Wind Energy: Large and Small Systems Competing

Among the possible alternative energy systems, wind power has often been thought more idiosyncratic than most. The first suggestions for solving the energy crisis with wind sounded impossibly grandiose—1000-foot-high windmills stretching in a great arc from Texas to North Dakota or anchored at sea off the coast of New England in numbers that seemed to rival the wheat in Kansas. Wind power also had to live with the unglamorous truth that it had been used for millennia by technically primitive cultures with rudimentary energy systems. Finally, like most other sources of energy that ultimately derive from the sun, wind bore the onus of being a fluctuating energy source.

Wind energy systems have consequently received markedly less support than other systems that utilize solar energy directly. Whether measured by the funding decisions of government energy research officials, the public support reflected in congressional lobbying, or the interest expressed by utility companies, wind power is lagging far behind.

This is the sixth in a series of Research News articles examining recent developments in solar energy research.

Windpower currently receives only $21 million out of the $290 million solar research budget. This is true despite the fact that sophisticated small and large wind turbines have been proved to work. A 1.25 megawatt machine operated successfully for 2 years in Vermont in the 1940's.

Both small and large machines have the potential for marked cost reduction, and even without the advantages of mass-production they offer one of the cheapest means of producing solar electricity available today. The problem of energy storage for wind power can be handled simply in many parts of the country because hydroelectric dams and underground gas formations suitable for compressed air storage are abundant in many windy areas. By the year 2000, wind could contribute 1 to 2 percent of the country's total energy needs.

An important fact that is not widely appreciated is that the amount of wind energy available on an annual basis is nearly as large as the average energy flux of sunlight in many regions. The average wind power on the Great Plains over the course of a year is over 200 watt/m^2. Two considerations could give wind energy the upper hand for certain applications in certain locations. First, the geography of the countryside provides natural concentrators for wind energy that may double its flux. In a low gap in the Rocky Mountains near Medicine Bow in southern Wyoming, for instance, the average annual wind speed is 21 miles per hour and the energy flux is 500 watt/m^2. Second, wind turbines are at least twice as effective as direct solar systems in extracting work from the natural medium. Wind power systems routinely operate with 35 percent efficiency (the theoretical maximum is 60 percent), whereas solar systems produce electricity or drive-shaft power with only 5 to 15 percent efficiency. Wind also has an inherent potential advantage in lower materials costs—the typical turbine blade covers only about 10 percent of the area from which energy is collected.

The major objections to wind installations have been raised against their esthetic impact and possible interference with television reception. Indeed, officials of the Energy Research and Development Administration (ERDA)—particularly those in the upper echelons—have been emphasizing the television interference problem as a possibly unacceptable drawback to wind energy. The visual assault posed by the gargantuan installations of early wind power proposals would have been considerable, but the large wind installations being built and projected for use by utilities are small by comparison. The tallest wind turbine planned by ERDA will have a tower 200 feet (61 meters) high, and that will "probably be the maximum height" for a practical wind turbine, according to the head of ERDA's wind program, Lou Divone. Such a structure would be only slightly larger than the towers for long-distance electrical transmission, and perhaps less visible than the grain elevators that already dot the Great Plains.

Television versus Wind

The problem of television interference can apparently be severe, but the extent of the problem depends on the specific site. Interference arises because the synchronization speed of U.S. television—30 cycles per second—is near the rotation speed of large wind systems. Large machines will cause interference for a range of 100 feet to 1 mile, depending on the site; for small machines it is seldom a problem. In any case, the use of fiber glass blades rather than metal ones could cut the interference range in half. Fiber glass blades are even more desirable for economic reasons. If produced in modest numbers they could undercut the cost of metal blades by two-thirds.

Until about 1 year ago, the government program concentrated overwhelmingly on large wind machines—those ranging up to 2.5 megawatts. The agency's "mission analysis" studies done by General Electric and Lockheed showed that the cost of power from a wind turbine dropped rapidly with increasing size up to 0.5 or 1 megawatt, and more slowly thereafter. From 1973 onward, the program for large machines grew rapidly because "it was obvious where to put the money to cut costs," according to Divone. "All the available data said that scale factors favored large machines," he says. The government began an accelerated 5-year program to develop three large wind machines dubbed Mods 0, 1, and 2, rated to produce 0.1, 1.5, and 2.5 megawatts, respectively.

In the eyes of many observers, ERDA concentrated on large wind turbines partly because agency officials thought that anything less would have a negligible impact on total U.S. energy supplies. But a thorough assessment of the sizes of the potential markets for large and small wind machines has yet to be made. Over 6 million windmills have been built and bought in the United States since the middle 19th century, and modern-day applications for heating and cooling, water pumping, and dispersed electricity generation could see a resurgence. "The market for small-scale machines," says a respected dean of the wind energy community, Frank Eldridge, "might be of the same order of magnitude in terms of total power as the market for large-scale machines in centralized electric power applications."

About 1 year ago it became clear that the first large machine to be built, Mod 0, had run into trouble. The 100-kilowatt machine, built by the National Aeronautics and Space Administration (NASA) at its Plum Brook field station 50 miles west of Cleveland (Fig. 1), developed severe forced oscillations and unexpected impulse loads on the propeller. The problems were so severe that it logged only 57 hours in the first 8 months operation. ERDA officials were afraid for a while that the machine might throw off a blade because of metal fatigue caused by the unexpected stress. The problems with the Plum Brook machine have been fixed now, according to ERDA, but its usefulness as a test-bed for advanced components has been curtailed by the delays incurred. The problems at Plum Brook may also have influenced the agency's recent decision to cancel long-standing plans to test fiber glass blades on the Mod 0 and Mod 1 machines. The Mod 0 was largely inspired by a German wind machine designed by U. Hutter that operated successfully for 10 years with fiber glass blades.

In mid-1976, after it was clear that the large-wind machine program had gotten off to a rather shaky start, the ERDA staff set up a small-wind machine program to complement the large one, and gave responsibility for the technical management of the small program to ERDA's Rocky Flats laboratory near Denver. Although the program received only \$2 million in fiscal 1977, out of a total of \$21 million, the Carter Administration has boosted its funding to \$8 million in fiscal 1978. The Rocky Flats laboratory (which is in a rather windy region, but has the fabrication of nuclear weapons parts as its principal mission) is installing instruments to evaluate the performance of many types of small windmills. Whereas the large-wind machine program is one of sequential development, the small-scale program is intended to emphasize parallel development of competing machines.

Small Turbines Being Marketed

A number of small machines for producing electricity are already on the market. One of the most successful machines in the 1930's, the Jacobs Wind Electric plant, is being sold in reconditioned units for \$1100 to \$1800 per kilowatt by Northwind Power, a small company in Warren, Vermont. The Jacobs machines are sized at 2 and 3 kilowatts. A similarly small company in Lowell, Massachusetts, U.S. Windpower Associates, is developing a 25- to 30-kilowatt machine, better matched to the power demands of a modern residence. The Grumman Corporation has already sold five prototypes of a 15-kilowatt wind turbine for about \$1300 per kilowatt and hopes to start a standard production run soon. In addition, there are about a half-dozen foreign-made machines available at 10 kilowatts or less. A study prepared for ERDA by the JBF Scientific Corporation has concluded that with a 10-kilowatt machine presently available, a home wind system (without storage) would be able to produce electricity for 15 cents per kilowatt-hour in 12 mile per hour annual winds.

Although ERDA has put up millions of dollars for solar heating and cooling demonstrations, so far no small-scale wind demonstration programs have been set up. The Rocky Flats office has, however, announced that it will fund competitions for three small machines, 1-, 8-, and 40-kilowatt in size. The burgeoning Rocky Flats program is a "pretty good slug of money for a little industry that had nothing 15 months ago," says Richard Katzenberg, who is president of the American Wind Energy Association and, like many of its members, a small-wind machine builder himself. Katzenberg's group is beginning to develop a reputation as a rather effective lobby for wind power, and this summer it was successful in prodding Congress to extend the Administration's solar tax credits to wind also.

While the small-scale wind industry has been wholly based on private funding until now, the large-scale wind program has been pursued as a big-contract government R & D program with a heavy aerospace cast. Cost overruns are already plaguing the program. The program has proceeded ahead by effectively sidestepping the near failure of the initial wind machine (which ultimately cost \$2 million) and the energy agency is building three upgraded versions of the Mod 0 for regions of higher wind velocity, using a 200-kilowatt generator on the same-sized (125 foot) turbine. The next step, the Mod 1, will have a much larger rotor, 200 feet in diameter, and will be designed to

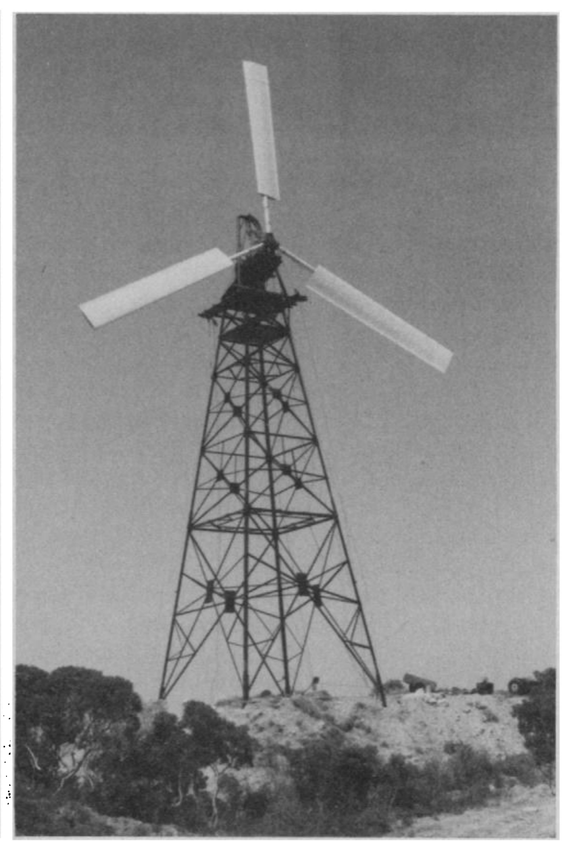

Fig. 1 (left). The first large wind turbine built by the federal program near Sandusky, Ohio. "Blade shadow" from the stairs posed problems and the stairs were eventually removed. Fig. 2 (right). A privately financed 175-kilowatt turbine put up this summer on Cuttyhunk Island, shown prior to installation of the machine cabin housing.

produce 1.5 to 2.0 megawatts in high-wind regions. The largest in the series, the Mod 2, will have a rotor 300 feet in diameter. It is due to start turning in late 1979 for a cost of $10 million.

While ERDA has not yet begun operation of one of its 200-kilowatt wind machines destined for Block Island, a private company has built a similar-sized wind machine—reportedly for much less money—on another island not far away. The inhabitants of Cuttyhunk Island, between the Massachusetts mainland and Martha's Vineyard, wanted a windmill to offset the skyrocketing cost of fuel for their diesel generating system. A company named WTG, Inc., in Angola, New York, wanted a site to test a prototype for a large wind system. Because the uncle of one of WTG's founders had a summer home on Cuttyhunk, the two parties got together. A 175-kilowatt wind turbine is now being given its first tests at a site just outside the town of Gosnold (Fig. 2). It will be linked with the present diesel unit to form a hybrid system to supply the island's needs. The turbine will reach its maximum rated power at a wind speed of 28 miles per hour. The average annual wind speed on the island is 16.8 miles per hour.

The WTG rotor was built to be as simple as possible for reliability. It is a fixed-pitch, three-bladed steel rotor, 80 feet in diameter, on an 80-foot tower. The system was modeled after the Danish Gedser mill in many respects, according to Alan Wellikoff at WTG. It will be operated as a test system for the next year, and then the town will have the option to buy it. The final cost of the Cuttyhunk machine is not yet known, but at one point the whole project was estimated to cost less than the hub mechanism of ERDA-NASA's Plum Brook machine, according to Wellikoff.

While the paper studies all show that large machines can be made cheaper than small ones, practical experience has yet to bear this out. The Mod 0 cost more than $5500 per kilowatt, and the Mod 1 machine is now projected to cost $1800 to $2200 per kilowatt. The studies all postulate a "learning curve" that will steadily reduce costs, but no two studies agree on the magnitude of the reduction. A recent survey of all the economic projections for large wind machines by JBF Scientific showed a range of $400 to $900 per kilowatt after the first 100 units were completed, but Divone says that the cost the agency realistically hopes to achieve is more like $750 to $1000 per kilowatt. Whether aerospace companies, which are accustomed to small production runs, can achieve the projected cost reduction is yet to be determined.

To achieve a given amount of wind generating capacity, more small machines would be produced with a greater potential for manufacturing cost reductions. The ERDA goals for the small wind program are illustrative of this. Based on a production run of 1000 units, the cost goals for the small wind program are $750 per kilowatt for the 8-kilowatt machine and $500 per kilowatt for the 40-kilowatt turbine, according to George Tennyson of ERDA. The sizes of small systems are close to the scale of industrial goods that have shown large economies of production in the past, whereas the rotor on a Mod 1 turbine will be almost identical in size to the wing of a 747 aircraft.

For wind turbines, however, there may be less correlation between the amount of energy generated over the course of a year and the name-plate capacity rating than for other types of energy systems.

The Bureau of Reclamation has done a rather thorough study of the wind conditions at Medicine Bow, Wyoming, and concluded that a field of Mod 1 turbines there could produce electricity at a cost of 2 cents per kilowatt-hour, even though the turbines would have a capital cost of $1300 per kilowatt. The extremely high average winds at the site, plus the opportunity to use the wind system in conjunction with the Flaming Gorge and Glen Canyon hydroelectric systems (getting the same effect as energy storage by holding back water when the wind is blowing), make this site particularly attractive. Forty-nine turbines would provide 8 million kilowatt-hours of electricity per year, according to the Bureau.

Other attractive storage possibilities for use with wind power also exist in the West. Particularly in the Panhandle of North Texas, gas companies have stored natural gas in underground wells for years. On the basis of typical pressures and flow rates, compressed air energy storage in the same formations would cost $95 per kilowatt or about 2 cents per kilowatt hour, according to Eldridge at the MITRE Corporation. Compressed gas is also stored in many other regions.

Both large and small wind systems have the potential to be competitive with conventional electric systems. A twofold cost reduction would make them attractive in many places, and such a reduction is quite feasible for a product that now has only 10 to 20 percent of its costs in materials. Once competitive, the primary limitation to wind energy use would be the rate of growth of the industry.

—William D. Metz

UPDATE

Drug for Treatment of Herpes Encephalitis

The first successful drug therapy of a life-threatening viral disease has been achieved by a nationwide team of investigators headed by Charles A. Alford and Richard J. Whitley of the University of Alabama Medical Center. They reported last month that as many as 90 percent of patients with the generally fatal disease herpes encephalitis can be cured with the drug ara-A. Their results lend strong support to the controversial concept that chemotherapy can be a successful weapon against viruses without killing an unacceptably large number of host cells.

Ara-A, also known as adenine arabinoside or vidarabine (and given the trade name Vira-A by its manufacturer, Parke, Davis & Company), has previously been shown in preliminary studies to be effective against chicken pox and herpes zoster or shingles (*Science*, 9 April 1976, p. 128). Parke, Davis also received permission earlier this year from the Food and Drug Administration to market ara-A for topical treatment of herpes keratitis, an eye infection with often serious consequences. Ara-A thus becomes the third commercial antiviral agent accredited in this country, joining idoxuridine, which is also effective against herpes keratitis, and amantadine hydrochloride, which is effective against influenza A viruses.

In the studies on ara-A, the investigators identified 28 individuals with herpes encephalitis, an infection characterized by a severe inflammation of the brain for which there was previously no effective therapy. Eighteen received ara-A and ten received a placebo. Seven of those who received a placebo died (70 percent), compared to only five of those who received ara-A (28 percent). Only one of ten individuals who received the drug before lapsing into a coma died (10 percent), indicating the importance of early diagnosis of the disease. These results are so impressive that the investigators have abandoned their original protocol and are no longer using the placebo.

Despite the success of ara-A against various types of herpes, it is still a limited tool because it must be given intravenously continuously. Investigators are trying to perfect forms of ara-A that would not have to be given in this way, and clinical studies with one such form are now in progress. When such forms have been perfected and are widely available, the age of antiviral chemotherapy will truly be with us.—T.H.M.