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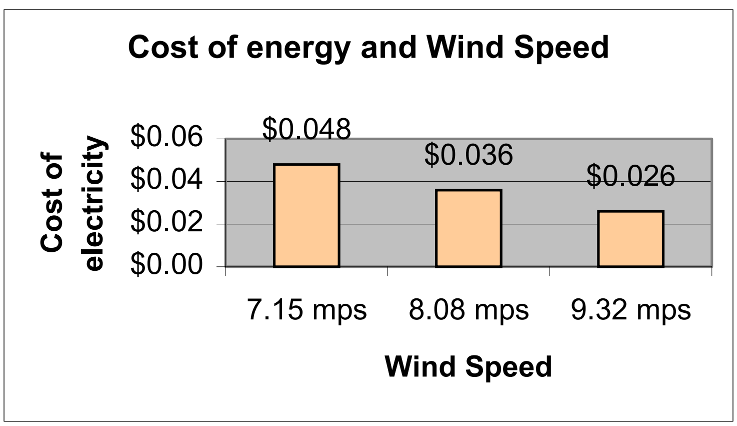
The Economics of Wind Energy

The economics of wind energy have changed dramatically over the past twenty years, as the cost of wind power has fallen approximately 90 percent during that period. Despite that progress, the wind industry is still somewhat immature, with production volumes that pale in comparison to what they will be two decades from now. Thus, the factors affecting the cost of wind energy are still rapidly changing, and wind energy's costs will continue to decline as the industry grows and matures.

A number of factors determine the economics of utility-scale wind energy and its competitiveness in the energy marketplace.

The cost of wind energy varies widely depending upon the wind speed at a given project site. The energy that can be tapped from the wind is proportional to the cube of the wind speed, so a slight increase in wind speed results in a large increase in electricity generation. Consider two sites, one with an average wind speed of 14 miles per hour (mph) and the other with average winds of 16 mph. All other things being equal, a wind turbine at the second site will generate **nearly 50% more electricity** than it would at the first location.



The three examples above are for costs per kilowatt-hour for a 51 MW wind farm at three different average wind speeds expressed in meters per second. Cost figures include the current wind production tax credit.

Improvements in turbine design bring down costs. The taller the turbine tower and the larger the area swept by the blades, the more powerful and productive the turbine. The swept area of a turbine rotor (a circle) is a function of the square of the blade length (the circle's radius).

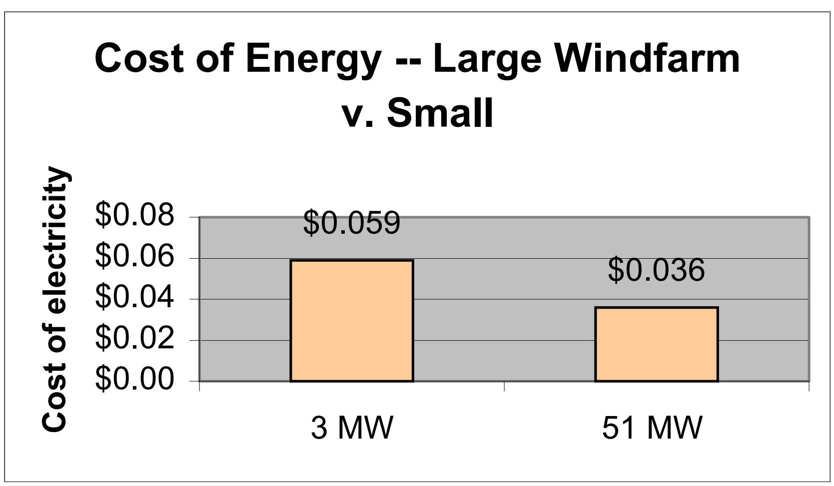
Therefore, a fivefold increase in rotor diameter (from 10 meters on a 25-kW turbine like those built in the 1980s to 50 meters on a 750-kW turbine common today) yields a 55-fold increase in yearly electricity output, partly because the swept area is 25 times larger and partly because the tower height has increased substantially, and wind speeds increase with distance from the ground.

Advances in electronic monitoring and controls, blade design, and other features have also contributed to a drop in cost. The following table shows how a modern 1.65-MW turbine generates 120 times the electricity at 20 times the cost of an older 25kW-turbine:

	1981	2000
Rated Capacity	**1981: 25 kW**	**2000: 1,650 kW**
Rotor Diameter	**10 meters**	**71 meters**
Total Cost ($000)	**$65**	**$1,300**
Cost per kW	**$2,600**	**$790**
Output, kWh/year	**45,000**	**5.6 million**

<u>A large wind farm is more economical than a small one</u>. Assuming the same average wind speed of 18 mph and identical wind turbine sizes, a 3–MW wind project delivers electricity at a cost of $0.059 per kWh and a 51-MW project delivers electricity at $0.036 per kWh—**a drop in costs of $0.023, or nearly 40%.** Any project has transaction costs that can be spread over more kilowatt-hours with a larger project. Similarly, a larger project has lower O&M (operations and maintenance) costs per kilowatt-hour because of the efficiencies of managing a larger wind farm.

Cost figures include the current wind production tax credit.



Optimal configuration of the turbines to take the best advantage of micro-features on the terrain will also improve a project's productivity. [i]

The cost of financing affects that of wind energy. Wind energy is capital-intensive, so the cost of financing constitutes a large variable in a wind energy project's economics. For a variety of reasons, financing for wind projects remains more expensive than for mainstream forms of electricity generation.

Project ownership affects cost of financing and the economics of a wind power project. Independent ownership—that is, financing of projects by private power producers on a stand-alone basis, which is how the vast majority of U.S. wind projects are financed—is more expensive than utility-owned financing. According to a study by Lawrence Berkeley National Laboratory, [ii] utility ownership of a wind facility results in a significantly lower estimated levelized cost of energy, because lower-cost financing available to large electric utilities (IOUs, or investor-owned utilities) is not available for non-IOU wind projects. IOU ownership reduces levelized costs by approximately 30%, the study found.

In addition, although wind turbine technology has steadily progressed to a point where its reliability is today comparable to that of other energy technologies, it is still regarded as "novel" and "risky" by many members of the U.S. financial community (most U.S. projects are still financed by European-based lenders). Lenders therefore offer less favorable financing terms and demand a higher return on investment than for more "conventional" energy sources.

Table: The economics of a 50-MW wind farm at a wind site with average wind speed of 13-17 mph (class 4). Figures are indicative only.

Project size:	50 MW
Capital cost:	$50 million ($1 million per MW)
Annual power production (assuming 35% capacity factor)	150 million kWh
Financing:	60% debt, 40% equity
Annual gross revenue:	$6 million (assuming power purchase price of 4 cents per kWh)
Expenses:	-Debt: 60% (15 years at 9.5%) -Distribution 22% -Operation and maintenance (8%) -Land, property taxes, or rent 5% -Mgt fees, insurance 5%
Tax credit and depreciation:	-5-year depreciation on wind equipment -1.5 c/kWh credit adjusted for inflation during first ten years of operation

The Lawrence Berkeley Laboratory study found that a 50-MW wind farm delivering power at just under 5 cents per kWh would, if using typical natural gas project financing terms, generate electricity for 3.69 cents per kWh.

Transmission, tax, environmental, and other policies also affect the economics of wind.
Transmission and market access constraints can significantly affect the cost of wind energy. Since wind speeds vary, wind plant operators cannot perfectly predict the amount of electricity they will be delivering to transmission lines in a given hour. Deviations from schedule are often penalized without regard to whether they increase or decrease system costs. Interconnection procedures are not standardized, and utilities have on occasion imposed such difficult and burdensome requirement on wind plants for connection to transmission lines that wind companies have chosen to build their own lines instead. (See "Fair Transmission Access for Wind" at http://www.awea.org/policy/documents/transmission.PDF).

As electricity markets are restructured and long-term power purchase agreements give way to trading on power exchanges, transmission and market access conditions will play an increasingly important role in the economics of a wind project.

The federal tax code, which provides a variety of permanent and temporary incentives for conventional forms of energy, also includes a production tax credit (PTC) for wind energy and a 5-year accelerated depreciation schedule for wind turbines. The 1.5 cent-per-kWh PTC is adjusted for inflation (currently it stands at 1.7 cents/kWh) and supports electricity generated from utility-scale wind turbines for the first ten years of their operation. The PTC, first adopted in 1992, was extended in 1999, and again, after its expiration in 2001, until December 31, 2003. In order to qualify for the credit, generators must now complete installations and start production before the 2003 expiration date. . The PTC may be reduced or cancelled if a project applies for state incentives such as a grant or no-interest loan, under federal "anti-double-dipping" rules. [iii]

The PTC, a key incentive, helps level the economic playing field for wind projects in energy markets where other forms of energy are also subsizided. It must be noted, however, that the current “on-again, off-again” status of the credit is hobbling project development and the industry as a whole. Uncertainty also affects relationships with vendors and substantially increases costs as orders are rushed to meet PTC deadlines or as planning grinds to a halt and income is lost while the industry awaits an extension. One major U.S. developer stated that a five-year extension of the PTC would provide enough long-term certainty to squeeze an additional 25 percent out of vendor costs. The wind energy industry is currently seeking a longer-term extension, until 2006.

Stricter environmental regulations enhance wind energy’s competitiveness. Wind power’s environmental impact per unit of electricity generated is much lower than that of mainstream forms of electricity generation, as wind energy neither emits pollutants, wastes, or greenhouse gases, nor damages the environment through resource extraction. The higher the air quality and other environmental standards adopted in a country, the more competitive wind energy therefore becomes in the marketplace. Conversely, a relaxation of standards or failure to internalize environmental costs through pollution charges or other processes makes polluting forms of electricity generation appear deceptively cheap.[iv] This is an important economic issue, because the hidden "subsidy" that governments and markets give to polluting energy sources by partially or fully ignoring their health and environmental costs is typically much larger than direct subsidies to such energy sources.

Wind energy provides ancillary economic benefits:

- less dependence on fossil fuels, which can be subject to rapid price fluctuations and supply problems (the price of natural gas, for example, more than doubled over a period of a few months in 2000);
- steady income for farmers or ranchers who own the land on which windfarms are built, and for the communities in which they live (in Texas, for example, ranchers have been reaping income from the wind even as their royalties from oil wells have declined);
- an increase in the property tax base for rural counties.

For information on the costs of wind energy and that of other electricity sources, see http://www.awea.org/pubs/factsheets/Cost2001.PDF

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[i] "Economics of Wind Farm Layout," Alan Germain and Donald Bain, Windpower 1997 proceedings (American Wind Energy Association, Washington, D.C.).
[ii] "Alternative Windpower Ownership Structures: Financing Terms and Project Costs," Ryan Wiser and Edward Kahn, Lawrence Berkeley Laboratory, Energy and Environment Division, 1996.
[iii] "Anti-Double Dipping Rules for Federal Tax Incentives, Edwin Ing, Windpower 1997 proceedings.
[iv] The cost of producing electricity from coal or oil would double and the cost of electricity production from gas would increase by 30% if some external costs such as damage to the environment (not including that of global warming) and to health were taken into account, according to a study by the European Union (more information available at http://europa.eu.int/comm/research/press/2001/pr2007en.html). Similarly, in the U.S., state attempts to set up a process by which some of the environmental costs of electricity production, or externalities, could be taken into account in economic calculations have focused on air emissions and set externalities estimates in the range of 3-6 cents per kWh for coal and 0.5 to 2 cents per kWh for natural gas. For a comprehensive study see Ottinger et al., “Environmental Costs of Electricity,” Pace University Center for Environmental Legal Studies, Oceana Publications, 1990.

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