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WILL THE U.S. HARNESS THE WIND? PROSPECTS FOR WIND-GENERATED ELECTRICITY

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Within the last few years, wind power has emerged as the only commercially competitive renewable energy source. Wind power has the potential to meet up to 20 percent of future U.S. electricity demand and develop into a worldwide industry worth hundreds of billions of dollars. Factors combining to create new opportunities for wind power include (i) continual increases in performance, reliability, and cost-effectiveness of modern wind turbines, (ii) a need to reduce the environmental costs of fossil fuel use, (iii) the move towards a competitive American energy market, and (iv) a renewed public and government desire for energy alternatives. Appropriate temporary government policies could reduce uncertainty in the U.S. energy market and spur wind power growth, just as similar efforts helped develop fossil fuels and nuclear power. This paper argues that supportive and consistent government policies are the key to the success of wind power in the United States.

INTRODUCTION

Within the last few years, wind power has emerged as the only commercially competitive renewable energy source (Tietenberg 1996, 163). Turbine-generated power has the potential to meet up to 20 percent of

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future U.S. electricity demand and develop into a worldwide industry worth hundreds of billions of dollars.

A number of factors are combining to create new opportunities for wind power. These include the continual increases in performance, reliability, and cost-effectiveness of modern wind turbines, a need to reduce the environmental costs of fossil fuel use, the move towards a competitive multifaceted American energy market, and a renewed public and government desire for energy alternatives.

This paper analyzes the current political and technical state of wind-generated electricity with the aim of assessing its potential for implementation and expansion in the near future. The first section considers the background within which wind technologies will be introduced and analyzes the commercial and technical feasibility of large-scale wind farms. Subsequent sections consider the market forces affecting the development of wind power, the environmental advantages of harnessing the wind, and its popular appeal among the public. Finally, this paper argues that supportive government policies are the key to the success of wind power in the United States.

Although this report focuses largely on the U.S. market and on grid-connected turbines, most of the conclusions made here apply equally to dispersed grid-connected systems or remote stand-alone systems.[1] Many of the findings also have global relevance and can be used to assess the feasibility of harnessing wind power in both industrialized and developing countries.

Background

Currently, the United States uses fossil fuels to generate 67 percent of its electricity (CEQ 1995, 319).[2] Limited supplies and environmental side effects, however, make this level of consumption unsustainable. Given that industrialized nations are unwilling to radically alter their lifestyles, and that energy conservation possibilities are limited, alternative energy sources must be found. Future demands will be substantial. According to the Department of Energy's Energy Information Agency (EIA), U.S. suppliers will need to increase generating capacity 26 percent by the year 2010 in order to satisfy the growth in electricity demand and to replace retiring facilities (CEQ 1995, 323).[3]

By tapping some of the enormous amount of unused supply, wind power can meet a significant share of this future demand. The atmosphere of the earth functions as a battery, storing radiant energy from the sun.

Some of this solar energy is converted into mechanical energy in the form of wind, which propeller-driven turbines can harness to generate electricity. The National Resources Energy Laboratory estimates that the 12 Great Plains states—the windiest region of the United States—have the wind energy potential to produce nearly four times the total amount of electricity consumed in the United States (NWTCb). To provide just 20 percent of the nation's energy, about 560,000 million-kilowatt hours (kWh) per year, only 0.6 percent of the land in the lower 48 states would be needed for wind turbine farms. This area equates to 16,000 square miles, or about one-ninth the state of Montana. Moreover, less than five percent of this land would actually be used for the turbines themselves, associated electrical equipment, and access roads. The remainder of the land can almost always maintain its existing use, in most cases farming or ranching (AWEAd).

In the United States, 1,700 megawatts (MW) of installed wind capacity currently produces over 3.5 billion kWh of electricity each year (AWEAe, NWTCc). This is enough electricity to meet the needs of over 570,000 homes, reducing 5,700,000 metric tons of CO_2 output that would otherwise be emitted from fossil fuel sources. Over 90 percent of this wind-generated electricity is produced in California—capacity left over from an early 1980s turbine installation boom inspired by favorable state government incentives. These incentives, and the role of government policies in general, are considered further on in this paper.

Commercial and Technical Feasibility of Large-Scale Wind Farms

Wind power has emerged as the most commercially competitive renewable energy source.[4] Generation costs have dropped an order of magnitude in the past two decades and are now comparable to conventional energy sources (DOEb). Today, unlike photovoltaic or geothermal renewables, no technical constraints prevent the large-scale adoption of turbine-generated electricity.

However, despite wind power's declining costs and inherent flexibility,[5] it does suffer from several disadvantages. These drawbacks stem mainly from the variability of seasonal wind patterns, the geographic distributions of wind locations relative to areas of electricity demand, and siting issues. Fortunately, incorporating wind farms into existing power grids, diversifying site locations, and setting up energy storage systems can mitigate these problems.

Turbine Technology

The modern wind turbine is a large, two or three-blade rotor mounted on a simple tower. Most turbines used on wind farms are 30 to 40 meters high, have rotors of a similar diameter, and produce around 500 kilowatts of electricity. However, both smaller models (common in stand-alone systems) and much larger models (up to 2 MWs) are available.

Although today's commercial turbines are essentially the same as those designed 50 years ago, modern technology has allowed for several significant advances. Lightweight composite-material blades enable rotors to turn faster with less wind and have helped standardize production techniques. Microprocessors now control for optimal rotor rotation using brakes to prevent overturning and switching gears to correlate with wind velocity. Some of the newest turbines even have "variable pitch" blades that can be adjusted to catch the wind, similar to a sail on a sailboat. These technological advances have contributed to lower generation costs. The greatest declines, however, have resulted from organizational developments such as standardized installation and maintenance procedures and improved understanding of how to place turbines more effectively (Weinberg and Williams 1990, 146–147). Further cost reductions are likely as wind turbines become mass-produced on a large scale.

Declining Generation Costs

The cost of wind energy technology has declined over 80 percent since the early 1980s when the majority of existing U.S. wind farms were installed in California (AWEAa). Electricity generating costs have gone from about $0.30/kWh in 1981 to a levelized cost of $0.045/kWh today. This compares with a levelized cost of a $0.039/kWh for a coal fired plant. That number, however, may be conservative. An analysis by the California Energy Commission showed the levelized costs of wind were $0.046/kWh compared with $0.046/kWh to $0.060/kWh for coal technologies.[6] By the year 2000, wind-generated electricity may cost as little as $0.025/kWh in ideal locations, making it comparable with all conventional electricity generation sources, including hydropower (AWEAe, NWTCc).

These figures compare only costs of generating wind power. If conventional power sources were calculated to include their social and environmental costs, wind power would be even more economical. These "externalities" associated with conventional sources are considerable. They include the health and environmental costs of pollution generated by the combustion of fossil fuels, the environmental degradation associated with many hydroelectric dams, and the military and economic security costs associated with relying on imports. Furthermore, conventional energy sources continue to benefit from overt and hidden financial subsidies driven by political favoritism and the traditional priorities of industry decision-makers.

Other Cost Considerations

Wind farms enjoy low capital investment requirements, quick installation times, and low maintenance costs. New turbines are coming on line that can cost as little as $750 per kilowatt and are extremely reliable over lifetimes of 20 to 30 years (NWTCc). Of course, wind farms have no fuel costs after initial installation. It costs approximately half as much to build a new wind farm as it does to install a nuclear plant with comparable capacity (Wasserman 1997, 12).

Wind energy is also remarkably scaleable. Capacity can range from a single small turbine supplying a rural, off-the-grid site to fields of turbines producing output levels useful for urban areas and industry. This lack of capital-intensive "lumpiness" that characterizes many fossil fuel, nuclear, and hydroelectric plants is an advantage for wind energy because predicting future fluctuations in electricity demand is difficult (Battle for World Power, 1995).

Speed of construction is another unique advantage of wind farms. Since the only construction requirements are concrete foundations and service roads, a typical farm takes less than a year to build. This compares with a decade or more for a nuclear plant and several years for a typical fossil fuel plant.

The operation and maintenance requirements for turbine farms are also relatively low. A study of 29 turbines in western Jutland, Denmark, estimated that operation and maintenance costs were 1.75 percent of the installed cost of the turbine, a figure the authors of the study predicted would probably decline as reliability and capacity increased (Johansson et al 1993, 147). In one maintenance study, the costs of maintaining a 150-kilowatt turbine included only about 17 worker-hours of labor per year (plus an extra 14 worker-hours within the first 100 hours of operation of the turbine) and required only inexpensive materials such as grease, hydraulic fluid, and brake pads (Johansson et al 1993, 148).

Availability and Reliability Considerations

One of the biggest complaints leveled by wind power critics is the intermittent nature of the supply. Although consumers place a high value on consistent electricity power supplies, they have little cause for concern if the power generated by wind is small relative to total system capacity. The problems created by intermittent electricity production are not qualitatively different from those created by daily or seasonal demand fluctuations. In fact, demand for electricity often more than doubles during the day, with even greater seasonal variations (Johansson et al 1993, 1028).

A diverse energy portfolio is the key to dealing with these problems. Even the most strident wind supporters agree that no more than 20 percent of the power on a given grid should be wind-generated. This low percentage allows grid managers to adjust to periods of little or no wind generation, much as they must do to accommodate demand fluctuations. In fact, if wind generation is only a fraction of total system loads, and is not correlated with demand, even a wind farm with intermittent supply capability can be treated as a statistically reliable plant with a capacity equal to its average output (Johansson et al 1993, 1028).

Combining several geographically dispersed wind farms is another way to increase the consistency of supply. Combined farms should be placed as far apart as possible to maximize the likelihood that lack of wind at one site will be compensated for by wind at a connected site. Data from California supports this concept. Although the output of a two-megawatt farm in Sacramento fell below 200 kilowatts 44 percent of the time, a system combining the output of four geographically dispersed two-megawatt sites would drop below the 200-kilowatt level about 20 percent of the time. Furthermore, if a large number of sites from all over the state were to be combined on the same grid, only seven percent of the time would output fall below 200 kilowatts (Johansson et al 1993, 1031).

Ideally, wind-generated electricity would supply local utility grids whenever possible. This would reduce fuel costs (because wind is free when available) and lower the environmental burden associated with fossil fuel plants. When wind is unavailable, utilities could buy electricity from other grids or adjust the output of their conventional plants accordingly. A similar system already exists among conventional power generation facilities. Typically, power companies adjust electricity production to match expected demand based on meteorological predictions and historic-use patterns. This is not an exact science, however, and plants often produce too much or too little electricity. To make up for these differences in supply and demand, electricity distributors (usually the regional utility companies) buy or sell excess power on the market, much like any other commodity. Inter-grid and even interstate transmission lines exist to transport the electricity. Today, virtually every U.S. electricity grid is interconnected, and trading is becoming increasingly common as the market moves towards deregulation.

Although wind turbines lack storage capacity—unlike fossil fuel systems that can store energy in the form of raw fossil fuel or hydroelectric dams that can store water in reservoirs—innovative energy storage systems can help. Pumped hydroelectricity is the most common method. During periods of slack demand, wind power is used to pump water from a lower reservoir to a higher one. Releasing the water back to the lower reservoir through a hydroelectric system can recover up to 75 percent of the electricity used for pumping. Batteries may also be used to store energy generated during windy times for use when wind levels are low. These are common components of remote stand-alone systems. Other methods for recapturing power include mechanical storage via spinning flywheels, physical storage using compressed gases, or thermal storage in the form of heated fluids (Johansson et al 1993, 1042–1043). Another possibility may be to use wind-generated electricity to produce hydrogen that can then be converted back to electricity via fuel cells (Williams 1993).

Availability and Transmission Considerations

Siting is a critical component of any successful wind farm. The challenge is to place installations in windy areas far enough apart to avoid correlations in wind supplies, while remaining close enough to existing electricity grids to avoid the potentially prohibitive cost of installing new transmission lines.

Unfortunately, the most plentiful wind resources in the U.S. are in the Great Plains, away from most urban and industrial centers. One study estimated that transmission costs for wind systems, exclusive of right-of-way costs, are about $0.036 per kilowatt-year per kilometer (Johansson et al 1993, 1041). Thus, transmission costs for a wind farm 100 kilometers from a grid would add $3.6 per kilowatt-year. Moreover, the costs of new lines can be prohibitive. Various studies calculate the construction costs of additional lines to be between $300,000 to $1 million per mile. Another drawback is that the lines created for wind farms are often underutilized because they must be sized for peak output (Bradley n.d.).

Nevertheless, studies by the National Wind Technology Center (NWTC), a division of the National Renewable Energy Laboratories (NREL), have shown that a remarkable amount of U.S. land is suitable for wind production (NWTCb). Even after excluding windy areas not suitable for development due to environmental and land-use considerations, the NWTC still found that 460,000 square kilometers—about six percent of total land in the contiguous United States—contained power "class four" winds or higher.[7] Furthermore, there is a significant amount of overlap between these class four areas and those that contain existing transmission line networks. It will be at these intersections that construction of the first generation of large-scale wind farms will occur.

Market Forces Driving Wind Power

A number of market forces are interacting simultaneously to create the necessary framework for wide-scale development of wind-generated electricity facilities. Chief among these is the restructuring of the U.S. energy market. Restructuring promises to price energy production closer to its true costs and diversify the options available to consumers. Business interests are also beginning to get involved. The technological advances that have enhanced the commercial feasibility of wind-generated electricity analyzed earlier, along with the lucrative nature of potential markets, have combined to form a new generation of wind turbine manufactures eager to take advantage of the emerging market.

The Restructuring of the Energy Market

Bolstered by the successful deregulation of the transportation and telecommunications industries, government policies are systematically restructuring the traditionally monopolistic electricity market. These changes promise to alter dramatically the business of generating, transmitting, and distributing power.

How the market will evolve is uncertain. Competition will surely lower prices in the current inefficient system, but at what costs? Many fear environmental protections will suffer as utilities try to cut costs any way possible. Others see restructuring as an opportunity for renewable energy sources to break into a market dominated by the interests of conventional power producers. In a new regime of consumer choice, environmental awareness may increase the demand for renewables. Restructuring is a unique opportunity for policy-makers to create government strategies that can help promote renewable energy sources.

Unfortunately, despite these opportunities, the uncertainty over how the electric industry will evolve tends to favor the status quo. Utility companies are unwilling to risk major capital expenditures and realignment until government policies are finalized.

Economic Development Potential

Future increases in electricity demand, coupled with continued progress in wind-generating technologies, will create a huge worldwide market for wind products. By the year 2000, wind may generate about $3 billion in annual global sales (Wasserman 1997, 12). By 2020, the World Energy Council estimates the amount of new worldwide wind capacity will total between 180,000 MW and 474,000 MW—equating to $150 billion to $400 billion worth of business (AWEAa).

Utilizing wind will also create jobs. Recent studies show that between 440 and 460 jobs are created for each billion kilowatt-hours of annual wind energy generation (NREL). Thus, under American Wind Energy Association's optimistic, yet feasible, scenario of installing 30,000 MW of capacity by 2010 (generating 105 billion kWh annually), about 50,000 jobs would be created. Furthermore, since any new wind-generating capacity will probably meet future demand, rather than replace existing conventional plants, these new jobs will not be at the expense of those at existing plants.

Until as recently as 1990, U.S. producers led the rapidly expanding world wind market. Since then, however, the removal of favorable government policies, the declining cost of fossil fuels, and the uncertainty surrounding restructuring have combined to rapidly erode America's dominant position. Today, Denmark, Germany, and Japan have captured the market, promoting installation at home and exporting millions of dollars worth of turbines abroad.

The United States must act now to recapture its lost dominance. Installing several large farms for the American electricity market will drive technological innovation and create economies of scale to give the United States a competitive edge in future exports.

Wind Farm Land Use

Wind farms use a considerable amount of land, about 0.12 square kilometers per gigawatt (AWEAd).[8] Turbines need to be spaced about 300 to 400 meters apart, roughly 10 times the diameter of their rotors. Closer spacing results in uneven wind flow between machines, lowering efficiency, and increasing stress on the units.

Typically, in order to lower initial costs, land is leased. At Altamont Pass, one of the major Californian installations, the land cost was a fixed percentage of the revenues produced by the farm. Since the market price was \$0.08/kWh (guaranteed by the state), the typical royalty rate was about \$0.003/kWh (Johansson et al 1993, 149). These royalties caused land prices to rise from \$400 to \$2,000 per acre (Weinberg and Williams 1990, 147). Moreover, the utility of the land was virtually unaffected. Since the turbines only used about five percent of the land they were sited on, the ranchers who owned most of the Altamont land were able to continue to let their cattle graze under the wind machines.

An alternative, offshore siting, is becoming more prevalent. In Denmark, several offshore farms take advantage of strong and steady offshore winds, and the "free" space. One project is situated six kilometers off the shore of Jutland in an area where the sea depth is three to five meters. So far, since their installation in 1995, the ten 500-kilowatt turbines installed have not met with any operational problems and have in fact produced 25 percent more electricity than originally expected (CADDET 1996).

Environmental Considerations

We pay a heavy environmental cost for our current reliance on fossil fuel-generated electricity. Despite considerable progress since the 1990 Clean Air Act and substantial investments in pollution control technologies, power plants are still the largest polluters in the United States. They are responsible for 66 percent of SO_2 emissions, 35 percent of CO_2 emissions, 30 percent of NO_x emissions, and 21 percent of the mercury released into the environment (AWEAa).

Wind-generated electricity represents a clean alternative source. Every 10,000 MW of wind capacity installed will reduce approximately 33 million metric tons (MMT) of CO_2 emissions annually if it replaces coal-fired generating capacity, or about 21 MMT if it replaces generation from the U.S. average fuel mix (see Endnote 2) (AWEAe).

An energy balance analysis of wind power also reveals lower environmental costs. An energy balance analysis considers the materials and energy used in manufacturing a particular product. Three separate European studies, showed that the energy generated by wind turbines pays for the materials used to make it in just a few months. This compares to photovoltaics that have a "payback" period of several years.[9] The comparison with coal-fired plants is even more striking. A Danish study found that over a 25-year lifespan, the typical coal-fired plant emits 360 times more SO_x, NO_x, and CO_2 to generate a comparable amount of wind-generated electricity (AWEAb).

Wind Power and Public Opinion

A growing awareness of the health and environmental costs of fossil fuel and nuclear power generation has made renewable energy alternatives attractive to the general public. In addition, the factors most commonly cited by wind power opponents—aesthetics, noise, and avian deaths—have largely been solved.

Findings From Surveys on Renewables

A national public opinion survey conducted immediately after the November 1996 U.S. elections found broad, bipartisan support for federal funding and tax incentives to promote renewable energy (AWEAh). Sixty-six percent of those expressing a preference gave the Department of Energy's renewable energy and energy efficiency research and development programs their highest funding priority. Additionally, 31 percent of respondents indicated that nuclear power should be the first R&D program subject to budget cuts, followed by 21 percent who said funding for fossil fuels R&D should be reduced.

More surprisingly, nearly two-thirds (62 percent) of respondents with a preference indicated they would support tax incentives for either renewable energy sources or energy efficiency efforts. Also, an overwhelming majority (83 percent) indicated they would like to see existing tax breaks redirected to renewable fuels, while only 10 percent felt they should continue to be given to oil companies.

Concerns Over Wind Farm Aesthetics, Noise, and Bird Strikes

Researchers have found that wind turbines produced the strongest "not in my backyard" response of any renewable energy source (Gipe). Concerns over aesthetics and noise pollution are the most common reason people oppose wind farms. Ironically, many of the windiest places are also the most beautiful and some people believe that wind turbines spoil the natural landscape.

Experience has shown that attitudes change quickly once a farm has been installed. The first British commercial wind plant located in Cornwall illustrates this phenomenon. Early opposition to the project was vocal and it took several years before local planning board approval was granted. A survey conducted before the farm was built showed that the majority of Cornish residents believed that the wind turbines would spoil the scenery and create a noise nuisance. After the installation, a follow-up survey showed that the number of residents who still believed that the wind turbines spoiled the landscape dropped to 28 percent. Also, after the installation, 80 percent of respondents found that noise was not a problem (12 percent were unsure). This compared with only 15 percent of those surveyed prior to installation who thought that noise problem would be *in*significant. Other surveys elsewhere in Europe also found that support for wind projects increased once they were installed (AWEAc).

Today, technological advances like computer-designed rotors and more appropriate sitings have virtually eliminated noise concerns. Unlike the first generation of windmills that were quite noisy, today's turbine designs can reduce noise emissions dramatically. Usually the sound is only slightly above general wind noise.

Wind farms have been accused of being "the Cuisinarts of the air," responsible for the deaths of tens of thousands of birds. A closer look shows these fears to be largely unjustified. For instance, wind farms are far less detrimental to birds than high-voltage electric power lines (Johansson et al 1993, 173). Furthermore, birds instinctively avoid a turbine's rotating blades. Migrating wildfowl will often change their course as they approach turbines, and local species rapidly adapt to avoid spinning rotors. However, several specific cases remain salient in the minds of critics. Endangered golden eagles were killed at Altamont Pass, California, for example, where, the wind farm was inappropriately sited in the middle of their migratory flight path. At a site in Tarifa, Spain, numerous bird strikes led to the closure of an entire wind farm. This problem was easily solved, however, by removing an illegal garbage dump from the base of one of the turbine towers (Wasserman 1997, 13). Besides more appropriate siting, another partial solution is to setup bird perches on nearby anemometers (devices used to measure wind direction). At a height of about 10 meters, these devices make an attractive perch for birds of prey and give birds an alternative to the turbine towers.

The Benefits of Proactive Government Policies

Supportive government policies are the key to the success of wind power in the United States. Policy solutions such as renewable energy tax breaks and renewable portfolio standards, along with a general atmosphere of support via government showcase projects and partnerships with industry, can enable wind power to overcome the barriers-to-entry posed by the current energy market.

Advantages of Wind Power

The federal government and taxpayers in general have much to gain from widespread adoption of wind power. Financially, government expenditures on the environmental and health costs associated with most conventional electricity sources would decline. This is because the federal government pays the majority of the costs of environmental remediation efforts. For example, the government spends millions on acid rain mitigation programs and assumes a great deal of risk in the case of a nuclear power plant accident.[10] Also, since the federal government assumes a substantial share of national health care costs through Medicare, Medicaid, and other programs, Americans would benefit substantially from a decline in pollution-related health care costs associated with a reduction in fossil fuel plant emissions.

America would also benefit significantly from a reduced reliance on imported fossil fuels. The United States pays a high price to maintain a reliable and relatively inexpensive supply of fossil fuel imports. The government maintains a large and expensive military in part to counter threats to this supply—as demonstrated in the Gulf War. Also, the risks of a fossil fuel price spike are significant and a major price increase would have a negative long-term impact on the U.S. economy—as illustrated during the oil embargoes of the 1970s. Finally, American foreign policy ideals have often been compromised to ensure continuing supplies—for example, the United States consistently overlooks the absence of democratic and liberal norms among oil-rich Arab countries.

Wind power can also play a significant role in helping the government meet its obligations under the Kyoto Greenhouse Gas (GHG) reduction treaty. The Clinton administration is committed to reduce GHG emissions 40 percent below 1990 levels by the year 2010.[11] Since fossil fuel power plants produce a significant share of America's GHG emissions, replacement with pollution-free wind turbines can help. Installing 30,000 MW of capacity by the year 2010 would reduce the utility sector's excess emissions by 18 percent, approximately 100 million metric tons (AWEAe).

American-manufactured wind technology can also play an important role in future joint implementation projects. Setting up wind farms in lesser-developed countries (LDCs) would enable the United States to earn credits for pollution abatement from the fossil fuel plants that the wind farms replaced. This would be mutually beneficial to both countries; by using credits, the United States would be able to meet its GHG reduction obligations less expensively abroad—since many LDC plants are "dirtier" than American ones—while the LDCs would receive a free and clean wind power farm. Although, joint implementation allowances will almost certainly be part of the finalized global climate change treaty, several issues still remain unresolved. There is considerable controversy over how credits should be allocated between countries and some LDCs are concerned that developed countries will grab all the "easy" emission reduction possibilities making it more costly for developing countries to meet their own reductions in the future.

Additional government financial support for wind power research and development, as well as tax incentives may be forthcoming. In his 1998 State of the Union address, President Clinton called for $6 billion in tax credits and R&D investments over the next five years targeted specifically to encourage energy efficiency and cleaner energy sources. Hopefully, Congress will respond to the challenge and allocate the necessary funds.

The federal government also has an interest in promoting the international competitiveness of the U.S. wind power market. Within the next few decades, the wind equipment manufacturing industry has the potential to grow rapidly. Tens of thousands of high-paying jobs may be created in the United States that would otherwise go to America's main economic competitors, Japan and the European Union.

Federal Wind Energy Research and Development

Today, after a series of changes in departmental management and budget levels, the National Wind Energy Program is run by the Office of Photovoltaic and Wind Energy Technologies in the DOE's Office of Energy Efficiency and Renewable Energy. The budget for fiscal year 1998 is $33 million (AWEAf). The mission of the program is to promote wind power research in DOE's field offices and national laboratories, as well as facilitate subcontracts with utilities, industry, and academia.[12]

The two primary federal laboratories working on wind energy technology are the NREL in Golden, Colorado, and the Sandia National Laboratories (SNL) in Albuquerque, New Mexico. The NREL operates the NWTC, responsible for wind technology testing and verification. In the next two years, the NWTC plans to finish building the Industrial User Facility (IUF) that will be the center for collaborative activities between the federal government and the U.S. wind industry. It will house experimental laboratories, computer facilities for analytical work, space for assembling components, turbines for atmospheric testing, and office space for industry researchers to work with wind program technical staff. The SNL focus more on applied research and industry/utility issues and leads an "Advanced Manufacturing Initiative" designed to reduce turbine costs through innovative component manufacturing (NWTCa).

Although the National Wind Energy Program has provided important research and support for U.S. wind manufacturers, more funding is needed to help make large-scale wind power a reality. In findings presented on 30 September 1997, the President's Committee of Advisors on Science and Technology recommended increasing government funding for wind research by 140 percent, from $29 million in fiscal year 1997 to $70 million in fiscal year 2003.

Additional government support could come from partnerships between the wind industry and the U.S. military. The Pentagon maintains a number of technology verification and certification centers available for private sector use. These centers could give priority use of their facilities and resources towards developing renewables such as wind power. Military bases could also be used to showcase wind energy technologies. Since several U.S. military bases exist in the windiest (class four or higher) regions of the country, and they have large quantities of available land, they would be ideal locations for demonstration wind farm projects.

Previous Government Policies Towards Renewables

Government support for renewable energy sources began in response to the oil shocks of the 1970s. High energy prices, the burden of dependence on foreign sources, and a realization of continued growth in demand led to the Energy Policy and Conservation Act of 1975. The 1975 act promoted energy efficiency improvements and diversification of supply and sources, and marked the beginning of a short-lived drive to find alternatives to fossil fuel energy sources. The election of Jimmy Carter in 1976 accelerated these efforts. President Carter set up the Department of Energy and, in a famous speech, declared that the United States must wage "the moral equivalence of war" to wean itself from cheap fossil fuels. Government support for renewables and energy efficiency and conservation projects followed as well as some restructuring of the energy market.

The Public Utility Regulatory Policy Act (PURPA) of 1978 required utilities to purchase the output of independent producers at a cost the utility could avoid by producing the electricity themselves.[13] This was followed by the Crude Oil Windfall Profits Act of 1980 that provided an additional 15 percent energy tax credit over and above the normal 10 percent credit for investments. Finally, the Economic Recovery Tax Act of 1981 allowed for an accelerated (five-year) depreciation of wind turbines (Johansson et al 1993, 149).

Unfortunately, falling oil prices and the election of Ronald Reagan coincided to end significant government support for renewables. The acts mentioned above all expired by 1985. However, they give an indication of effective types of legislation the federal government can use to promote renewable energy sources.

Production Tax Credits and Renewable Portfolio Standards

Currently, a $.015/kWh inflation-adjusted credit exists for electricity produced from any new wind facility. This credit lasts for 10 years and is designed to provide equitable tax treatment for wind plants relative to the tax breaks enjoyed by fossil fuel competitors.[14] Unfortunately, this production tax credit (PTC) is scheduled to expire on 30 June 1999, and renewal is uncertain. This uncertainty is already hindering wind farm investment because financing and permits require two to three years of lead time. It is essential that Congress act soon to maintain the PTC over the next decade—or until tax breaks for fossil fuels are also eliminated. The Congressional Joint Committee on Taxation has estimated that a five-year extension of the PTC would cost $156 million over the next 10 years (AWEAe).

Renewable Portfolio Standards (RPS) are the most prominent government policies being considered to promote renewable energy sources. RPS are essentially quotas requiring that a certain percentage of electricity be derived from renewable energy sources. Utilities could either generate the renewable energy themselves or buy tradable credits from renewable energy projects in other locations. Enforcement is strict and based on penalties of approximately two and a half times the estimated national average market value of renewable energy credits. RPS are quite popular among both lawmakers and consumers.[15] They encourage development of renewables while allowing the market to choose the most cost-effective renewable technology. They are also simple and flexible to administer and do not require large enforcement bureaucracies or complex regulations.

Two pending House bills, one sponsored by a Republican and one by a Democrat, include RPS provisions. H.R. 655, sponsored by Congressman Dan Schaefer (R-CO), requires that all generators of electricity maintain energy credits equal to two percent of their production (rising to four percent by the year 2010). A similar provision in bill H.R. 1960, sponsored by Congressman Edward Markey (D-MA), requires an RPS of 10 percent by the year 2010. Similar proposals at the state and local government level are also under consideration.

The costs of RPS are relatively low. A conservative estimate by the Tellus Institute (using DOE's National Energy Modeling System) shows the cost of H.R. 655 would translate into about a 20-cent increase per residential consumer per month, while the cost of H.R. 1960 would be approximately $1.30 per customer per month (AWEAa). It is important to remember, however, that two-thirds of electricity demand comes from the commercial and industrial sectors who would face much higher monthly bills.

The Role of State Governments

State governments may also play important roles in encouraging the use of renewables such as wind power, as was demonstrated in California during the early 1980s. In 1981, Governor Jerry Brown facilitated the installation of 17,000 turbines with tax credits and generous terms on long-term purchase contracts for renewable energy technology. Unfortunately, one result of these incentives was that unreliable turbines were rushed into production, and a few unscrupulous promoters operated some installations essentially as "tax farms". Nevertheless, many of the appropriately developed Californian wind farms are still in operation today. Three of them (Altamont Pass, Tehachapi, Palm Springs) produce over 90 percent of the total wind generated electricity in the United States. That equates to almost three billion annual kilowatt-hours, about 1.2 percent of the electricity used in California—enough electricity to meet the residential requirements of one million people (NWTCc; Johansson et al 1993, 150–151).

Other states are considering various options to promote renewables including pending RPS legislation in Massachusetts and Oregon. Unfortunately, state legislatures lack enforcement options and are often more susceptible to lobbying by local utilities opposed to renewable energy sources. For example, Iowa's largest electric utility, MidAmerican, fought for 14 years against a state mandate that required 1.5 percent of its power to be wind-generated. MidAmerican finally settled last March by making a deal with Enron for 150 turbines (Wasserman 1997, 14).[16] States are also hampered by the current uncertainty over restructuring and deregulation because they fear that any RPS requirements might make their local utilities less competitive with respect to states without requirements.

Conclusion

The combination of technological advances, significant cost reductions, and a desire for renewable alternatives to conventional sources of electricity has enabled the global wind industry to expand rapidly in the past few years. Capacity additions outside the United States rose 40 percent in 1994, 65 percent in 1995, and 35 percent in 1996, and the momentum is likely to continue through the next few decades.

During the past decade, however, inconsistent government policies have combined with the uncertainty surrounding the restructuring of the energy sector to constrain development of the American wind market. This situation could easily be changed. Temporary government policies that promote and support wind power could help, much as similar policies in the past encouraged construction of fossil fuel and nuclear generation plants. An example: since wind power is the most commercially competitive of current renewable energy options, adoption of pending federal RPS standards would provide a significant boost to this emerging industry.

Utilities, government, and the American public are becoming increasingly aware of the feasibility and desirability of pollution-free wind power. Enactment of appropriate policy measures in combination with continuing technical advances will assure that wind power becomes a significant and clean contributor to future U.S. electricity production.

Notes

[1]Dispersed grid-connected systems refer to wind turbines used to produce electricity for homes, businesses, and farms already connected to the utility grid. Those systems typically purchase supply off the grid when wind power is low, while excess electricity is sold back to the grid. Remote stand-alone systems are used for sites a half-mile or farther off the grid. Such applications usually need to be coupled with electricity storage systems like batteries or diesel generators to meet demand during low wind periods. These systems may be ideal for application in many developing countries without an electricity transmission infrastructure.

[2]The U.S. energy mix for electricity production is about 55 percent coal, 22.5 percent nuclear, 10 percent natural gas, 2 percent oil, and 10 percent hydroelectric. Renewables account for only 0.2 percent of the mix (CEQ 1995, 319).

[3]The United States will need to install 869.4 gigawatts of capacity by 2010, up from 688.9 gigawatts in 1990.

[4]Hydroelectric power, because of its environmental damage to natural ecosystems, is not considered a renewable energy source in this paper.

[5]Flexibility in terms of wind power's scalability and low start-up and maintenance costs.

[6]It should be noted that these comparisons are made on a distinctly American scale. Most other industrialized countries have far higher energy costs. Electricity in Denmark costs US$0.18/kWh: seven cents in actual production costs and 11 cents of added taxes designed to discourage consumption and pay for CO_2 reduction programs.

[7]Areas designated as class four or greater are suitable for today's turbine technology. Average wind speed for class four areas are 7.0 to 7.5 m/s

(about 15 or 16 mph), equating to a wind power density of 450 Watts/ m^2, and an average power output of 1.33 MW/km^2. Class three sites, of which over 1,000,000 square kilometers are available in the U.S., are expected to be suitable for a new generation of turbines produced in the year 2000 and beyond.

[8]This may seem high, but according to the same study, hydroelectric plants use 0.75 sq.-km/GWh.

[9]The "payback" period for a crystalline silicon solar cell would be about two years in Phoenix and about 4.4 years in Copenhagen. However, the payback period for amorphous silicon is probably significantly shorter (Nijs et al 1997, 291–327).

[10]In the case of a nuclear power plant accident, the federal government will pay for any damages in excess of the coverage of nuclear plant's insurance policy. Currently, insurance companies will cover up to around $1 billion.

[11]The United States agreed to reduce its GHG emissions to seven percent below 1990 levels by the year 2010—although the treaty has yet to be ratified by the Senate. Including the 34 percent increase the United States would have experienced over the 1990 levels under business-as-usual scenarios, the total GHG emission reduction is about 40 percent.

[12]The agreements between utilities and industry typically foster the development and accelerate the commercialization of new wind energy technologies. Subcontracts with universities on the other hand typically help to build the wind energy technology base.

[13]PURPA also allowed new producers to generate up to 30 (now 80) MW of electricity while still being exempt from federal and state utility regulations and remaining eligible for energy tax credits. This effectively ended the monopoly power that the utilities had previously enjoyed and laid the competitive foundation for the current restructuring drive.

[14]Federal subsidies to the energy sector of the U.S. economy are "persuasive and large". In 1989 they amount to $36 billion: $21 billion for fossil fuels, $11 billion to nuclear, $1 billion to renewables, $1 billion to energy efficiency, and $600 million for hydropower (Koplow 1993).

[15]The majority (57 percent) of respondents in a 1996 poll favored RPS even if it meant higher utility bills (AWEAh).

[16]Enron, the huge Texas-based petroleum conglomerate, recently bought Zond, one of the largest U.S. wind manufacturers.

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