# WIND FARM TECHNOLOGY: IS IT THE ANSWER?

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**Abstract**

A growing concern for the environment and pressure to develop new energy technologies continue to drive the wind energy markets. Wind energy is the fastest growing energy technology in the world and is one of the most cost-competitive renewable energy sources. Wind energy not only provides zero pollutant emissions, it is also a low cost renewable energy at about 3 to 5 cents per kilowatt-hour (kWh). According to the American Wind Energy Association (AWEA) estimates, the global wind power capacity increased from 7,600 MW in 1997 to 31,000 MW in 2002. AWEA predicts that the world wind power installation would grow as much as ten fold in the next decade.

Federal mandates and public relations are key driving forces to increase the use of renewable energy. Executive Order (E.O.) 13123 and 12902 require the Federal government to reduce energy usage and greenhouse gas emissions, and implement renewable energy programs. DoD has made significant progress in installing renewable energy technologies. In FY 2002, the DoD's total renewable energy usage in both generation and purchase was 4 trillion BTUs (approximately 1.17 million kWh). Large-scale wind farms have been established at several DoD locations, including San Clemente Island, Ascension Island, and Camp Williams.

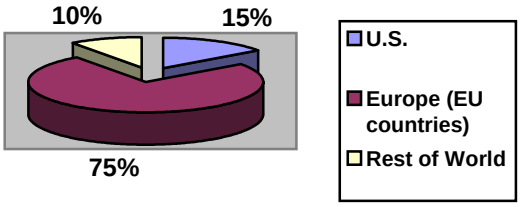
Congress has directed DoD to assess the potential for developing and purchasing renewable energy for DoD installations, including wind, geothermal, and solar. DoD, under the leadership of the Air Force, is assessing the potential for wind resource development. The renewable energy assessment will generate a list of DoD installations with the highest potential for renewable energy development. Approximately 20 sites have been selected for detail wind data collection and site assessment. Results from the wind monitoring and energy market assessment will create a business case for each site. The assessment, which is due to Congress in Summer 2004, will serve as a road map for DoD to develop renewable energy resources.

DoD has emerging security requirements, numerous isolated installations, available land and offshore areas suitable for wind farms. However, potential environmental consequences of wind farms include: the impacts to biological resources such as bird migrations and marine species habitats, impacts to recreational activities, changes in landscapes and seascapes, and potential disturbances to archeological sites. In addressing the question "Is it the Answer?" the paper analyzes the positive and negative environmental impacts of wind farms. Case studies are presented to demonstrate the feasibility of using land/offshore wind farms for DoD installations.

## Wind Resources in the United States

As one of the top five wind generators in the world, the U.S. accounts for 15% of the global wind energy market with a total generating capacity of 4,685 MW[1]. In 2002, the U.S. and Europe provided 90% of the worldwide wind generating capacity (see Figure 1).

**Figure 1. Worldwide Wind Energy Generation**




**Top Five Wind Energy Markets**

| | 2002 Generating Capacity (MW) |
|---|---|
| Germany | 12,001 |
| Spain | 4,830 |
| U.S. | 4,685 |
| Denmark | 2,880 |
| India | 1,702 |

Source: AWEA, Global Wind Energy Market Report, 12 March 2003.

The Department of Energy (DOE) estimated that the abundant wind resources in the U.S. could more than supply the nation's electricity needs. Excellent wind resources can be found in places with an average annual wind speeds of 7 meter per second (15.5 mph) or higher at about 50 meters (164 ft) above ground. The DOE assessed the U.S. wind resources and provided 7 wind power classes to describe the wind resource potential in geographic areas (see Figure 2)[2]. Sites with Wind Class 3 or higher are suitable for wind farm development, while Class 2 or higher provides possibilities for small wind generators. Although there are good resources along the coasts, 90% of the wind energy for electricity generation is found in the 12 heartland states, from Colorado on the west to Iowa on the east, and from Texas on the south to the Canadian border.

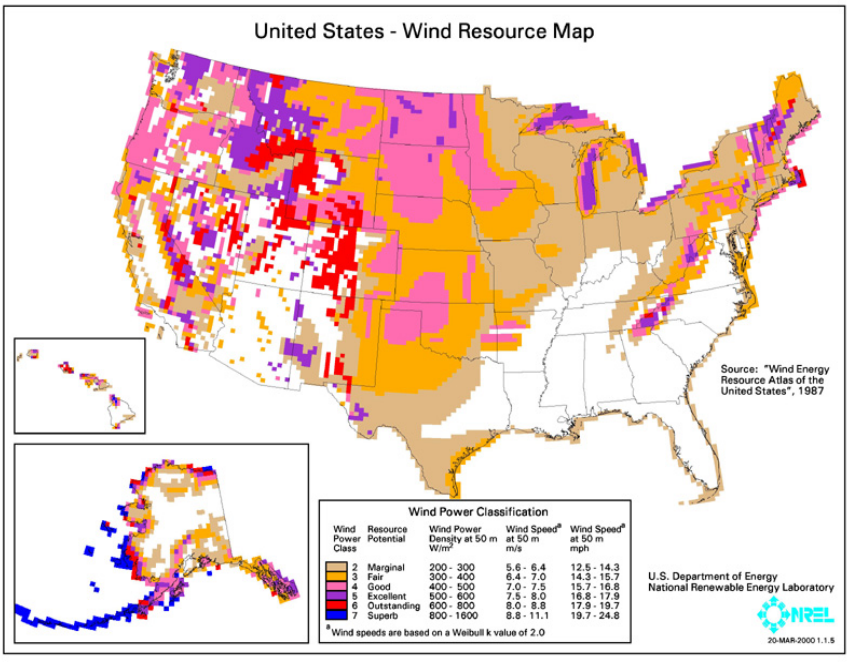



**Figure 2. U.S. Wind Resource Atlas**

**Top 17 States with High Wind Energy Potential**

| Rank | State |
|---|---|
| 1 | North Dakota |
| 2 | Texas |
| 3 | Kansas |
| 4 | South Dakota |
| 5 | Montana |
| 6 | Nebraska |
| 7 | Wyoming |
| 8 | Oklahoma |
| 9 | Minnesota |
| 10 | Iowa |
| 11 | Colorado |
| 12 | New Mexico |
| 13 | Idaho |
| 14 | Michigan |
| 15 | New York |
| 16 | Illinois |
| 17 | California |

## Wind Energy Development Criteria and Applications

In some areas of the U.S., electricity can be currently generated by wind energy at a cost of 5 cents per kWh or less. It is expected that the increased demand for advanced wind

systems and advancements in turbine technology will further drive down the cost of wind-generated electricity. Wind-generated electricity can provide a cost effective option for many DoD facilities that have access to good wind resources and relatively high utility costs, and those with high dependency on diesel power generation.

The following criteria can be used to evaluate the feasibility of using wind technology[3]:

- Sites with good wind resources, i.e., sites that are designated as Wind Class 3 or higher are candidates for wind farm development.
- Facilities with high cost of electricity at 8-12 cents per kWh or more.
- Diesel oil or other fossil fuel is being transported to the site for power generation. Using wind turbine and hybrid energy system can reduce life-cycle energy costs and lower the risk of fuel spills.
- The current power generation system results in noncompliance with air pollution regulations.

Wind turbines can be installed as either stand-alone or utility grid connected systems depending on the facility's need and characteristics. Grid connected systems allows the facility to connect with the local utility's electricity transmission and distribution system. Wind systems have a variety of applications which include:

- Communication equipment
- Navigation aids
- Special military operation requirements
- Pumping and irrigation systems
- Desalination and water treatment systems

Hybrid energy systems that combine wind turbines and solar power and backup diesel generators are effective means of generating electricity. The diesel generator can provide backup power during the period when winds are calm. In general, hybrid systems require smaller battery banks to store wind-generated electricity. In a hybrid system, batteries are sized to maintain the system load for two to three days, about half of the five to six days normally required for a solar or wind-only system. In addition, wind and solar hybrid systems do not produce carbon dioxide ($CO_2$) and nitrogen oxide (NOx) emissions that are commonly associated with burning fossil fuels.

## Environmental Impacts of Wind Farms

Wind energy is a renewable and sustainable form of energy. Unlike coal or fossil fuel burning systems, wind energy generation does not deplete natural resources. About one pound of coal can be saved for every kilowatt-hour of electricity generated by wind[4]. The use of wind energy can significantly reduce mining of fossil fuels. Wind energy also provides substantial environmental benefits, as it does not produce green house gas emissions. DoD facilities can use wind energy to attain emission-reduction goals and displace the $CO_2$ and NOx emissions otherwise produced by traditional power stations. A 675 kW wind turbine can displace approximately 10,000 lbs of NOx and 15,000 lbs of

SOx emissions per year[5]. It also prevents air pollution from particulate matter and mercury fallout. In addition to environmental benefits, wind energy diversifies the fuel portfolio and improves energy security. Wind energy reduces the U.S. dependency on imported fuels and protects utility and energy consumers from fuel price volatility risks.

Although wind energy provides great environmental benefits, the potential consequences of wind systems should be fully analyzed in order to determine the feasibility of establishing wind farms. One of the environmental concerns associated with wind farms is the visual impact. Wind turbines are highly visible structures and are often opposed by homeowners or real estate developers owning lands near the site. Opposition related to visual impact can be reduced if homeowners find the structures aesthetically pleasing and realize their environmental benefits. Careful arrangement of the wind turbines to reduce the impact to landscape and public education are important in promoting wind energy. Wind farms can contribute to bird and avian mortality. However, bird deaths due to wind turbines are low compared to other manmade structures. According to the study conducted by the National Wind Coordinating Committee, the annual avian mortality from wind generating facilities is 10,000-40,000, while power lines contribute to174 million bird deaths and 98-980 million from building and windows[6]. When selecting a site for wind farms, it is important to identify bird breeding and migration routes to reduce the impact to birds. Wind farms can potentially contribute to noise pollution as mechanical and aerodynamic noise is generated by wind turbine. Advancement in technology can practically eliminate mechanical noise from gearbox and generator. Aerodynamic noise can also be improved through better rotor design. The noise level emitted by a 660kW wind turbine at 200m (650 ft) is 47 dB(A), which is less than the noise level of a normal suburban residential area at 53-57 dB(A)[7]. As a comparison, a vacuum cleaner operating at a distance of 10 feet has a noise level of 70 dB(A). Therefore, overall noise pollution from wind turbines is not a significant concern and can be improved by advanced technologies and better system design.

Offshore wind farms have potential effects on seabed, birds' migration routes, navigation, and marine mammal activity, as well as military operations and aesthetics[8,9,10]. The construction of turbine foundations on seabed can reduce the seabed area used by animals and plants. However, the foundations can also provide a new habitat for marine fauna and flora. The wind turbine can reduce the ocean current velocity and as a result, may impair the water quality in adjacent sea areas. There are risks of oil spill associated with the operation of the offshore wind farms, as leaks may occur from the turbine and substation. Ships may also run into the wind farm structures creating oil spill and navigation risks. However, oil spill risk can be minimized as oil spill collection systems can be installed to collect leaks from turbines and substations. The biological concerns of an offshore wind farm include the impact on bird migrations and marine mammal activity. Mapping of the distribution of birds and marine mammal are important in identifying sensitive areas and selecting a site that can minimize the biological effects. Moreover, ocean noise from the turbine and electromagnetic field from the cables may influence the local distribution of fish. Finally, offshore wind farms can affect the natural beauty of the coastline, interfere with fishing, diminish property values, and hurt recreation and tourism. Although offshore wind farms may obstruct the natural beauty

of coastlines, it can establish itself as an attraction. To reduce the visual impact, wind turbines can also be sited further from the shore.

## DoD Wind Farm Applications – Two Case Studies

***San Clemente Island (SCI).*** Federal mandates continue to be the driving force for the DoD and Federal agencies to implement renewable energy programs. In 1998, the U.S. Navy partnered with DOE's National Renewable Energy Laboratory (NREL) to install a wind farm at the Naval Auxiliary Landing Field (NALF) SCI. Located 52 miles offshore from San Diego, SCI served as a naval research, development, testing, evaluation and training facility. The wind farm was established on SCI to reduce the use of diesel fuel for power generation, reduce $CO_2$ and NOx emission, and lower fuel transportation cost.

The wind farm consists of three 225-kilowatt Micron wind turbines producing about 17 percent of the island's electrical power. Operating on 100-foot high towers, the energy generated from the wind turbines is transferred directly to the SCI's power grid to provide supplemental power. The grid is also connected to diesel generators to provide back up power when winds are very low or calm for an extended time. With optimum wind conditions, the wind farm can provide at least half of the island's total electricity need. The turbines can be operated locally or remotely through a computerized system monitor and control interface. The wind farm results in annual energy saving of $112,000 per year and provides electricity at a cost of 3-4 cents/kWh[5]. The use of the wind energy reduces 3 million lbs of $CO_2$ emissions and 14 tons of NOx emissions per year.

To minimize the environmental effects of the wind system, the U.S. Navy worked closely with the U.S. Fish and Wildlife Service to protect the Federally listed island night lizard. Prior to the construction of the wind turbine, all night lizards from the wind farm site were relocated to a new habitant. Archeological sites were clearly marked to prevent disturbance.

***Ascension Island.*** Located about 500 miles south of the Equator in the middle of the Atlantic Ocean, the British Ascension Island is the site to a U.S. Air Force missile and satellite tracking station. In 1997, the U.S. Air Force installed a wind farm on the island to reduce the cost of fuel transportation and protect the island from environmental pollution. Before the installation of the wind farm, diesel fuel was the primary source of energy to generate electricity and power the desalination system to provide drinking water. Four 225-kilowatt wind generators were installed and connected to the current diesel electrical distribution system to supplement the island's power requirement. The wind farm also allows for electrical generation at a reduced output (0-40 kW) when wind levels are low. This feature optimizes the operation of wind system and ensures full utilization of wind resources. The wind farm on Ascension Island reduces fuel consumption by 287,000 gallons (3.2 million kWh of electricity) per year and provides an annual cost saving of $350,000[11]. It also reduces $CO_2$ and NOx emissions by 2.8 million and 98,000 pounds, respectively, each year.

## Conclusion

In general, wind energy presents a cost saving option when the price of fuel currently used is high and the wind resource is good. The remote location of many DoD facilities validates the use of renewable energy in reducing the cost of fuel transportation. The current DoD review of DoD installations for future wind farm locations should be complete this summer. Each service will then determine what new initiatives are in their best interest. Numerous wind power projects have proven that wind energy not only is cost competitive, but also offers substantial benefits to the economy and the environment. Wind energy is a clean renewable energy, which does not generate emissions of green house gas or other pollution. The development of wind energy also allows the creation of new jobs and businesses while supporting local economies and reducing reliance on imported energy. The benefits of environmental protection, long-term price stability and economic development will continue to make wind power a viable industry and energy resource.

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