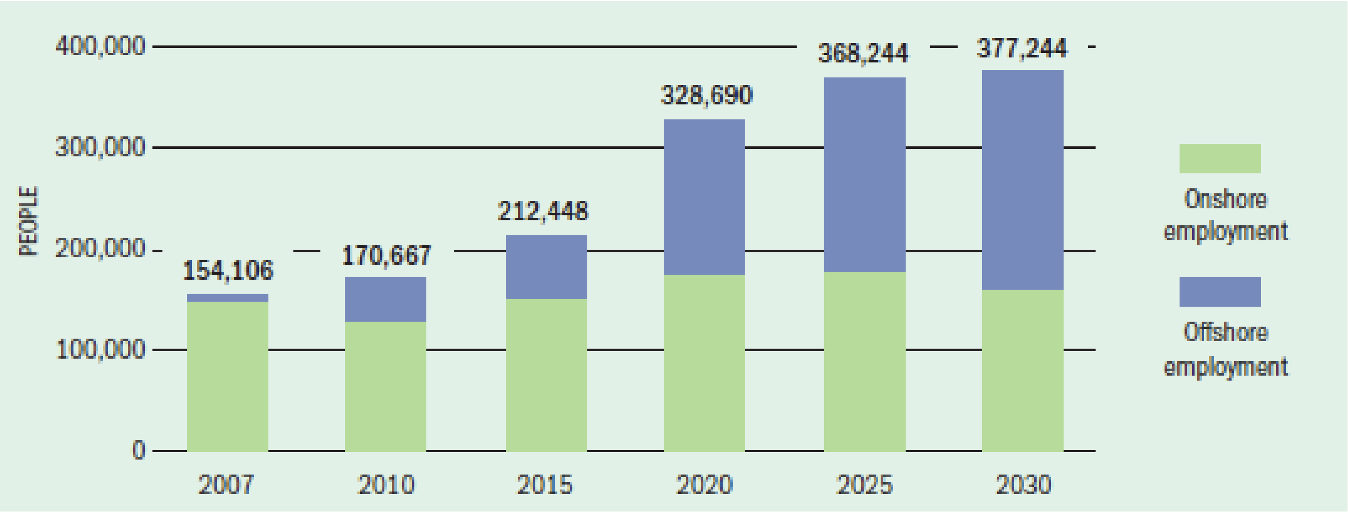
BENEFITS: JOB CREATION

EU Wind-Related Jobs

Employment/MW (2007)	Jobs	Jobs/Annual MW	Jobs/Cumulative MW	Basis
WT Manufacturing - Direct	64,074	7.5		Annual
Wt manufacturing - Indirect	42,716	5.0		Annual
Installation	10,665	1.2		Annual
Operations and maintenance	18,657		0.33	Cumulative
Other direct employment*	15,204	1.3	0.07	75% annual/25% cumulative
Total employment	151,316	15.1	0.40	

* IPP/utilities, consultants, research institutions, universities, financial services and other.

Wind Energy Sector Employment (EU 2007-2030)



Source: EWEA, 2009

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Technology-Specific Benefits: Job Creation

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-fueled power generation. One study from the United States, for example, estimates that wind power creates 27% more jobs than the same amount of energy produced by a coal plant and 66% more jobs than a natural gas combined-cycle power plant. 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. The remaining one-third is accounted for by installation, services, transport, and development. 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.

Several studies have estimated the total number of jobs created by the wind industry. The European Wind Energy Association's report on Industry and Employment calculated the total number of direct and indirect jobs in the EU created by the wind industry to be 72,275 for 2002 (including manufacturing, installation, and maintenance), with the majority of the jobs in the manufacturing sector (47,625) and the rest in installation (21,150) and maintenance (3,500). According to the European Wind Energy Association data presented above, 7.5 jobs per MW of wind installed are directly created, plus an additional 5 jobs/MW of indirect jobs. If consultants, research, and financial service jobs are included, the number increases to a total of 15.1 jobs/MW installed.

References

- 216. Lewis & Wiser – A Comparison of Wind Power Industry Development Strategies in Spain, India and China
- 218. EWEA – Wind at Work

BENEFITS: GREENHOUSE GAS MITIGATION

Wind power is one of the most cost effective energy options for carbon mitigation

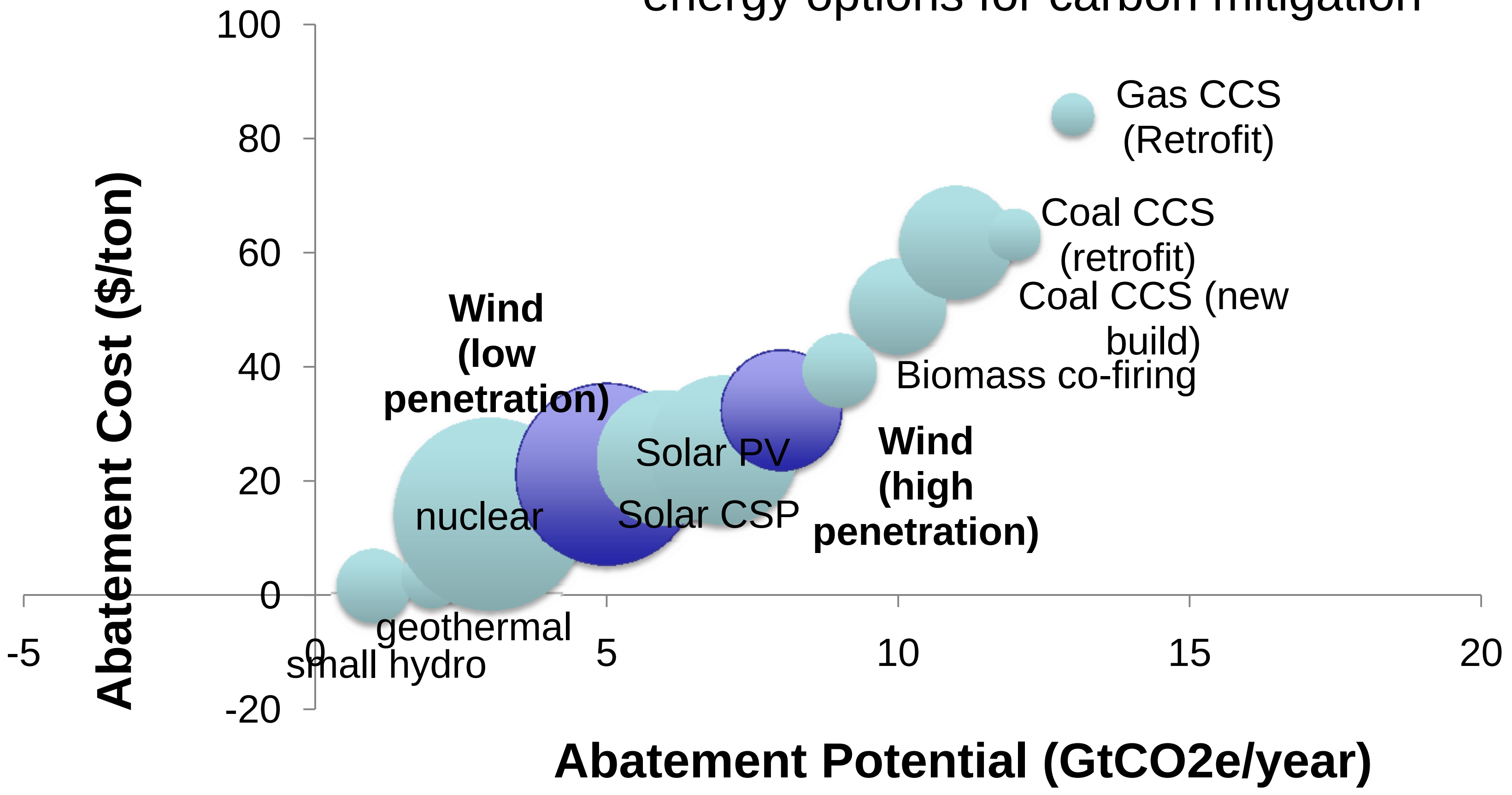

Chart data based on McKinsey, Global Greenhouse Gas Abatement Cost Curve v.2, Jan 2009.

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Technology-Specific Benefits: Low Cost Carbon Mitigation

According to a study by McKinsey & Company that attempted to put a cost per ton on all carbon mitigation options currently available, wind power ranks among the most cost-effective mitigation options available today. The power sector has the largest source of abatement potential available in any sector – an estimated 10 Gt per year through 2030. Carbon abatement from wind power is estimated to be achievable between 20 and 30 dollars per ton of carbon (though exact cost will vary with location). This is less expensive than many power sector mitigation options, including carbon capture on coal plants (without EOR), and biomass co-firing. It is expected that once higher penetrations of wind are reached, there will be additional costs incurred – for example, through storage to maintain grid stability. However, low penetrations of wind are one of the most cost-effective carbon mitigation options, less expensive than solar PV and solar CSP, but more expensive than geothermal or small hydro. However, there is thought to be a much larger abatement potential for low-penetration wind than for these other technologies.

Under the Global Wind Energy Council (GWEC) Advanced scenario, the annual CO_2 savings by wind power would increase to 245 million tonnes by 2010, 1,591 million tonnes by 2020, and 3,236 million tonnes by 2030. Between 2003 and 2020, over 9,494 million tonnes of CO_2 would be saved by wind energy alone (assuming that wind energy is displacing the mix of thermal power that would have otherwise been utilized). This would increase to over 130,000 million tonnes over the whole scenario period. (The size of the bubble represents the total magnitude of the Abatement Potential)

In the US Department of Energy (DOE) US scenario, generating 20% of US electricity from wind could avoid approximately 825 million tonnes of CO_2 emissions in the electricity sector in 2030. The 20% Wind Scenario would also reduce cumulative emissions from the electricity sector through that same year by more than 7,600 million tonnes of CO_2 (2,100 million tonnes of carbon equivalent).

References

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Wind Power

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Challenges to Wind Power Development

CHALLENGES: RESOURCE VARIABILITY

- Wind is an energy resource, not a capacity resource
- Wind power cannot replace the need for many capacity resources
- Aggregated wind generation is more predictable and less variable
- The use of well-functioning hour-ahead and day-ahead markets and the expansion of access to those markets are effective tools for dealing with wind’s variability

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Technology-Specific Challenges: Resource Variability

There are different types of variability that impact a power system, as described below:

Second to second (intra-minute): Wind power variations are insignificant at this level, do not tend to impact the system, and there is no need for regulation services.

Minute to minute (intra-hour): Here there is a bit more variability than second-to-second, requiring real time reserves or load-following services.

Hour to hour (intra-day): Here wind variability tends to be more significant and may affect intra-daily dispatch/unit commitment and therefore re-dispatch costs in the next time-frame market. [Storm transitions take place in this time frame, leading to cutoff speeds or zero speeds. Variations could be correlated with demand.]

Day to day and beyond (seasonal): Seasonal wind variability is predictable. It may affect long-term energy availability and capacity factor of the wind plants. Variations will affect investment decisions and any form of “capacity” crediting to wind plants, but will not directly impact system operations integration cost.

Wind energy has characteristics that differ from those of conventional energy sources. Wind is an energy resource, not a capacity resource. Capacity resources are those that can be available on demand, particularly to meet system peak loads. Because only a fraction of total wind capacity has a high probability of running consistently, wind generators have limited capacity value. Incorporating wind energy into power system planning and operation, then, will require new ways of thinking about energy resources. Capacity values depend on load versus seasonal/hourly wind variation. Recent reports indicate that for planning purposes the value of effective wind capacity ranges from 3% to 23%, depending upon the complementary effects of load and resource curves.

Capacity is needed to meet specified goals. Because wind is not a capacity resource, it does not require 100% backup to ensure replacement capacity when the wind is not blowing. Wind power cannot replace the need for many “capacity resources,” which are generators and dispatchable load that are available to be used when needed to meet peak load. If wind has some capacity value for reliability planning purposes, that should be viewed as a bonus, but not a necessity.

Similarly, as more wind turbines are installed across larger geographic areas, the aggregated wind generation becomes more predictable and less variable. Experience has shown that the use of well-functioning hour-ahead and day-ahead markets and the expansion of access to those markets are effective tools for dealing with wind’s variability. When wind blows strongly, the real-time price falls, signaling other, more controllable generators to reduce their output and save costly fuel. Conversely, when wind drops off, real-time prices rise and dispatchable generators increase their output.

There are particular challenges integrating wind power for developing countries which may have less advanced, less stable power grids in place. While wind variability is unlikely to be a significant challenge in the early stages of wind power development when overall wind penetration on the grid is likely to be low, this could become a larger challenge as penetration increases with increased capacity. In some locations where smaller, regional power grids are used, even modest amounts of wind power could result in relatively high levels of penetration rather quickly. For example in Inner

Mongolia, China, there have been reports of very high levels of wind penetration on a regional power grid that was not well-suited to withstand the on-off nature of wind power. As a result, several wind farms were occasionally kicked off-line.

References

- 205. DOE – 20% Wind Energy by 2030
- 264. Madrigal – Integrating – RE Transmission System

CHALLENGES: GRID INTEGRATION

- Integration need not degrade the grid
- Modern wind plants can improve grid system
  - Support post fault voltage recovery
  - Dampen power swings
- Balancing costs 0.5 – 4 €/MWH

Denmark study of high wind penetration:

- showed system could reach 30% wind without excess protection but after 50% surplus wind increases
- If wind generated 100%, more than 1/3 would be surplus power generated during times when use was low

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Technology-Specific Challenges: Grid Integration

The objective of a power system is to supply all electricity load reliably, which means that supply should be adequate and secure. Adequate means that the system is able to meet all demand needs today and in the future; secure means that the system is able to meet demand despite unanticipated events and failures.

In most cases, modern wind plants can be added to a power grid without degrading system performance, and in some situations they can actually contribute to improvements in system performance. A severe test of the reliability of a system is its ability to recover from a three-phase fault at a critical point in the system. (A “fault” is an unintended electrical connection – typically a short circuit.) System stability studies have shown that modern wind plants – equipped with power electronic controls and dynamic voltage support capabilities – can improve system performance by supporting post-fault voltage recovery and damping power swings.

According to most studies, wind integration costs are manageable. For levels below 10% of energy penetration, costs are small. For levels between 10-15% more studies are required, but it is expected that there will be more impact on reserves and other services. For levels between 15%-30%, certainly more flexibility will be required, particularly for large interconnected areas. There are very few regions around the world with such high penetrations of wind energy, and therefore this is not something that is very well understood. Much more detailed studies will be needed as countries begin to explore much higher penetrations of wind power going forward. The one place that has been moderately well studied is Denmark, which is described below. Future studies should examine in particular the Hawaiian Islands of Maui and Hawaii (the Big Island), which have relatively small loads and increasingly large penetrations of wind power. The Big Island already has up to 30% wind penetration at night, and is forecasting up to 70% by 2018.

A recent IEA initiative summarizes integration cost experience to date and came to the following estimates:

- Costs for balancing range from 0.5-4 €/MWh. This is small compared to the production cost of wind power (30-50 €/MWh) or to avoided fuel costs (20-30 €/MWh at 2001 prices). In some countries wind power producers already pay imbalance payments that are greater than the actual extra cost incurred to the power system.
- Integration costs for grid reinforcements range from 50-100 €/MWh depending on wind resource location versus load centers.

(See the Overview Module for additional information on grid integration issues).

In 2005, Energinet.dk published the preliminary results of a study of the impact of meeting 100% of western Denmark’s annual electrical energy requirement from wind energy (Pedersen 2005).(Note that due to Denmark’s interconnection with neighboring countries, this could theoretically be achieved.) The study showed that the system could absorb about 30% energy from wind without any excess (wasted) wind production, assuming no transmission ties to outside power systems. Surplus wind energy starts to grow substantially after the wind share reaches 50%. And if wind generates 100% of the total energy demand of 26 terawatt-hours (TWh), 8 TWh of the wind generation would be surplus because it would be produced during times that do not match customer energy-use patterns. Other energy sources, such as thermal plants, would supply the deficit, including the balancing energy. In the Pedersen study, the cost of electricity doubled when wind production reached 100% of the load.

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- 220. Pedersen – System and Market Changes in a Scenario of Increased Wind Power Production. Report No. 238389
- 296. Denmark – Wind Power to Combat Climate Change – How to Integrate Wind Energy into the Power System
- 297. APEC REGIS Workshop – Hawaii Energy, Environment, and Sustainability: Aspects of Grid Integration of As-Available Resources
- 298. VTT – Design and Operation of Power Systems with Large Amounts of Wind Power, first results of IEA Collaboration

CHALLENGES: ISLAND ELECTRIFICATION

Island wind power and microgrids

- Island wind resources can be less reliable
- Can be more or less cost-effective
- Have more limitations
- Small populations and close-knit communities provide opportunities for community-based wind development models

Nan’ao Island, China

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Technology Specific Challenges: Island Electrification

While advances in renewable technologies have improved the penetration of renewable energy systems in less developed countries, lack of national capacity, remoteness from global supply chains, and myriad socio-political barriers prevent renewable energy technologies from achieving their full potential in electrifying developing countries. Any discussion of island electrification is of course dependent upon the size of the island and its population. This discussion focuses on small island developing states (SIDS). SIDS represent perhaps one of the most pronounced examples of developing country barriers. As Weisser observes, "[t]he smallness of SIDS leads to limited capacities both in terms of production and consumption. They are rarely in a position to develop economies of scale and cannot create substantial internal markets, as well as being unable to raise large amounts of capital/finance on the home market." SIDS arguably represent the epitome of both remoteness and smallness.

Island wind resources can be less reliable than mainland resources, alternating between periods of high and low winds. Wind power on islands can be more or less cost-effective than in larger electricity jurisdictions depending on fuel competition, and transmission access. If fossil fuels are imported and transported over long distances, wind can be particularly cost-competitive for island electricity suppliers. However, integrating large quantities of wind-generated power into an island grid is more challenging due to limited interconnections with other grids, leading to the potential of having a weak grid and less diversity of the wind resource. (See Transmission section of the Overview Module)

On the other hand, small populations and close-knit communities provide opportunities for community-based wind development models. Community support for wind is particularly important in a small community, as has been illustrated in the Philippines, the Maldives, the Greek Islands, Jamaica, and numerous other locations.

Photo credit: Joanna Lewis

References

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- 301. Badgley – Community Development through Wind Energy: Lessons from Wind Developments in Remote and Small Island Nations
- 303. Mianda & Lewis – Wind Energy in Greece: An Interdisciplinary Analysis of Greece's Progress Towards EU RES Targets

CHALLENGES: TRANSMISSION

- Wind power expansion can require both trunk-line transmission and backbone high-voltage transmission
- Barriers to transmission are site specific, often require coordination between project developers, utilities, and grid companies depending on the structure of the power sector
- Transmission costs in the US found to be about 25% of the total cost of building a wind project

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Technology-Specific Challenges: Transmission

There are generally two types of transmission lines that would be built for wind power. The first is **trunk-line transmission**, which runs from areas with high-quality wind resources to load centers or backbone transmission and often carries a high proportion of energy from wind and other renewable sources. The second is **backbone high-voltage transmission**, which runs across long distances to deliver energy from production areas to load centers.

While transmission challenges are a key barrier to wind energy globally, the reasons for these barriers are very site specific. Traditionally the electric utility builds transmission for its own power plants and recovers the costs as part of the electricity rates. When renewables are built by non-utility developers, securing needed transmission can be a challenge. China is trying to get around this by centrally planning large tracts of wind development called “wind bases” that allow the government to coordinate wind development with transmission planning. The Western United States is trying to address this by planning Renewable Energy Zones that would maximize resource utilization (including wind and solar) and minimize transmission costs. For example, the state of Texas has approved a plan for the building of enough transmission to serve some 18,000 MW of wind, as well as other renewable energy resources, which if carried out would exceed the state renewable portfolio standard by more than three times. (See Overview Module for more details).

While there is very little public information on the added cost of transmission for a wind project, a recent LBNL study synthesized available information from all existing US wind transmission studies and found that the unit cost of transmission for most projects in the U.S. is under $500/kW, or about 25% of the total cost of building a wind project (estimated at $2,000/kW). The median cost is $300/kW, or 15% of the total cost of the project. The authors concluded that in general, transmission is relatively inexpensive to build, and that the incremental cost of the transmission needed to meet a 20% wind scenario in the U.S. is roughly $60 billion. While this is a substantial sum to be sure, it is at most just 20% of the cost of building the wind projects themselves. Finally, in many cases new transmission or transmission upgrades would be required regardless of the type of generation being constructed so it is important to separate the costs specific to wind projects from those required for general electricity system support.

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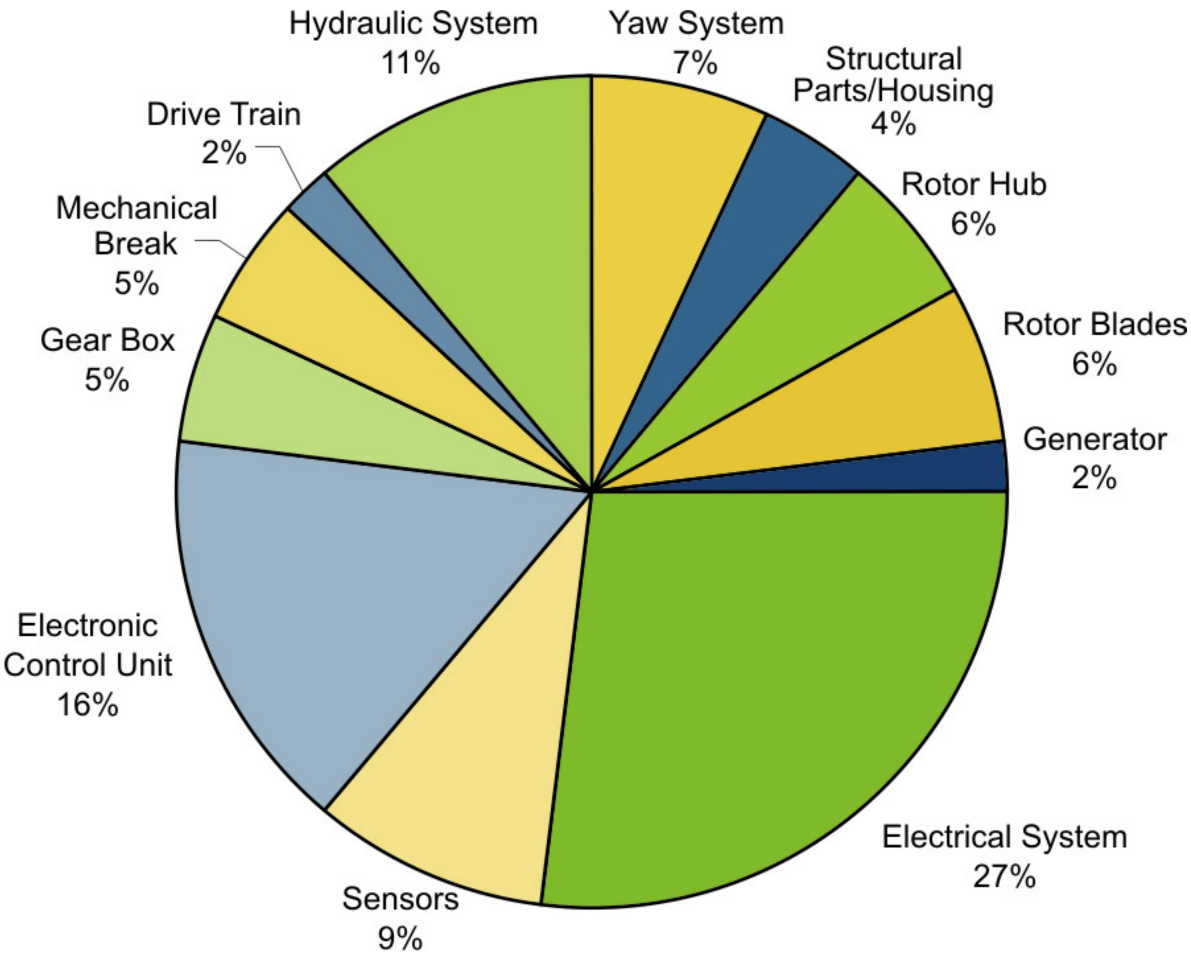
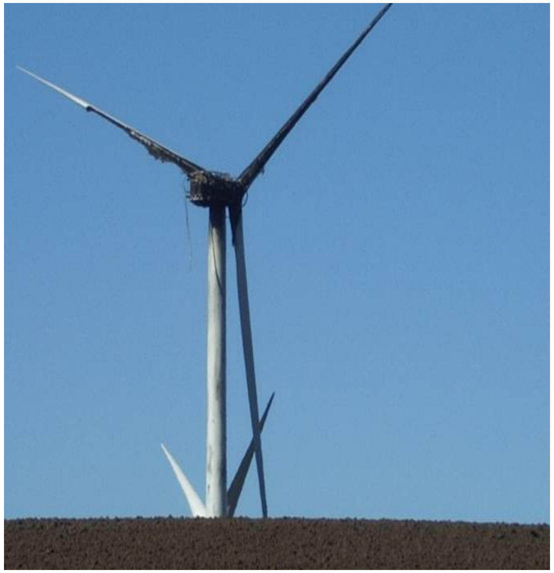
CHALLENGES: O&M

Types of Repairs on Wind Turbines from 2.5 kW to 1.5 MW





Wind turbine electrical fire at High Winds Wind Farm, Solano, CA (2004)

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Technology-Specific Challenges: Know-How

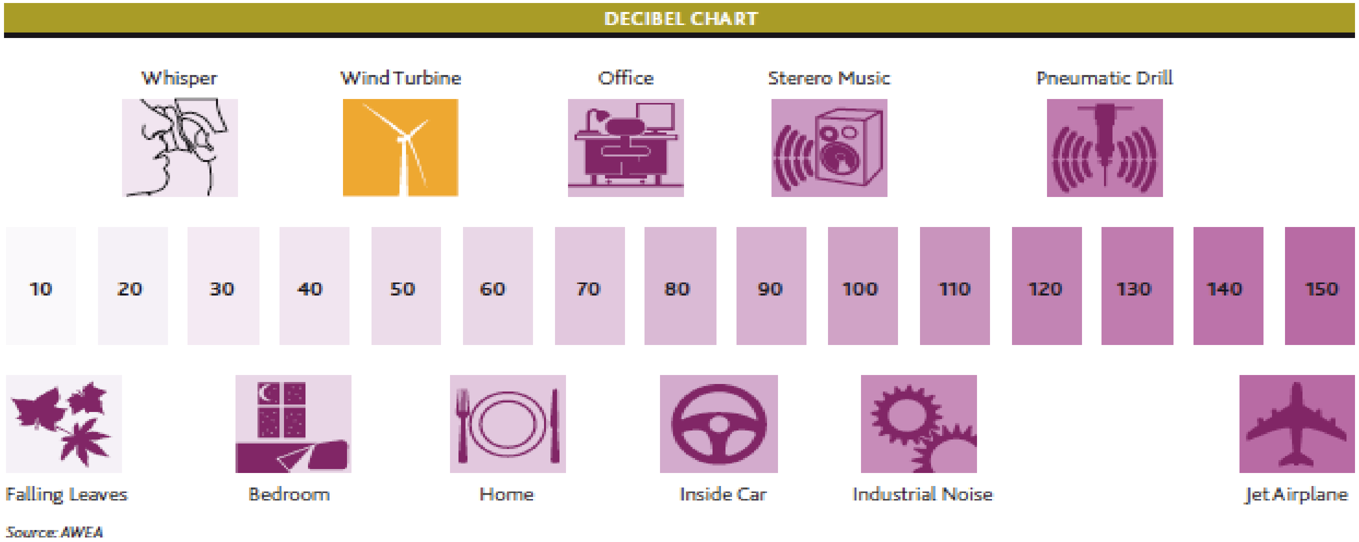
There have been many technological failures in recent years, which point to local capacity needs for successful operation and maintenance of wind farms. On large wind turbines, the majority of failures are related to the electric system (27%), followed by the electric control units (16%), and the hydraulic system (11%). Repairs and retrofits can be very costly and labor intensive, as well as result in lost electricity generation. As a result it is particularly important to have well-trained operation and maintenance teams available to service wind facilities. These can be either skilled teams brought in by the project developer to provide the required services or specially trained local labor. The terms for training of local maintenance technicians could be negotiated as part of the terms of the development of the wind project. For example, in a tendering process, one criteria used to evaluate the potential bids could be the training of local workers.

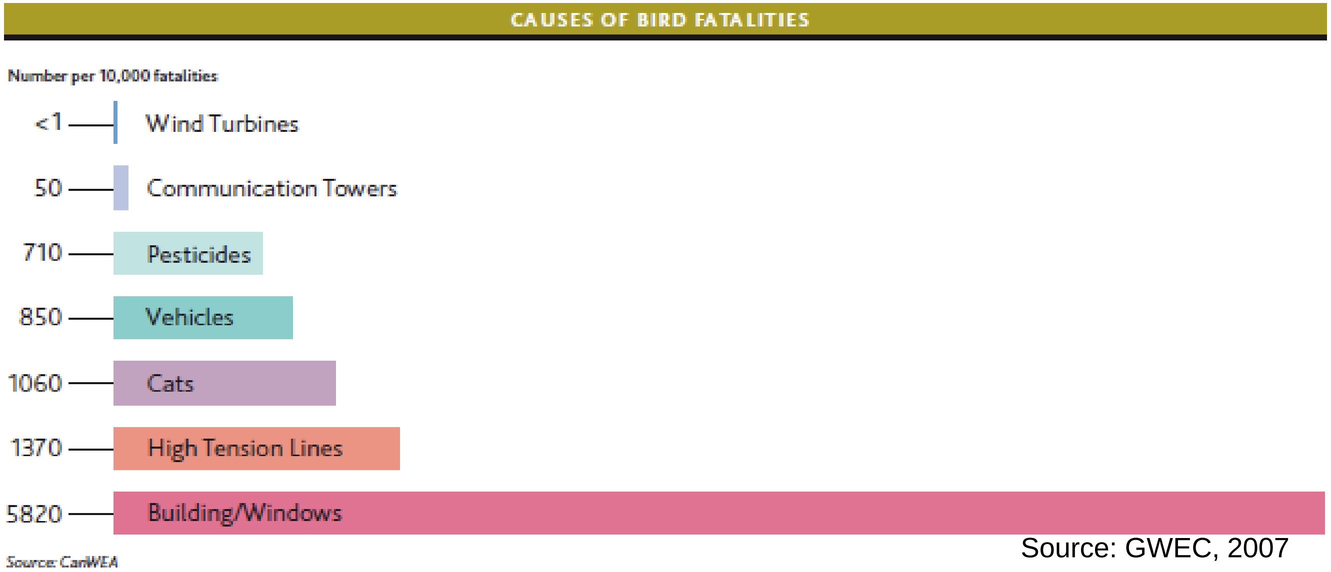
Photo credit: Joanna Lewis, 2004.

References

- 205. DOE – 20% Wind Energy by 2030

CHALLENGES: BIRD MORTALITY AND NOISE POLLUTION





Source: GWEC, 2007

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Technology-Specific Challenges: Bird Mortality and Noise Pollution

Both onshore and offshore wind turbines present direct and indirect hazards to birds and other avian species. For example, birds can hit a turbine blade when they are fixated on hunting and pass through its rotor plane; they can strike support structures; they can hit parts of towers; or they can collide with associated transmission and distribution (T&D) lines. These risks are exacerbated when turbines are placed on ridges and upwind slopes, built close to migration routes, or operated during periods of poor visibility such as fog, rain, and at night. Some species, such as bats, face additional risks from the rapid reduction in air pressure near turbine blades, which can cause internal hemorrhaging through a process known as barotrauma. Indirectly, wind farms can positively and negatively physically alter natural habitats, the quantity and quality of prey, and the availability of nesting sites.

There has been a huge range in the number of birds killed at wind farms around the world, which is thought to be due to differences in weather patterns, the layout of the wind farm, the type of wind technology, specific bird migration routes, and topography, along with the particular bird species and number of birds found in the area. One of the most deadly wind farms, Altamont Pass in Northern California, is located near bird migration routes. Not only does its terrain makes it an ideal location for birds of prey, it is also populated with mostly outdated turbine designs. These older models of turbines were mounted on towers at the same level as bird flight paths (60-80 feet in height). They are also smaller machines (it takes between 15 and 34 Altamont turbines to produce as much electricity as one modern turbine) which spin at faster speeds. Newer wind farms produce the same amount of electricity with fewer turbines, and the turbines are mounted on towers that typically avoid birds at a height of 200-260 feet. Larger turbines tend to be spaced at a greater distance between each other, and many blades have slower rotational speeds which are less harmful to birds.

It is standard practice in many countries for all wind projects to involve habitat mapping, nest surveys, and general avian use surveys with a particular focus on threatened, engendered, or sensitive species. In some cases the standards are so strict they often cause developers to significantly modify the layout of wind farms and to abandon high-risk projects. However, many wind farm developers have begun to agree to active mitigation measures as a means of allowing development to continue in spite of known risk of mortality.

Death rates of all flying animals have decreased in recent years as wind power entrepreneurs have installed larger turbine blades that turn more slowly, and have used advanced thermal monitoring and radar tracking to site turbines more carefully. Developers commonly avoid placing wind farms in areas of high nesting or seasonal density of birds, remove potential perches on lattice towers, and utilize micro-siting and bird sensitivity mapping to position turbines in ways that minimize intersection with flight paths.

Concerns about avian and bat mortality have also been a concern of environmental groups who might otherwise support wind power development. In the United States, wind industry leaders have teamed with environmental advocates to establish the American Wind and Wildlife Institute, with a goal of facilitating “timely and responsible development of wind energy while protecting wildlife and wildlife habitat.”

Although birds do collide with wind turbines at some sites, modern wind power plants are collectively far less harmful to birds than numerous other hazards. The leading human-related causes of bird kills in the United States, according to the US Fish and Wildlife Service, are cats (1 billion deaths per year), buildings (up to 1 bn), hunters (100 million), vehicles (60-80 m), as well as communications towers, pesticides and power lines. A recent study estimates that wind farms and nuclear power stations are responsible each for between 0.3 and 0.4 fatalities per gigawatt-hour (GWh) of electricity while fossil-fueled power stations are responsible for about 5.2 fatalities per GWh. While this paper is only a preliminary assessment, the estimate means that wind farms killed approximately seven thousand birds in the United States in 2006 but nuclear plants killed about 327,000 and fossil-fueled power plants 14.5 million.

While noise pollution from wind farms has been a cause of complaint in some developed country wind projects, the decibel count for wind farms is much lower than of industrial activity or a jet airplane.

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Wind Power

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- Global Status and Costs
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Best Practices

BEST PRACTICES: WIND POWER

To promote deployment:

- Stable policy environment (5-10 years)
- Clear regulatory guidelines
- Assistance through price subsidies that can be phased out as experience increases
- Community involvement, education, and outreach is crucial, particularly in isolated areas or small towns

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Best Practices to Promote Wind Development

In reviewing global experience with wind power development to date, and the implications for “best practices” to promote wind power development with respect to **wind power deployment** in the developing world, the following things stand out.

A stable policy environment is crucial to promoting wind power development. There are several different policies that have been shown to be successful in promoting wind power deployment, including feed-in tariffs, renewable portfolio standards, and tax incentives, and the choice of the best instrument may vary according to national or sub-national characteristics. However, no matter the instrument utilized, long-term certainty over the policy instrument is very important to shaping long-term investment decisions in wind power. For wind policy instruments, stable usually means at least a 5-10 year time horizon.

Clear and transparent regulatory guidelines are also highly important, particularly in a developing country setting where access to information can be more difficult particularly for outside (often foreign) investors, but also for local investors. This can mean anything from making policies clear, easily available to the public, and accessible in English on the internet, to providing policy briefings and developer information and training sessions, as well as opportunities for local conferences and workshops to build stakeholder awareness.

Subsidies can be useful in the early stages of wind power development, but as experience increases, **assistance can be phased out over time**. Cost declines should occur with experience and learning. Care should be taken to design policy support programs that allow for this gradual phase out with the rules and timing made clear up front so that investors are aware of the phase out, and so that projects don’t become overly reliant on the subsidy.

Finally, **community involvement in wind development can be critical, particularly in isolated areas or small towns** where a wind project will directly impact a local community, and its support can make or break a project. Public education and outreach about wind energy can be very important to gaining project acceptance and success. For example, in the Bangui Bay wind farm of the Philippines, the local utility, Northwind Power, took several steps to support the communities located near its wind turbines. The utility employed local workers to service transmission lines and many were trained as technicians. The utility also pays one centavo into a community fund for each kilowatt-hour it produces. This money, in turn, can be used by the local municipalities to carry out community improvement projects. Even the mere presence of the turbines has promoted tourism, providing additional revenue flow into the communities. This symbiotic relationship promises to improve the standard of living in the area while simultaneously allowing the utility company to generate profit.

BEST PRACTICES: WIND POWER (2)

To promote industry development:

- Stable policy environments support domestic wind turbine manufacturers that can also compete globally
- Licensing agreements can be successful, but full control over intellectual property rights superior (e.g. obtained through buy-out)
- Vertically integrated supply chain can reduce costs, ensure stable production (particularly in highly competitive market)

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Best Practices to Promote Wind Industry Development

In reviewing global experience with wind power development to date, and the implications for “best practices” to promote wind power development with respect to wind power industry development in the developing world, the following things stand out.

Stable policy environments can help to support the establishment of new, domestic wind turbine manufacturers that can also compete globally. In countries that were late-comers to the wind power industry such as Spain, India, and China, stable policy support has led to the establishment of many leading global wind turbine manufacturers.

For many years, late-comers to the wind turbine manufacturing industry, and developing countries in particular, have relied on licensing agreements to obtain technology. While these models of technology transfer can be successful, **full control over intellectual property rights is generally superior** since it gives the recipient companies more control over the IPR on which they rely. Recently, Indian manufacturer Suzlon and Chinese manufacturer Goldwind have purchased smaller European firms outright (Repower in the case of Suzlon, and Vensys in the case of Goldwind), giving them control over the IPR that they had previously licensed from these firms.

Finally, a **vertically integrated supply chain for wind power system manufacturing can reduce overall equipment costs and help to ensure stable access to wind power equipment** in case of shortages, particularly in developing countries with lower labor and materials costs. Wind turbines being manufactured in China by Chinese companies are selling their turbines for 65% less than comparable US and European manufacturers.

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