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FACTSHEET

Office of Education,
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Assistant Secretary for Intergovernmental
and Institutional Relations

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Department of Energy

3. WIND POWER

INTRODUCTION

For centuries, power from the wind has been used to pump water for crop irrigation, to propel sailing ships across the oceans, and to turn millstones to grind flour from grain. From its origins in Persia in the 7th century, the windmill concept spread throughout the Islamic world and reached Iran and China by the time of the Mongol conquests. In the 11th century, windmills appeared on the farms of western Europe and, by the 17th century, the Netherlands had become the world's most industrialized nation by extensive use of wind power to drive trading ships, to power grinding mills, and to pump water from lands that were once beneath the sea.

Over the centuries, the original windmill design was refined and improved. By 1850, use of windmills in America to pump water and turn sawmills represented 1.4 billion horsepower-hours-of-work, an amount equivalent to 11.83 million tons of coal.

This growth was curtailed somewhat by the introduction of the steam engine, but interest picked up again as settlers moved out into the American West and Great Plains areas. By 1900, a large windmill industry existed in the United States with a capital investment of over $4 million. By the 1920's, wind power had become a major source of electrical power on farms and homesteads across the United States. Similar developments took place in Europe. These small-scale generators served well for years, providing cheap, clean electrical power to thousands of rural and farm homes. However, the establishment of the Rural Electrical Administration (REA) in 1930 made federally-subsidized, centrally-generated electrical power available to farms. Installation of all the cables took about twenty years, but by 1950, small-scale windmills were a thing of the past.

Interest remained in the potential of large-scale wind generators, however, and between 1935 and 1955 a number of machines, ranging in power from 90 kw to 1.25 Mw,* were built. One of the largest and most well-known, the 1.25 Mw Smith-Putnam generator, was built on "Grandpa's Knob" in the mountains of central Vermont. While the success of that experiment was short-lived, due to mechanical failure and the complications and expense of war-time materials supply, it did demonstrate the feasibility of capturing wind power for electrical generation on a large scale.

Wind power differs from most other "alternative energy technologies" in that it is an old and proven source. Its demise was brought about to some degree by the overly optimistic projections of cheap nuclear power and the unrealistic energy prices of the 50's and early 60's. It is a technology which could by quickly brought to large scale use given determination and support on the part of the private and public sectors.

* See Glossary for definition (Fact Sheet #18).

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RESOURCES

About 2 percent of all the solar radiation that falls on the Earth is converted to wind energy in the atmoshpere. Calculations have shown that the amount of wind available over the continental United States is about 14 times the 1973 energy demand of the U.S. A 1973 NSF/NASA solar panel study estimates that an annual output of 5.1×10^{15} Btu's of wind energy would be possible by the year 2000. That amount is close to the total electrical demand in the U.S. for the year 1970 and would represent about 5 to 10 percent of our total energy needs in the year 2000.

TECHNOLOGY

The basic configuration of windmills, which has remained unchanged for centuries, is a horizontal shaft to which is attached a number of blades designed to turn in the wind. This provides mechanical energy to turn a mill, or pump water, or turn a generator which will produce electricity. The ideal wind machine has not yet been invented, but the laws of physics tell us that it should be able to capture about 59 percent of the kinetic energy of the wind that passes through the sweep of its blades. Actually, blade inefficiencies and mechanical losses reduce practical efficiencies to about 35 percent.

The power output of a wind machine depends both on wind velocity (or speed) and on the diameter of the blades. For maximum power, then, a wind machine should have the longest blades possible (about 100 feet is the maximum now) and should be located in the strongest winds. The height of the wind machine is another important factor because there is greater wind speed and constancy at higher altitudes than at the Earth's surface. The expense of building a tower also increases with its height, however, so that most present designs call for a tower between 100 and 150 feet high.

The major deterrent to wind power is the relatively high cost per unit of power output from the wind generating machines due to the variable nature of wind energy. On the average, "energy winds," those with speeds of 10-25 mph, blow only about two days out of the week in the United States. The more common winds, called "prevalent winds," blow the other five days and have a speed of 5-15 mph. Wind power generators operate at their rated capacity only when the wind is blowing at or above some minimum speed. Thus, a typical wind power generator operates at an overall load factor between 15 and 25 percent--which means it can only produce one-fourth or so of the total energy produced by a conventional plant of the same generating capacity.

Wind variability also has an effect on rotor revolutions per minute, which in turn influences the output frequency of the generator. Since standard U.S. power networks require constant frequency (60 cycles per second) and Alternating Current (AC), some means for regulating the frequency is needed. While constant-speed drives or converters are available, they add to the expense.

The storage problem must also be solved. What do you do when the wind stops blowing? There are several storage technologies. The most familiar is lead-acid batteries, which can be charged while the wind is blowing and then be used at a later time. Unfortunately, these can cost as much as the wind machine itself. Another alternative is to use pumped water or air--either pump water up into a reservoir and then let it fall to turn the turbines as needed (as is presently done with many conventional power plants), or use the wind machine to compress air that can be stored in tanks or natural caverns, and then fed into gas turbines as needed. Flywheel storage has also been suggested. In the future, one technique may be to use wind power to electrolyze water into hydrogen and oxygen and store the hydrogen for use as a fuel, or convert it to electricity in a fuel cell.

It may be that the storage problem can be circumvented. If enough wind machines covering a large area are linked together in a grid, the fluctuations can be averaged out to some extent and the difference made up by conventional plants or hydroelectric plants. An interesting future possibility will be to combine wind and direct solar generation of electricity for, to some extent, the winds tend to blow when the sun is not shining (at night and during storms).

In general, however, the components of a wind power generating system have relatively modest technical requirements by today's standards. Electrical generators, in fact, are available off-the-shelf for home use and it should be possible to engineer these designs into efficient large-scale systems. A major part of the potential for wind power in the U.S. can, in fact, be realized with current technology and with straightforward development.

WIND-GENERATED ELECTRICITY

In 1891, Paul La Cour started experimenting with electric wind generators in Askov, Denmark, and his basic design supplied that town with electricity until 1960, when hydroelectric power was introduced. The Soviets constructed a large scale (100 kw) wind electric plant in 1931 overlooking the Black Sea at Yalta, but like the Smith-Putnam machine, its bulk led to mechanical problems and the Soviets switched back to smaller plants (around 30 kw each) between 1935 and 1955.

At about the same time, the Jacobs Wind Electric Company in Minnesota was popularizing wind electric generators in the United States. Their machine, rated at 1500 watts capacity, generated 400 to 500 kw-hr per month and cost, with a full set of batteries, cables, and a 60 foot tower, $1000 at the factory. By 1957, when the REA shut his doors, Jacobs had sold $75 million worth of wind machines.

The only other innovation during those years was the 1.25 Mw wind electrical station built by Putnam at Grandpa's Knob. While Putnam's experiment proved that large-scale wind electric generation was possible, it was not until the 1970's that the idea was picked up again.

The increasing price of energy coupled with our growing dependence on foreign supplies has revived the Federal Government's interest in wind power. Its relatively low environmental impact, compared to fossil and nuclear plants has also made it popular with environmental spokesmen. As a result, the Federal funding of research and development has increased from $200,000 in 1973, to $1,500,000 in 1974, to an estimated $7,000,000 in 1975 and a requested $12,000,000 in 1976.

With some ERDA funding, NASA has built an experimental 100 kw wind turbine at Sandusky, Ohio. Mounted on a 100 foot tower, it has a rotor made of two blades, each 62½ feet long, the second largest windmill built in this country in 30 years. It will turn in 8 mph winds and reaches its rated capacity in winds of 18 mph or better.

At present the leading spokesman for wind power is William Heronemus, a professor of engineering at the University of Massachusetts. Dr. Heronemus has identified several sites where large amounts of wind energy are available: the Great Plains, the eastern foothills of the Rocky Mountains, the Texas Gulf Coast, the Green and White Mountains of New England, the continental shelf of the northeastern United States, and the Aleutian Islands. One of his schemes calls for constructing a grid of wind machines at half mile or mile intervals throughout the Great Plains area. Such a system, he claims, could produce 190,000 Mw of installed electrical capacity, roughly half of the U.S. total in 1971. He has also proposed an offshore scheme in which the winds would be used to electrolyze water into hydrogen and oxygen. The hydrogen could then be piped to shore or brought in by refrigerated tankers.

It is generally thought that large-scale central power applications will call for straightforward "energy farms," each covered with a grid of identical wind turbines. This would take advantage of mass production economies and simplify R & D on basic units. Power densities of 40 Mw per square mile are thought possible in the Midwest with this approach, and should be entirely compatible with high-yield crop farming and cattle grazing. Because of the problem of wind power shutdown, a back-up fossil fuel plant may be needed to insure continued service.

Small-scale schemes may also continue to prove promising. A ten foot rotor could provide enough energy for an all-electric single family home in many parts of the U.S. Another option, too, would be to tie into, or remain tied into the existing utility line, switching to central-station power when the local generator is down or inadequate. Modern "homesteaders" are still finding wind power an economical alternative to having the nearest power company run lines out to their remote areas, and a number of companies are now producing wind electric generators designed for home use.

For all its antiquity, wind machine design is a new challenge to American engineers and several exotic designs have already appeared. Among these are the "Sailwing" (developed at Princeton and scheduled for production by Grumman Corp.) whose blade deforms in the wind and is therefore self-orienting. A prototype is already in operation in India. Also under development are several vertical axis designs which are not dependent on wind direction.

ENVIRONMENTAL PROBLEMS

Because wind machines are relatively passive "low technology" machines, there are no direct by-products or residues to dispose of and the secondary effects of their manufacture are not especially troublesome.

Their major drawback is land use. Although a single machine does not occupy much space, a giant grid of them complete with power lines would have aesthetic drawbacks, but wind harvesting should be compatible with other uses of the land such as pasturage and farming.

The efficiency of land use is also expected to be comparable to farm use. If "solar efficiency" is defined (for a large area windmill farm) as the ratio of power output from the windmills to the solar-power incident on the land they occupy, it is estimated that efficiencies of about 5 percent are possible in the Great Plains area. Photosynthetic efficiency of growing plants is about 1 percent.

If really large-scale use becomes a reality, there will be questions to answer about possible effects on weather caused by the removal of large amounts of kinetic energy. In general however, wind energy, like other forms of solar energy, seems to be environmentally benign.

OTHER PROBLEMS

Wind power development has been held back so far by economic considerations. Proponents insist, however, that once development is past the pilot plant stage and components are mass produced, wind power generators will be competitive with fossil fuel and nuclear plants. A recent comparison estimates the cost of building wind power generating plants at $150-$200 (in 1974 dollars) per installed kilowatt. The wind power system suffers because it is at full capacity only 25 percent of the time on the average, while coal and nuclear operate at 50 to 60 percent load factors. However, the low load factor of the wind machine is compensated for by low maintenance and zero fuel costs. The total cost of its electric energy is projected at 2 or 2½ cents per kw-hr--about the present average cost of electricity produced by conventional power plants. Given the early stage of development, this is an encouraging picture.

SUMMARY

The most telling measure of the increasing importance attached to wind power is the funding level which has risen from $200,00 in 1973 to a (requested) $12 million in 1976. To the wind power enthusiasts, however, this is not enough They argue that wind power is in fact an old and proven system far more worthy of accelerated development than the breeder reactor (for which the 1976 developmental support is $475 million).

What does arise clearly, in spite of the controversy, is the real potential of wind power as a supplementary source of electricity. The energy is there, and we have sufficient technological knowhow to tap it. No one questions that the technology can be improved and that there will be problems to overcome. The task of building a large grid of wind machines is, however, one that could be accomplished relatively inexpensively and, in contrast to other power plants, quickly. (The 1.25 Mw generator on Grandpa's Knob was constructed in 19 months.) If the priority and support is forthcoming we can begin to define the windmill's new role before the decade of the 70's is over.

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Factsheet Titles

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2. Fuels from Wastes (Bioconversion)
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