Approved: 1-25-94
Date

MINUTES OF THE SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES.

The meeting was called to order by Chairperson Don Sallee at 8:00 a.m. on January 19, 1994 in Room 423-S of the Capitol.

All members were present or excused:

Committee staff present: Raney Gilliland, Legislative Research Department
Dennis Hodgins, Legislative Research Department
Don Hayward, Revisor of Statutes
Clarene Wilms, Committee Secretary

Conferees appearing before the committee:
Edward Schaub, Western Resources
Dale Osborn, Vice President, Development, Kennetech Corporation

Others attending: See attached list

Edward Schaub, Western Resources, was called on to present information clarifying a question raised in committee concerning the imposition of fees against major utilities by the Central Interstate Low-level Radio active Waste Compact. Mr. Schaub told the committee the Compact Commission has the authority, regarding low-level waste that is generated in the five state compact area and is exported outside of those states, to take charge of those exports, and set a fee for those exports. These fees are used for administration of the commission. At the time the compact members were denied access to Barnwell the executive director, on his own initiative, sought to replace those export fees with a storage fee from the utilities. This was clearly outside of the authority of the commission and at the June meeting of the Compact Commission this order was rescinded and any fees collected under that order were refunded. In October access was again granted to the Barnwell facility and the fees were resumed.

Chairman Sallee introduced Dale Osborn, Kennetech Corporation, who provided the committee with information concerning windpower technology. Attachment 1

Mr. Osborn told the committee that wind energy is cost effective, generating power at roughly 5 cents per kilowatt-hour. Under the Clean Air Act Amendments of 1990, wind power helps utilities save SO2 emission allowances.

Mr. Osborn stated wind energy is proven. The 3.8 billion kilowatt-hours produced worldwide by wind turbines is enough electricity to meet about one and one-half percent of the residential requirements of North Americans. Kenetech/Windpower is the world's largest wind energy company and have been in operation since 1982. Kenetech/windpower has manufactured, installed, and are operating more than 4,200 wind turbines, logging over 79 million hours of operation.

Wind energy helps the environment and this energy can offset the emission of nitrogen dioxide, sulfur dioxide and particulates. Wind energy can save fossil fuels preventing production of carbon dioxide.

Mr. Osborn told the committee that Kansas has a huge capacity for wind energy. When asked about the strategy for power at times of insufficient wind energy, Mr. Osborn stated that utilities are able to statistically predict capacities and usually have excess capacity available.

A member asked what the minimum and maximum speeds were for the units. Mr. Osborn stated the minimum speed was 8 miles per hour and it reaches rated output of about 26 miles per hour. It will run up to 65 miles per hour at which time it will stop itself to prevent damage. Sixteen miles per hour is needed to produce power economically. Basically, dust is not a problem but in high dust areas filters can be installed to prevent problems.

It is most feasible to build close to utility transmission lines which are numerous in Kansas.

A member questioned that if, in fact, this production method is so good, why utilities have not embraced this method of production and why various subsidies have been needed. Mr. Osborn stated that in his opinion the industry itself has never focused well on the utility sector. Wind developers have been adversaries to the utility companies. Communication has not been handled in a efficient manner until recently. Presently, regulatory expenses are causing utilities to investigate other possibilities. People are now recognizing that wind power is the way to go.

The meeting adjourned at 9:55 a.m.

The next meeting is scheduled for January 25, 1994

SENATE COMMITTEE ON ENERGY & NATURAL RESOURCES

DATE January 19, 1994

| (PLEASE PRINT) NAME AND ADDRESS | ORGANIZATION |
|---|---|
| Robert Eye 2137 Tenn. Lawrence, Ks 66046 | |
| Jim Ludwig Topeka | WESTERN RESOURCES |
| John Peterson | Browning Ferris Industries |
| Gary Johnson 1630 Osage, Manhattan, KS 66502 | Kansas State Univ., Elect. Engg. |
| Lori Oliver 1500 S.W. Arrowhead Rd Topeka | Kansas Corporation Commission |
| Patrick Hurley Topeka | KCPL |
| J C Long Topeka | UtiliCorp United |
| Larry Holloway 1500 SW Arrowhead Rd Topeka | Kansas Corporation Commission |
| JOE KING 7015 COLLEGE BLVD OV. PK, KS. | MERIDIAN CORP. |
| Bill Ward 2145 Barker Lawrence KS 66046 | Kansas Natural Resource Council |
| Lee Sippel, 1201 Walnut, KCMO | KCPL |
| MARK DOLJAC | KCC |
| EDWARD ROWE, 828 MARKET, EMPORIA 66801 | LEAGUE of WOMEN VOTERS |

ENERGY

# THE SUN SHINES BRIGHTER ON ALTERNATIVE ENERGY

## Nonfossil sources of power are back—and getting more efficient

In the late 1970s, alternative energy was nearly as popular in California as alternative lifestyles. Fertilized by state and federal tax incentives, windmills sprouted east of San Francisco by the thousand. Patches of the Mojave Desert were carpeted with panels that collected the sun's energy. But when the tax breaks dried up, so did the projects. Luz International Ltd., a top maker of solar gear, went bankrupt.

The times are changing, however. Bolstered by improved technology and revived support from Washington, renewable energy is making a comeback—and not just out West. On Aug. 6, some 68 utilities across the country agreed to buy as much as $500 million worth of solar panels over the next five years to generate electricity. Two weeks later, utilities in Maine, Texas, and Vermont signed on for Energy Dept. tests of new, more efficient wind turbines. And in October, the industry-funded Utility Renewable Resources Assn. decided to refocus exclusively on finding clean ways to burn biomass—wood and other plant material. "We're seeing a revolution in the way we create and use power," says Frank M. Stewart Jr., acting assistant energy secretary for efficiency and renewable energy. Already, Southern California Edison Co., a pioneer in such efforts, gets 13% of its electricity from these renewable sources vs. 1% in 1985.

**"TRUCKING ALONG."** Most of the renewables are still infant technologies with big cost disadvantages (table). So they won't displace fossil fuels right away, if ever. Currently, nearly 55% of the nation's electricity comes from coal, 22% from nuclear reactors, 13% from oil and natural gas, and about 9% from hydro generators. Wind and solar power account for less than 1% of the total, a share that's expected to rise only slowly.

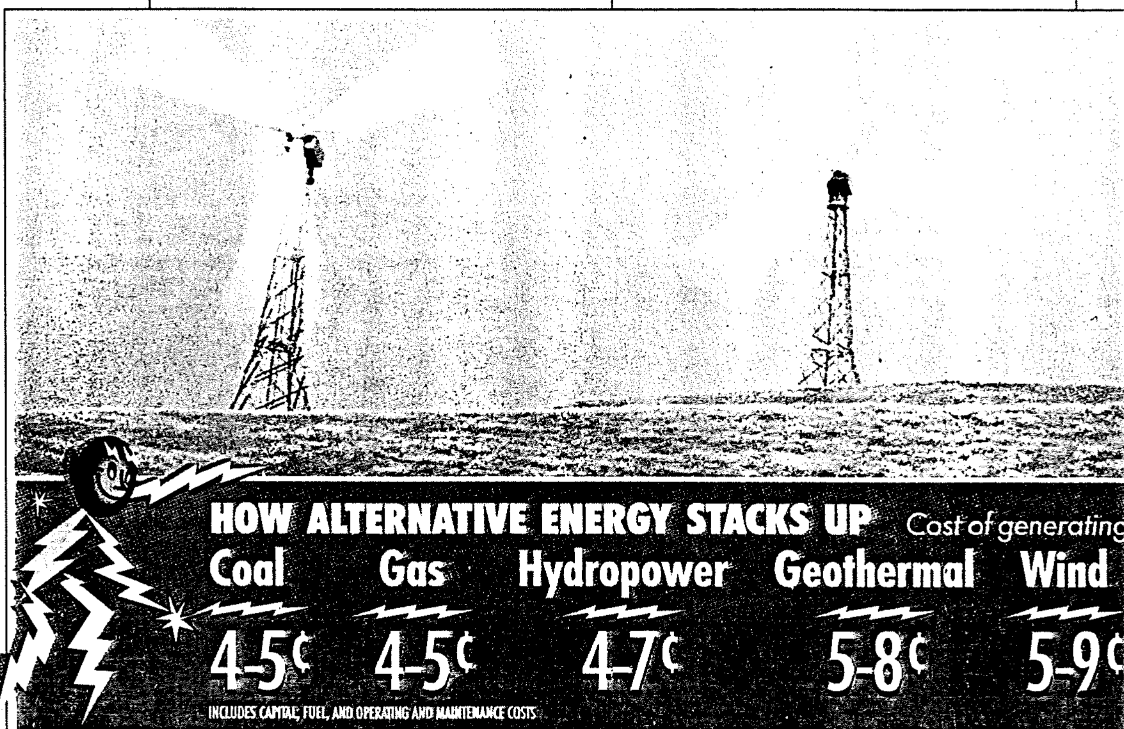
Still, after being slashed by 76% during the Reagan era, federal spending for research on renewable energy will climb 36% in fiscal 1994, to $347 million. If this money is used well, says Robert L. San Martin, deputy assistant secretary for utility technologies at the Energy Dept., perhaps 5% of U.S. electricity could come from wind and sun within 20 years. Well before then, the market opportunities could be tantalizing. "If we supplied just 1% of the world's electricity by the end of the century, we'd be trucking along at $3 billion to $4 billion [in sales] a year," says Gerald R. Alderson, president and CEO of Kenetech Inc. in San Francisco, the nation's largest wind-power company.

Wind power, in fact, "is on the doorstep of commercial reality," says Edgar DeMeo, manager of the solar-power program at the utility-funded Electric Power Research Institute in Palo Alto, Calif. Since 1981, commercial power generated from wind worldwide has leaped from 15 megawatts to 2,652 megawatts, according to the Worldwatch Institute, a nonprofit research body in Washington. The U.S. generates most of this—65%. But maybe not for long: Worldwatch experts say that by 2005 the European Community aims to be generating 8,000 Mw of electricity from wind, or 1% of its total.

**FASTER SPIN.** Those windmills will be more sophisticated than the giant propellers that covered California's Altamont Pass in the 1980s to catch the powerful Pacific breezes. None of those early models could generate electricity for less than 7½¢ per kilowatt hour, 50% more than from coal or nuclear. But in late 1991, a Kenetech subsidiary, U.S. Windpower Inc., unveiled a better turbine, the 33M-VS. The company is now selling electricity from this machine for as little as 5¢ per kwh.

To finance production of the new turbine, Kenetech went public in September, raising $92 million. Alderson says the company has $600 million in firm orders from such utilities as New England Electric System, which will buy roughly 20 Mw of wind power by 1998. Last April, meanwhile, U.S. Windpower formed a partnership with a Ukrainian utility called Krimenergo to build a 500-Mw wind farm on the Crimean peninsula in hopes of hastening the closure of nuclear plants at Chernobyl. The company is also negotiating with the European Utility Consortium to provide 150 Mw of power—enough to run about 50,000 homes—by 1999.

Sitting atop a 90-foot tower, its 54-foot-long blades facing into the breeze,




PHOTOGRAPH BY CYNTHIA CHEAK/KENETECH; CHART BY RAY VELLA/BW

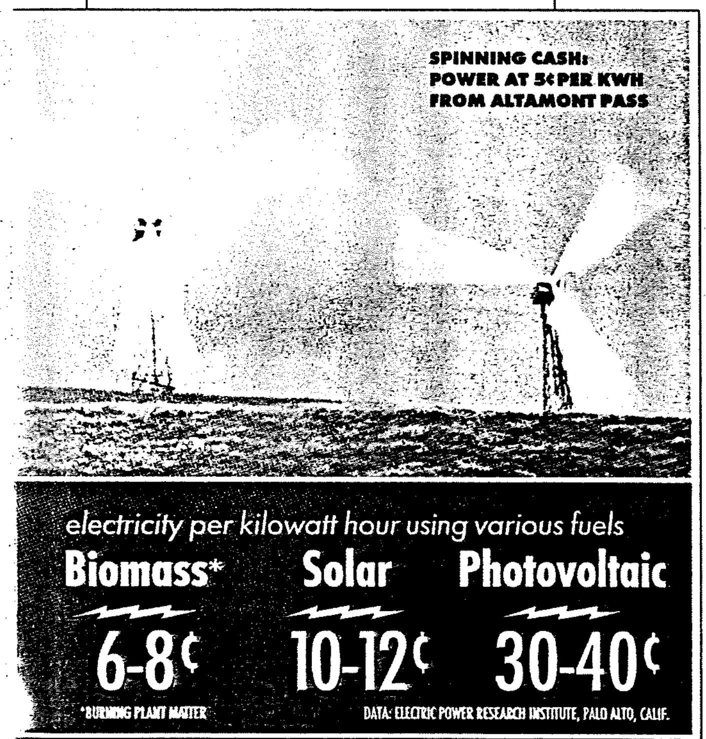


Senate Energy & Nat'l Resc January 19, 1994
Attachment 1

the 33M-VS looks like any other wind machine. But it isn't. Until it came along, turbines spun at a constant velocity, no matter how hard the wind blew. This was necessary to generate alternating current with a frequency of 60 hertz, as used in the U. S. By contrast, the Kenetech machine accelerates or slows down as wind speed changes, and a computerized converter produces a steady 60-hertz current. It thus captures more energy as the wind blows harder, and it can take strong gusts without breaking —as earlier models did.

FloWind Corp. in San Rafael, Calif., is doing well, too, with a new turbine that produces electricity for 5.3¢ per kwh. Its blades spin at a constant speed, but a new blade design allows the turbine to draw extra power from strong winds. FloWind has won its first order for the new turbines, from Washington state's Bonneville Power Administration, which will build a 91-unit wind farm by 1995.

Solar power is about a decade behind wind, experts say, in the race to become commercially feasible. Still, scientists are steadily improving the efficiency of solar cells, a key to getting prices down. In July, scientists at the National Renewable Energy Laboratory set efficiency records for two technologies. Thin-film cells made of copper indium diselenide and gallium converted 15.5% of sunlight into electricity, surpassing the 15% mark for the first time. Tandem cells made of gallium indium phosphide and gallium arsenide, which soak up different parts of the light spectrum, reached 29.5% efficiency, up from 27.6%. Energy Dept. scientists say Martin Marietta, Solarex, Siemens Solar Industries, and International Solar Electric Technologies are monitoring the developments in thin-film technology with an eye to making solar cells for utilities.




**SPINNING CASH: POWER AT 5¢ PER KWH FROM ALTAMONT PASS**

**SALTING IT AWAY.** SoCal Edison is also working on solar advances. In partnership with Texas Instruments Inc., the utility is developing sheets of tiny photovoltaic cells made of silicon. These would be built into roof shingles or other construction materials to generate electricity for homes. The cells now operate at 8.5% efficiency and produce electricity at 16¢ to 18¢ per kwh. Joseph N. Reeves, research manager at SoCal Edison, says the companies hope to hit 9% efficiency before deciding early next year whether to commercialize the cells. Despite the high cost, Reeves says, this technology makes sense in some situations. For instance, extending an electrical distribution line can cost $20,000 to $50,000 a mile. "If you pay $10,000 or $20,000 per kilowatt for a photovoltaic system, that still might be cheaper [in remote areas]," says Reeves.

SoCal Edison is also leading a 12-member consortium in a $48.5 million project called Solar Two, which the participants hope will generate as much as 35% more electricity than an earlier project did. Solar Two will use mirrors to concentrate the sun's rays, then store the resulting heat in molten salt to be drawn out later to generate electricity at night or on cloudy days. Salt, it turns out, holds heat much longer than did oil, the storage medium in Solar One. The new project would let utilities use solar energy as more than an intermittent power source, says Reeves, and SoCal hopes to be using it by 2000.

The push for alternative energy sources could also lead to more burning of crops or trees grown especially for that purpose. Some 0.5% of U. S. electricity is now produced this way, a share that is likely to double by 2010. Georgia Power Co. in Atlanta, for instance, burns as much as 2,000 tons of peanut shells and scrap wood a month in place of coal. Using wood is 30% cheaper and reduces harmful emissions, says Dwight H. Evans, executive vice-president.

True, alternative energy is still only peanuts in the nation's energy mix. But with more money from Washington and more support from adventurous utilities, the idea may go further this time.

*By Mary Beth Regan in Washington*

American Wind Energy Association

# 1993 WIND TECHNOLOGY STATUS REPORT: WIND ENERGY ON VERGE OF EXPANSION IN U.S.

After a decade of growth in California the U.S. wind industry is on the verge of breaking out of its birthplace into fertile new markets. The announcement by Northern States Power Co. (NSP) of plans for a 50 to 100 turbine wind power plant in Minnesota signals the start of wind development in the Midwest. With completion slated for next year, the 25 megawatt (MW) project in the southwest corner of the state will be the first large-scale wind plant built outside of California or Hawaii.

Municipal utilities have been operating small wind farms for several years in Princeton, Mass., Livingston, Mont., and in Marshall, Minn. More than 16,000 wind turbines in California churn out 2.7 billion kilowatt-hours of renewable electricity annually. But the NSP project will be the first large wind farm commissioned by a major investor-owned utility, and the first in the Midwest, where there are sufficient wind resources to meet 10 to 20 percent of the nation's electrical needs. The Minnesota project also has further significance; Hazel O'Leary, President Clinton's Secretary of Energy, was a senior executive at NSP when the decision was made to rely more on wind energy.

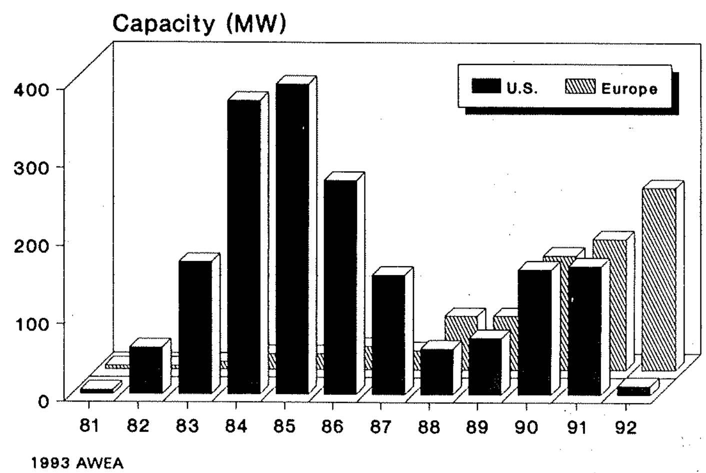
By 1997 NSP expects to expand its project to 100 MW generated from as many as 400 wind turbines. At about the same time the Bonneville Power Administration (BPA) will be bringing on line the first modern wind plant in the Pacific Northwest. The 50 MW plant, resulting from a BPA solicitation, could be followed by a number of other projects currently in negotiations.

Meanwhile, Eastern utilities have taken the first tentative steps towards projects. Niagara Mohawk Power Co. has installed prototypes of a new wind turbine in the Adirondack mountains near Lake Ontario in anticipation of an eventual pilot project, and Green Mountain Power has proposed a 20 MW project in Vermont and a 10 MW project in Massachusetts.

Growing utility interest also is evident in California where wind power plants have been identified as one of the technologies independent producers must bid against for the addition of new generating capacity in 1997. Two of the country's largest electric utilities, Pacific Gas & Electric Co. and Southern California Edison Co., have proposed to build wind power plants as one of the most cost-effective means of meeting future electric demand.

Small wind turbines also are finding markets as more and more families are building homes beyond the reach of utility lines. Utilities themselves, with the aid of the DOE's National Renewable Energy Laboratory, are examining innovative uses of small wind turbines.

**NEW U.S., EUROPEAN WIND TURBINE INSTALLATIONS**



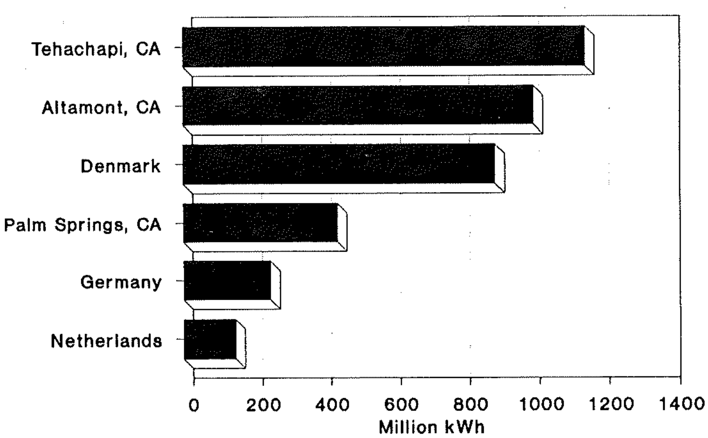

A virtual renaissance of wind energy in the United States is possible if public policy finally swings toward renewables after more than a decade of federal neglect. The passage of the Energy Policy Act, with its 1.5 cent per kilowatt-hour production tax incentive for wind energy, could mark a turning point in official recognition of wind energy's potential. Further, the election of the Clinton-Gore Administration has increased expectations of renewable energy development, as both advocate an increased reliance on energy efficiency and renewable energy technologies such as wind. Despite this noteworthy progress during 1992, European wind developments far outstripped those in the United States, where wind market development has been stalled outside of California.

777 N. Capitol Street, NE, Suite 805, Washington, DC 20002-4239, (202) 408-8988

## Europe Outpacing U.S.

Only 5 MW of new wind turbines were installed in the entire United States during 1992. In contrast European nations erected 225 MW. Ironically, Spain installed more wind turbines using American technology in 1992 than were erected here. And Canada is expected to install more U.S. wind technology than the United States during 1993. The Ukraine, struggling to establish its own non-nuclear generation, plans to use more U.S. designed wind turbines than all the proposed projects in the United States combined. Countries concerned about meeting international treaty obligations to reduce their emissions of greenhouse gases increasingly are turning to renewable sources of energy for power. They are finding, in areas with potential resources, that wind energy is the most cost-effective of all renewable technologies, and one of the most cost-effective sources of new electrical generation of any kind.

MAJOR WIND ENERGY CENTERS 1992 PRODUCTION




1993 AWEA

As recently as the late 1980s California's windy passes ranked in the top three of the world's leading areas of wind generation. With Europe's rapid growth, Denmark has already pushed aside Palm Springs and is expected to exceed the Altamont's total generation within only a few years.

European development is now expected to dwarf that in the U.S. throughout the next few years. Denmark, England, Spain and the Netherlands each will surpass the U.S. in new installations of wind turbines in 1992 and subsequent years. By the mid 1990s Denmark, a nation of 5 million, will become the world's largest regional producer.

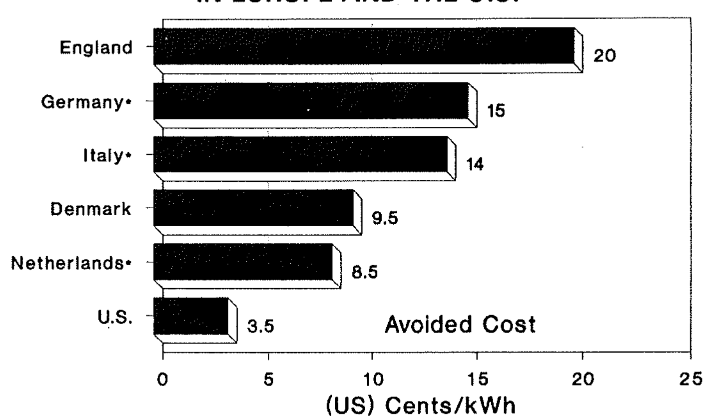
Outside Europe, wind programs in other nations also are accelerating. India now has more wind generating capacity on line than is currently on line in the United States outside California.

## Europe Successfully Using "Market Pull"

Analysts attribute Europe's success to effective market incentives that "pull" technological advancements into widespread use. Europeans have convincingly demonstrated that there are two essential elements for expanding the renewable energy marketplace: available utility contracts, and a "Green Tariff" for clean sources of electricity generation.

In the two countries with the most successful programs, Denmark and Germany, utilities will buy wind-generated electricity from all suppliers, for a pre-defined and stable price, for a fixed number of years. Denmark sets the non-fossil fuel tariff at 85 percent of the retail rate and exempts the sale of wind-generated electricity from the value added tax (similar to the Administration's proposed Btu tax). Germany sets its green tariff at 90 percent of the retail rate. Many German projects also qualify for a renewable research premium of four cents per kilowatt-hour (kWh), plus an equipment credit. As a result Germany has the most rapidly expanding market for wind energy in the world. There is also a non-fossil fuel premium in Italy, and an equipment credit in the Netherlands.

PAYMENT FOR 1993 WIND CONTRACTS IN EUROPE AND THE U.S.



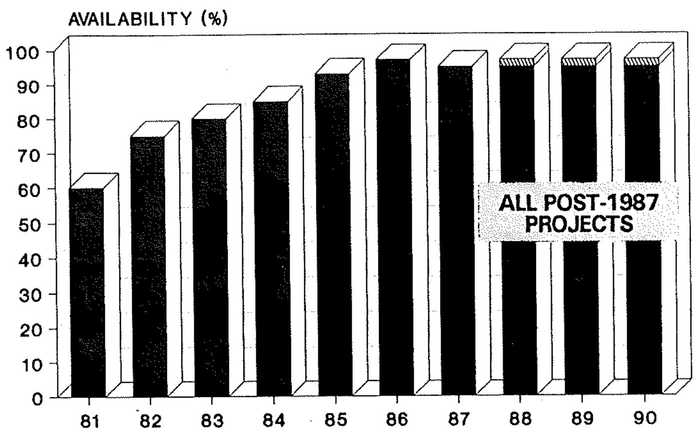

• Equipment credit not included
1993 AWEA

In England, short-term, high-paying contracts have stimulated fast-paced development, attracting wind engineers from America and Europe. Because of a weak domestic market, the largest project for a U.S. wind company during 1992 was not in the United States at all, but was in Wales. In just two years England will increase its installed wind capacity from 10 MW to 130 MW.

Denmark expects to supply 10 percent of its electricity from 1,000 MW of wind capacity by 2000, and by 2005 they plan to add another 500 MW. The Netherlands is equally ambitious. They have set an official policy goal of 1,000 MW of wind generation by the year

2000 and 2,000 MW by the year 2010. The German states of Schleswig-Holstein and Nedersachsen plan to install 1,000 MW of wind turbines each by 2010. Just in this small corner of northern Europe planners are eyeing 5,500 MW of wind generation within two decades. By contrast, the United States has set no goals for renewable energy development, and currently receives less than one-tenth of one percent of its electricity from wind energy.

**AVAILABILITY AT TOP CALIFORNIA WIND PLANTS**




SOURCE: R. LYNETTE & ASSOCIATES

European success has been built upon gradual but steadily increasing support for wind energy as the technology has proven itself and environmental demands for cleaner sources of electricity have grown. U.S. policy, on the other hand, has been inconsistent.

During the late 1970s and early 1980s, the United States launched an aggressive market incentive program that was dropped in 1985, creating a boom and bust cycle during the mid-1980s. The effort did pay dividends however, as it proved conclusively that wind energy would become a commercial generating resource.

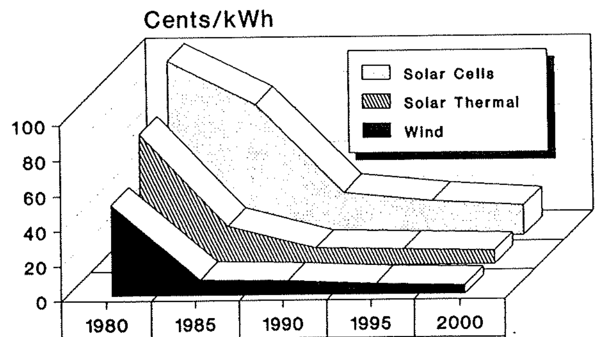
## Reliability Increases, Costs Decline

Wind technology proved itself in California during its first decade of commercial application. Even after tax incentives expired, new wind turbines continued to be installed on the basis of long-term utility contracts that were initiated by progressive state regulation.

Wind energy is now a conventional resource, generating as much electricity in California as a medium size coal or nuclear plant. Reliability has improved dramatically while costs have declined from more than 50 cents per kilowatt-hour in 1980 to about 6 to 9 cents per kilowatt-hour for projects today. Proposals using next generation turbines have bid contracts at less than 5 cents per kilowatt-hour for the mid-1990s.

Wind turbines in the United States have now operated nearly one billion hours interconnected with local utilities, and generated more than 15 billion kilowatt-hours of electricity. At windy sites it's not uncommon for a wind machine to be in operation for two-thirds of the time, or about 6000 hours per year. This is no small feat. The typical wind turbine operates as many hours in its first 4 months as an automobile does over its 100,000-mile life. Most modern wind turbines are available for operation, ready to generate electricity, more than 97 percent of the time.

**DECLINING COST OF RENEWABLES FOR PG&E BULK POWER GENERATION**




| | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|
| Solar Cells | 100 | 75 | 25 | 20 | 17 |
| Solar Thermal | 75 | 23 | 10 | 9 | 8 |
| Wind | 52 | 9 | 8 | 6 | 5 |

SOURCE: PACIFIC GAS & ELECTRIC

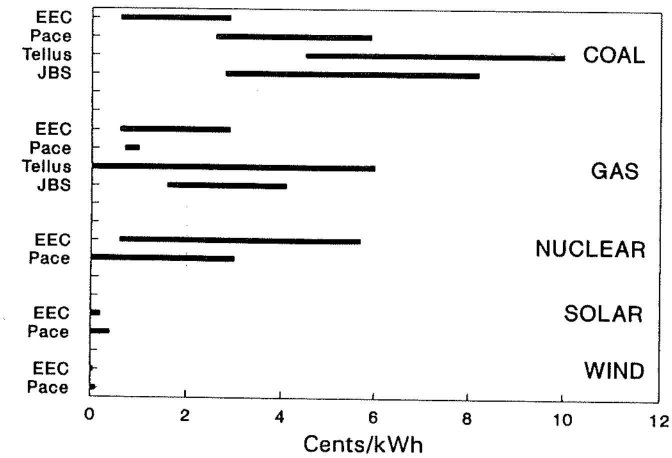
Wind turbines now provide electricity for high-reliability telecommunication applications in a range of harsh environments from the Arctic to the Antarctic, and in rural power systems across the American Great Plains and the Asian Steppes. Reliable wind power plants produce bulk power for electric utilities from the beaches of the Arabian Sea, to the Sonoran Desert of Southern California, to the shores of the North Sea in Denmark, Germany, and the Netherlands.

As the technology has matured, costs have continued to decline. Today wind energy is one of the least expensive sources of new electrical generation according to both the California Energy Commission and Pacific Gas & Electric Co.

## Environmental Benefits

In addition to its cost-effectiveness wind energy offers substantial environmental benefits. Several U.S. and European studies have found that traditional technologies, especially coal and nuclear plants, have substantial hidden costs. For coal, analysts estimate that these costs vary from 0.6 cents to as much as 10 cents per kilowatt-hour. The external costs of nuclear power can range as high as 5.7 cents. The social costs of wind and solar energy are virtually non-existent. These benefits accrue whether the electricity was generated by 250 kW wind turbines in a Minnesota wind power plant or by a 10 kW wind machine in a remote Mexican village.

**ESTIMATES OF EXTERNAL COSTS**




SOURCE: U.S. ENVIRONMENTAL PROTECTION AGENCY 1992

## The End of the Line

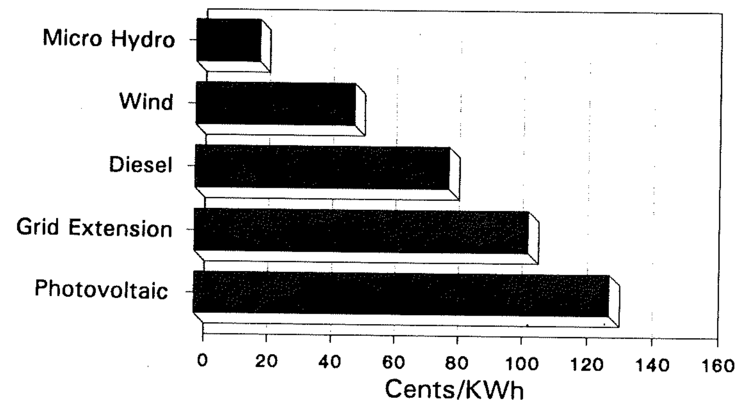
The benefits of providing even small amounts of power to remote villages are magnified because so little electricity is needed to raise the quality of life. A 10 kW wind turbine, which would supply only one home with electric heat in the United States, today pumps safe drinking water for a village of 4000 in Morocco. A village on the Yucatan Peninsula installed Mexico's first wind farm, six 10-kW wind turbines as part of a hybrid wind and solar power system, offsetting the construction of a proposed $3.2 million power line.

A recent report by the Congressional Office of Technology Assessment noted that "with reasonable assumptions concerning discount rates, capacity factors, and fuel costs, micro-hydropower and wind turbines can have the lowest life-cycle costs in locations where the resource is sufficient." The report criticized the over-reliance on engine-generators, noting "diesel generators have by far the lowest initial capital cost, but when fuel and O&M costs are considered, diesel generators are of comparable expense to renewable technologies—*more expensive than wind turbines and micro-hydro, and less expensive than photovoltaics.*"

Both small and medium size wind turbines can be used in industrialized countries as well to meet the needs of remote communities. The government of New South Wales now provides stand-alone power systems for remote cattle stations in Australia's outback in lieu of central-station power from the provincial utility. Even a utility as conservative as *Electricité de France* has found that wind turbines make good economic sense for rural areas of France and its overseas territories by avoiding costly transmission line extensions.

Some in the U.S. utility industry now see their companies owning and operating small, dispersed wind turbines as part of their distribution network. This is a new market for wind turbines that's only now being examined. To test the concept, the National Renewable Energy Laboratory is sponsoring a project where utilities will install small wind turbines at the end of heavily-loaded transmission lines. Analysts believe this will reduce the need for costly transmission line upgrades.

**RESOURCE COSTS FOR VILLAGE ELECTRIFICATION**
(50 kWh/day)




SOURCE: U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

## Challenges Remain

Despite emerging markets wind energy will never grow to its full potential in the United States unless several market obstacles are overcome. The most important is utility contracts and responsible valuation of wind-generated electricity. After more than a decade of anti-renewable bias in federal energy programs, and a lack of coordinated state regulatory actions, the gains made by wind energy could be lost as existing contracts begin to expire in California.

The tremendous reductions in cost and increases in efficiency have presented new opportunities for the wind energy industry, both here and abroad. As the U.S. focuses on preparing itself for the 21st century economy, the wind industry stands at a crossroads of moving a commercially competitive technology into the international marketplace while competing against heavily-financed European and Japanese companies which have the regulatory and financial support of governments.

**"If wind power does not fulfill its promise as a major energy source by the end of the century, it will not be a failure of technology. It will be a failure of vision on the part of society to make the necessary commitment."**

*Time Magazine*, **January 13, 1992**

# THE 33M-VS

## THE STANDARD FOR A NEW GENERATION OF POWER

### ADVANCED FEATURES

By incorporating recent engineering developments in advanced electronics, aerodynamics and wind turbine design, the 33M-VS captures significantly more energy than existing constant speed wind turbines at far lower cost. An advanced power electronic converter allows the rotor and generators to accelerate with higher winds while maintaining a constant frequency output. This feature increases the range of wind speed over which the turbine operates while significantly reducing the loads to which the turbine is exposed.

### COST COMPETITIVE TODAY

The 33M-VS generates power at a cost to utilities of roughly 5¢/kWh, a price competitive with newly constructed fossil-fuel power plants. If utilities choose to own the Windplant, the lower cost of utility capital may reduce the effective cost to 4 – 4.5¢/kWh.

### SUPERIOR POWER QUALITY

The 33M-VS uses a state-of-the-art electronic power converter — developed by USW — to convert the wind turbine's variable speed operation into constant frequency power required by the utility. The converter uses insulated gate bipolar transistors switching at high frequency to create the AC current waveform delivered to the grid. The resulting high quality power is in full compliance with IEEE–519 requirements.

### REACTIVE POWER AND VOLTAGE SUPPORT

The 33M-VS is capable of generating both real and reactive power. The capability to control reactive power can provide transmission efficiencies and enhanced voltage stability — a particularly valuable feature if a Windplant is connected to a weak grid.

### UNPRECEDENTED PLANNING FLEXIBILITY

A Windplant offers utility managers unprecedented flexibility in planning additional capacity and energy requirements. Assuming all permits have been obtained, a Windplant can be expanded in a matter of months by anywhere from 5MW to 50MW, or more.

### FUEL DIVERSITY AND RISK MITIGATION

Wind represents an inflation-free, zero-emission fuel source for utilities. With the enormous environmental uncertainties facing utility planners, wind power is an effective risk mitigation tool — a cost-effective hedge against increasingly tough environmental legislation. Additionally, the short construction period minimizes a utility's exposure to start-up delays, cost overruns and negative prudency reviews.

### WARRANTY

U.S. Windpower offers a warranty designed to meet traditional utility purchasing requirements and be consistent with warranties offered by other suppliers of utility generating equipment.

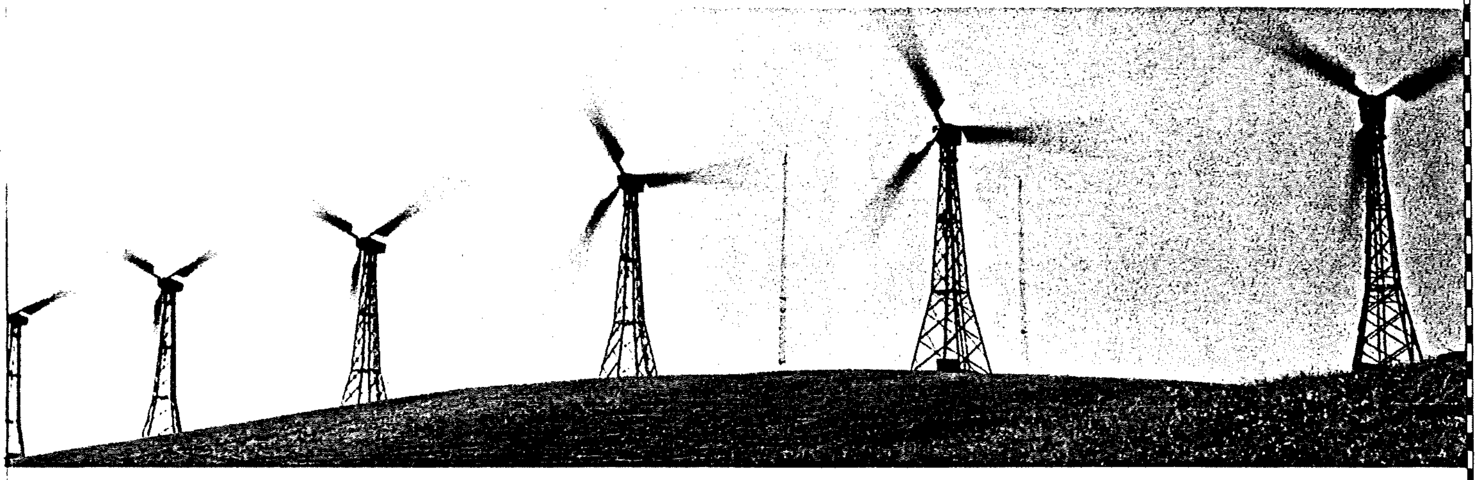
### UTILITY SUPPORT

The utility-grade 33M-VS wind turbine was designed and developed by a Consortium led by U.S. Windpower including Pacific Gas & Electric Company, Niagara Mohawk Power Corporation and the Electric Power Research Institute.

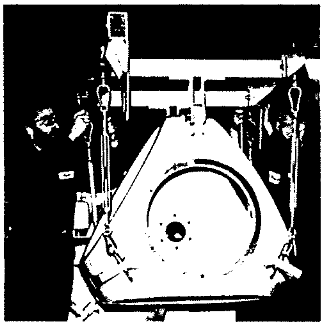
KENETECH/U.S. WINDPOWER

# KENETECH/U.S. WINDPOWER

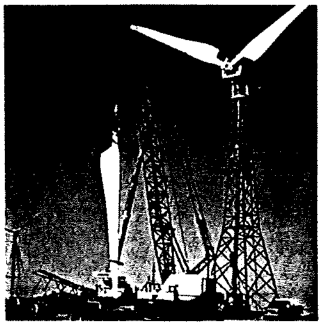
## THE QUALITY FULL-SERVICE SUPPLIER TO UTILITIES



**THE WINDPLANT**
An innovator in energy technology, USW originated and developed the Windplant concept — a large array of sophisticated wind turbines, sited, installed, interconnected and operated as a single power plant.

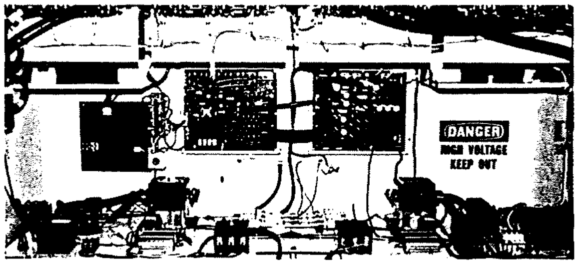


**MANUFACTURING**
USW's engineers have designed precision quality into all aspects of the manufacturing process.



**CONSTRUCTION**
USW provides turnkey Windplant construction through KENETECH's CNF Industries subsidiary.

**MAINTENANCE**
The USW design philosophy embodies simplicity, robustness, and maintainability. Semi-annual preventive maintenance ensures high availability.

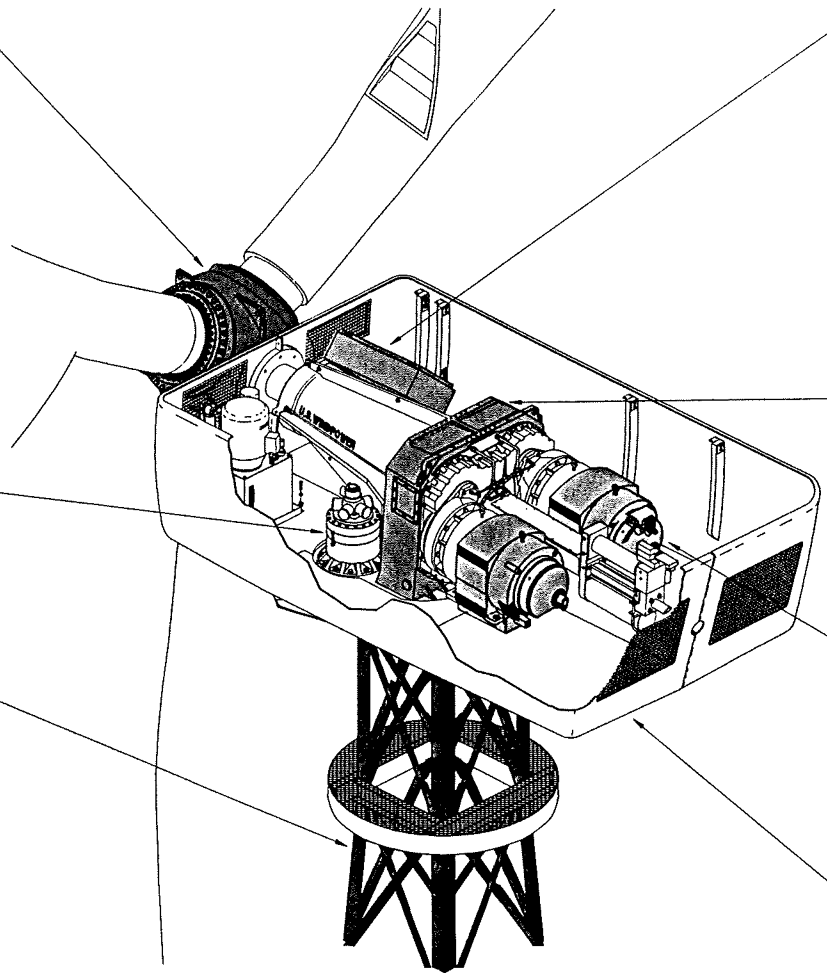



**ENGINEERING**
The Power Electronics controller uses patented state-of-the-art technology to convert the variable frequency power of the generator to the constant frequency power required by the utility.

**OPERATIONS**
From a single workstation, USW operators can control and optimize the performance of several thousand turbines simultaneously, while scanning detailed operating data on individual turbines.

# THE 33M-VS

## STATE-OF-THE-ART TECHNOLOGY



**ROTOR**

**Blade Design**
Variable Pitch Laminated Fiberglass
**Blade Weight**
2,000 lbs. each
**Rotor Diameter**
33m/108′
**Swept Area**
855m²
**Rotational Speed**
Variable

**YAW DRIVE**

Hydraulic Motor
Planetary Gear
Hydraulic Damping

**TOWER**

**Type**
Truss or Monotube
**Height**
80′, 100′, 120′, or 140′
**Weight**
80′ = 19,000 lbs.
**Base Diameter**
20′X20′ (80′ tower)
**Material**
Galvanized Steel
**Foundation**
Piers or Pad

**CONTROL SYSTEM**

**Blade Pitch Control**
Linear Hydraulic Cylinder
**Turbine Control**
USW Proprietary Microprocessor
**System Control**
Utility-Grade Site Control and Data Acquisition System

**TRANSMISSION**

**Type**
Parallel Shaft
Dual Output
Helical Gears
Ratio 45:1

**GENERATOR**

**Type**
2 Dual Squirrel Cage Induction
**Voltage**
50 – 60Hz, 3 Phase

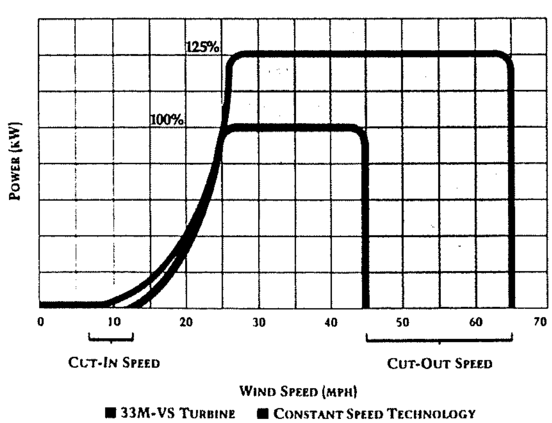
**NACELLE**

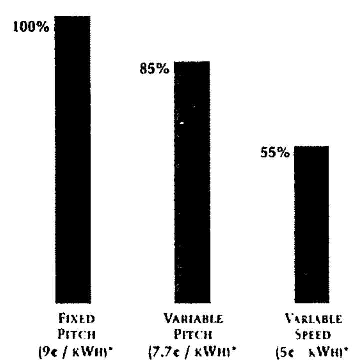
**Material**
Fiberglass
**Access Device**
Built-In Work Platform
**Weight**
22,000 lbs.

**PERFORMANCE**

| | |
|---|---|
| Cut-In Wind Speed | 9 mph |
| Rated Wind Speed | Variable |
| Cut-Out Wind Speed | 65 mph |

## INCREASED ENERGY CAPTURE... AT A LOWER COST




*Average Wind Resource, QF Financing, 1991 dollars.

33M-VS TURBINE COMPARED TO CONSTANT SPEED TECHNOLOGY

# THE 33M-VS

## THE ADVANCED UTILITY-GRADE WIND TURBINE

### BUILT ON 3 BILLION KILOWATT HOURS OF EXPERIENCE

U.S. Windpower (USW) is the world's leading manufacturer of wind turbines and developer of utility-scale Windplants™. USW designed, developed and currently operates a 420 MW Windplant in northern California, as well as Europe's largest Windplant located in southern Spain. USW Windplants average 95% availability and have generated over 3 billion kilowatt hours (kWh) of electricity — operating experience unmatched anywhere in the world.

### 4 TIMES THE ENERGY AT 2.5 TIMES THE COST

Building on its singular success in the 1980s, USW has developed a new generation of utility-grade wind turbines, the 33M-VS, that provide *four times the energy at two and one half times the cost* of conventional wind turbines. Designed in conjunction with a consortium of utilities, the 33M-VS offers utilities zero-emission power at roughly five cents per kilowatt hour — a price competitive with newly constructed fossil-fuel plants.

### COST-EFFECTIVE AND ENVIRONMENTALLY COMPATIBLE

Throughout the United States and abroad, wind power is increasingly recognized for its demonstrated ability to meet the challenges facing utility managers in a cost-effective and environmentally compatible manner. The predictability of the wind resource and the rugged reliability of the turbines, combined with a Windplant's modularity and short construction lead times, give utility planners unprecedented flexibility in meeting additional capacity and energy requirements.

### USW'S TOTAL COMMITMENT TO WIND ENERGY

U.S. Windpower, a KENETECH company, provides its utility customers with a full range of services necessary to bring a Windplant on-line. USW builds and sells Windplants on a turnkey basis, or develops Windplants on an independent power basis. USW's services include resource assessment, land negotiations, siting, permitting, project financing, construction, and operations and maintenance. USW's total commitment to wind energy — as well as KENETECH's broad financial strength — ensures the long-term success of a USW Windplant.

The blades of a wind turbine work in the same way as the wings of a plane. As air passes over the surface of a wind turbine's blades or an airplane's wings, it creates "lift". In the case of wind turbines, lift is the force that pulls the blades in a circular motion. Thus, the blades convert the linear motion of the wind into rotational motion which is used to drive an electrical generator.

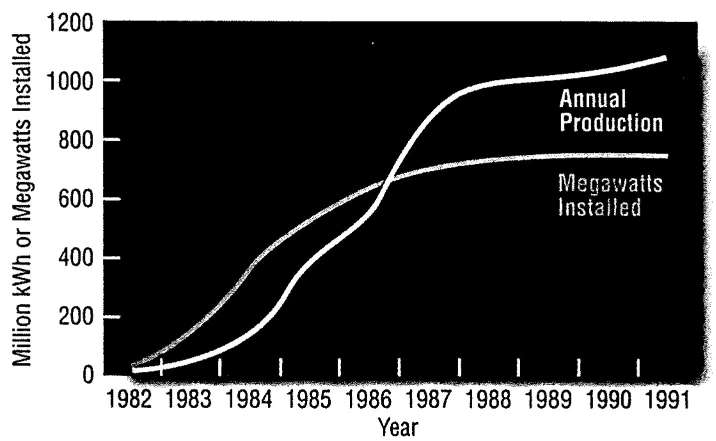
The proportion of the energy in the wind used to generate electricity is controlled by the angle of the blades to the wind. A higher angle captures a greater proportion, allowing the wind turbine to operate at lower wind speeds. A smaller angle makes it possible to operate at higher wind speeds. Therefore, selecting the appropriate angle involves a tradeoff between the capability of operating at lower or higher wind speeds. To minimize this tradeoff, some manufacturers build variable pitch machines which can adjust the angle of their blades to the wind. Although this construction allows these machines to operate over a wider range of wind speeds (increasing their efficiency), controlling these machines requires more sophisticated technology to ensure the pitch of the blades matches the wind speed on a moment-to-moment basis.

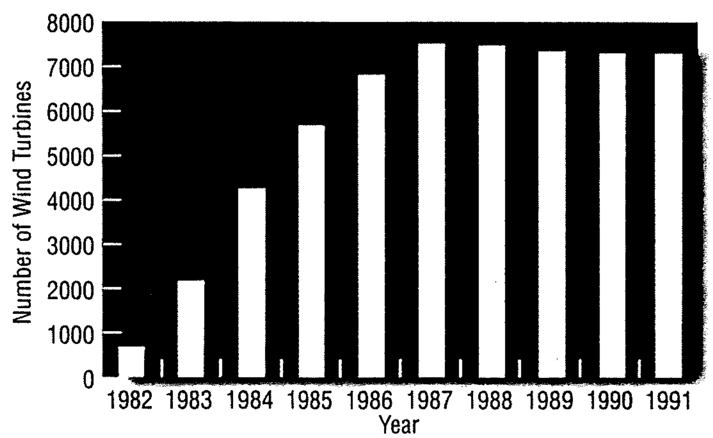
Wind turbines are designed to operate under different wind conditions, as evidenced by their "cut-in" and "cut-out" speeds. Both design specifications and wind fluctuations account for some of the performance variation at any given time in Altamont Pass.

***Why wind turbines may not be operating when you drive by:***

- ***Wind speed is below cut-in (minimum wind speed at which wind turbine generates power)***
- ***Wind speed is above cut-out (maximum wind speed at which wind turbine generates power)***
- ***Winds are in-line (wind direction is parallel to row of wind turbines—limiting operation to one out of every three or four machines)***
- ***Machine requires repair***
- ***Work crews in the vicinity***

The wind power plants have not been without technical problems. Machines have had to be shut down temporarily for repairs, and important lessons continue to be learned in this new industry. Manufacturers are refining their designs as they strive for more reliable, less expensive machines. Significant progress has been made in machine reliability and is clearly demonstrated by the increase in wind power plant output from year to year. The following graphs track the industry's growth in the Altamont Pass over the last ten years. Because many early small turbines have been replaced with new and larger turbines in the last few years, the number of turbines has decreased, while the total installed capacity (megawatts) has remained constant.




For the Livermore Valley, the wind power plant has provided a new industry with many new jobs in construction, maintenance and computer operations. For PG&E customers, the plant is providing the benefit of electricity produced by a clean, renewable resource – the wind.

The Altamont Pass was chosen by wind energy companies for a number of reasons. One obvious attraction was the strong summer winds. Hot Central Valley summers create air currents that draw in cool air from the Pacific Ocean. The Pass produces a funneling effect and the result is predictable winds at speeds which produce commercial wind power. The rows of wind turbines in the Altamont Pass are oriented to capture these prevailing summer winds from the southwest. Wind speeds average 16 – 28 miles per hour during the months of April through September, and turbines produce 70 – 80% of their energy during these months. An hourly wind curve during the summer months shows wind speeds sufficient to operate the turbines by mid-afternoon and increasing in the evening hours. Typically, the wind speeds decrease in the early morning hours. In the winter months, the average wind speed drops to 9 – 15 miles per hour.

A second reason for development is the compatible land use. The primary land use in the Altamont hills has traditionally been livestock grazing and dry farming. Wind power plant developers acquire easement rights from ranchers and preserve this use by providing additional income to help keep ranching profitable. The wind turbines cover approximately 54 square miles, averaging one turbine for every five acres of land. This low density leaves ample land for agricultural use.

The Pacific Gas and Electric Company (PG&E) has been and continues to be supportive of viable alternative energy projects by independent companies. As of April, 1992, private wind power plant developments in Altamont Pass, Pacheco Pass and Solano County account for over 800 MW of wind plant capacity. New wind generation may be installed through the California Public Utility Commission Bidding Process in the late 1990s.

PG&E purchases wind power at its "avoided cost", which is the cost the utility would otherwise incur in generating the same electricity from a fuel-fired plant. Payment is based on the amount of electricity delivered to the utility.

Each wind power plant has its own power collection system. Electricity is transmitted from each wind turbine through padmount transformers to an on-site substation where it ties directly into PG&E's 60kV, 115kV and 230kV transmission lines. The energy goes to PG&E substations and is fed into PG&E's main system.

Wind power plant developers finance their projects through a combination of limited partnerships, sales to individual investors and institutional financing such as major banks and insurance companies. Federal and State solar energy incentives in the early 80s reduced the high up-front cost in this type of investment and encouraged the use of private funds for developing additional energy capacity. In 1984 – 1985, revisions in the Federal and California tax codes eliminated these incentives. Since then, increased competition in independent power production has caused a consolidation of the wind industry with fewer, but stronger, manufacturers and developers.

The Altamont Pass turbines range in size from 40 to 750 kilowatts, with rotor diameters as large as 149 feet. In 1992, the average turbine rating is 101kW as compared to 52kW in 1981. The majority of the machines are manufactured in the United States; however, Belgian, British, Danish, Dutch, German and Scottish machines are represented in Altamont Pass. Machines are classified according to the following design characteristics:

| | |
|---|---|
| **Horizontal Axis** | Axis of rotation is parallel to ground |
| **Vertical Axis** | Axis of rotation is perpendicular to ground (eggbeater design) |
| **Upwind Rotor** | Blades rotate in front of tower |
| **Downwind Rotor** | Blades rotate in back of tower |
| **Free Yaw** | Machine freely rotates on tower to track the changing direc tion of the wind |
| **Driven Yaw** | Motor actively positions wind turbine relative to the wind |
| **Damped Yaw** | Device slows down the rotation of the machine as the wind changes |

The size of a wind turbine is described in terms of power output and rotor diameter.

| | |
|---|---|
| **Rated Output & Rated Windspeed** | Capacity (in kilowatts) and lowest wind speed (in miles per hour) at which this occurs |
| **Rotor Diameter** | Measurement from center of rotation to tip of blade, multiplied by two (Horizontal Axis). Maximum dimension in the horizontal plane (Vertical Axis) |

Since the fall of 1981, over 7,300 wind turbines have been installed in the Altamont Pass outside Livermore, California. These wind turbines represent the largest power plant fueled by wind in the world. The wind turbines flanking Interstate 580 are strikingly different in appearance and represent over 20 manufacturers. Each distinct cluster of machines is a privately owned wind power plant with its own collection and transmission system for delivering electrical power to PG&E. Placed alongside the simple water pumping devices that have been a part of the Altamont landscape for years, these wind turbines incorporate recent engineering advances in materials, electronics and aerodynamics.

By April 1992, these wind turbines had produced over 6,000 million kilowatthours of electricity, enough energy to meet the needs of about 800,000 California homes for a full year.

While driving through the pass, tune your radio to 530 AM for more information about wind energy.

## Altamont Pass Wind Power Plant Operators

**Altamont Energy Corp. (AEC)**
337 Preston Ct.
Livermore, CA 94550
(510) 373-1900

**Arcadian Renewable Power Corp. (Fayette)**
P. O . Box 1149
Tracy, CA 95378
(209) 836-2260

**FloWind Corp.**
1183 Quarry Ln.
Pleasanton, CA 94566
(510) 484-3300

**Howden Windparks, Inc.**
6400 Village Pkwy.
Dublin, CA 94568
(510) 551-0100

**LFC Power Systems Corp.**
4000 Kruse Way Pl.
Bldg. 1, Suite 255
Lake Oswego, OR 97035
(503) 636-9620

**SeaWest Energy Group, Inc.**
14740 Altamont Pass Rd.
Tracy, CA 95376
(510) 443-8240

**Thompson Engineering Management**
410 Erickwood Ct.
Manteca, CA 95336
(209) 823-1266

**TERA**
1288 West 11th St., Suite 115
Tracy, CA 95376
(209) 836-3853

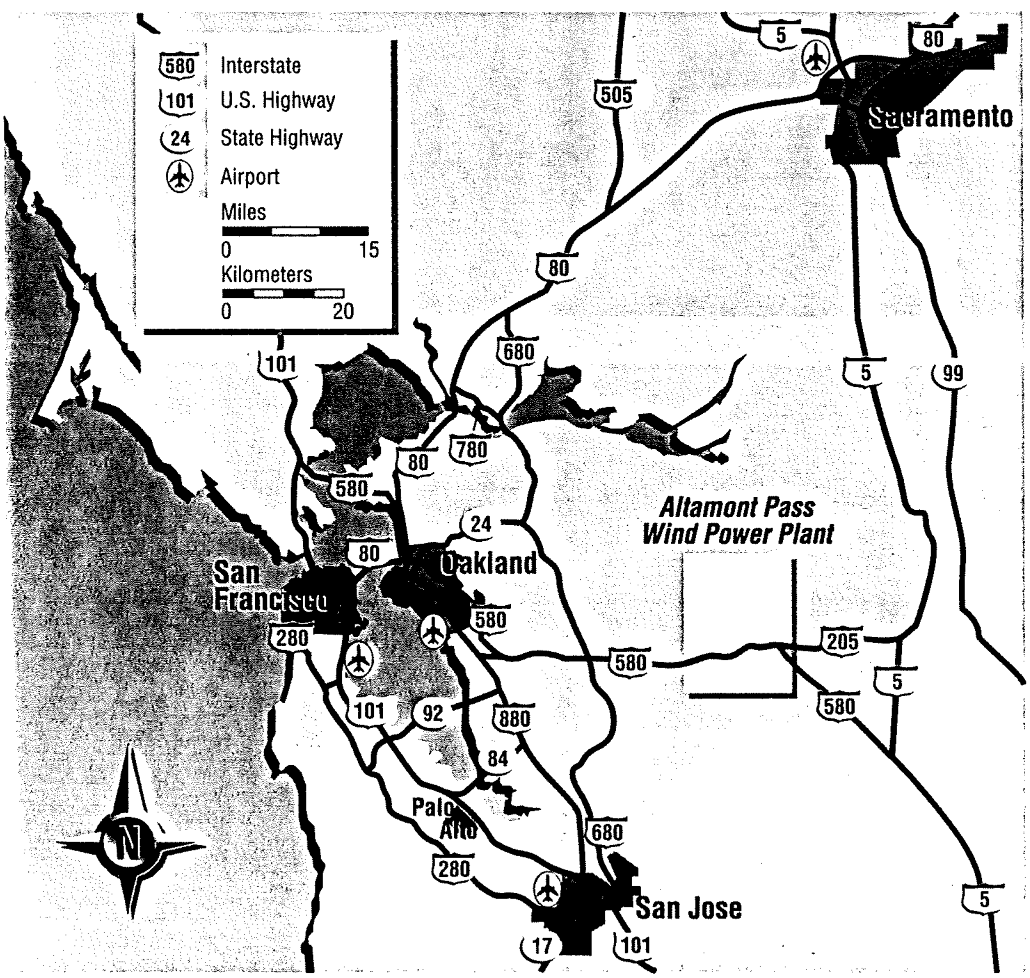
**U.S. Windpower, Inc.**
6952 Preston Ave.
Livermore, CA 94550
(510) 455-6012

**Weta3**
611 Broadway, Suite 630
New York, NY 10012
(212) 505-7850

**Wintec Ltd.**
19020 N. Indian Ave., #1K
North Palm Springs, CA 92258
(619) 329-2933

**WindMaster**
P.O. Box 669
Byron, CA 94514
(510) 634-9463

**Zond Systems, Inc.**
P.O. Box 1910
Tehachapi, CA 93581
(805) 822-6835




*The Altamont Pass Wind Power Plant is centrally located in California between Sacramento and the San Francisco Bay Area and is close to four major airports as well as having direct freeway access.*


Brochure prepared through the cooperative efforts of the Pacific Gas and Electric Company and U.S. Windpower, Inc.
April, 1992
Design: Manfred Geier
Landsat Satellite Image reference provided by Terra-Mar Resource Information Services, Inc., Mountain View, California.

Printed on recycled paper

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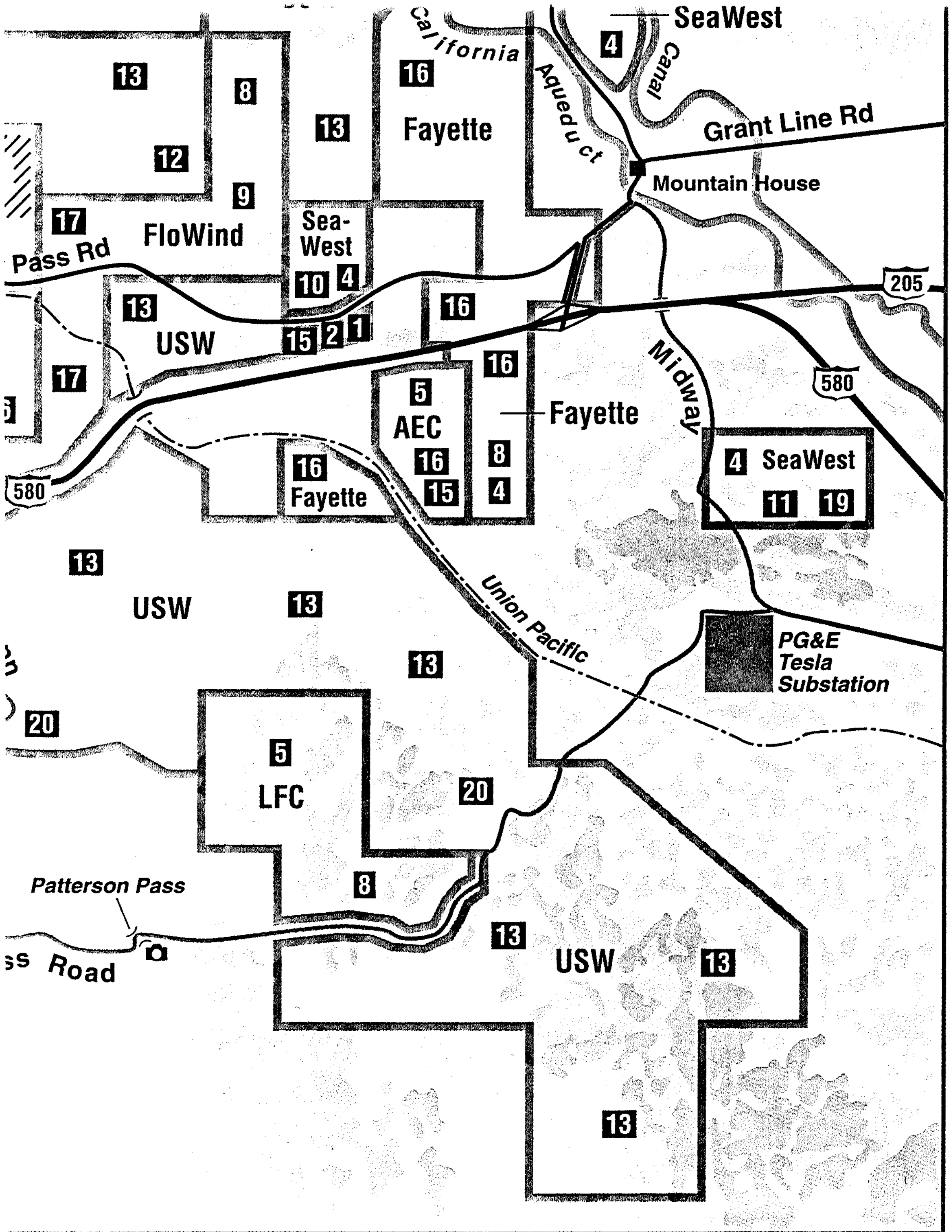
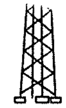
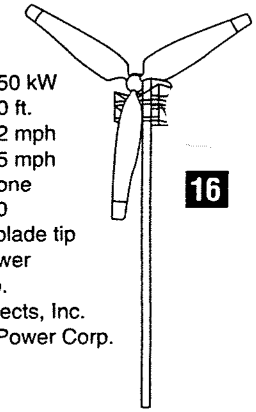


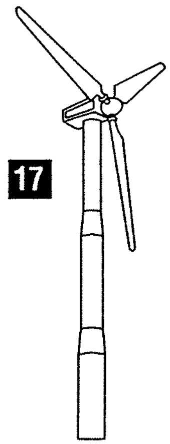



TERA



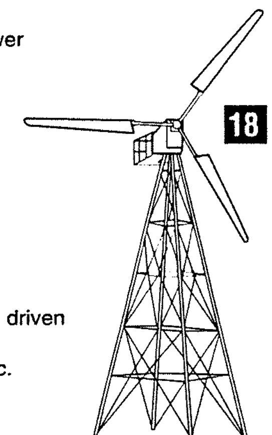
16

| | | | |
|---|---|---|---|
| Manufacturer: | **FAYETTE** | | |
| Size of Turbine: | 75 kW | 95 kW | 250 kW |
| Rotor Diameter: | 33 ft. | 36 ft. | 80 ft. |
| Cut-in Speed: | 12 mph | 12 mph | 12 mph |
| Rated Wind Speed: | 40 mph | 37 mph | 35 mph |
| Cut-out Speed: | none | none | none |
| Number Installed: | 222 | 1,202 | 30 |
| Description: | Downwind, free yaw, blade tip brakes, guyed pipe tower | | |
| Operator: | Altamont Energy Corp.<br>American Energy Projects, Inc.<br>Arcadian Renewable Power Corp. | | |



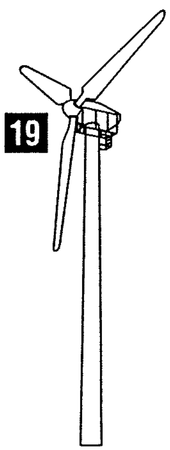
17

| | |
|---|---|
| Manufacturer: | **DANWIN** (Danish) |
| Size of Turbine: | 110 kW |
| Rotor Diameter: | 62.3 ft. |
| Cut-in Speed: | 7.8 mph |
| Rated Wind Speed: | 30 mph |
| Cut-out Speed: | 57 mph |
| Number Installed: | 25 |
| Description: | Upwind, tubular tower |
| Operator: | FloWind |



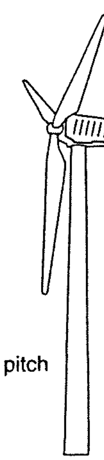
18

| | |
|---|---|
| Manufacturer: | **BSW/WAGNER** (German) |
| Size of Turbine: | 65 kW |
| Rotor Diameter: | 56 ft. |
| Cut-in Speed: | 8 mph |
| Rated Wind Speed: | 30 mph |
| Cut-out Speed: | 67 mph |
| Number Installed: | 15 |
| Description: | Upwind, fixed pitch, driven yaw, lattice tower |
| Operator: | Energy Projects, Inc. |



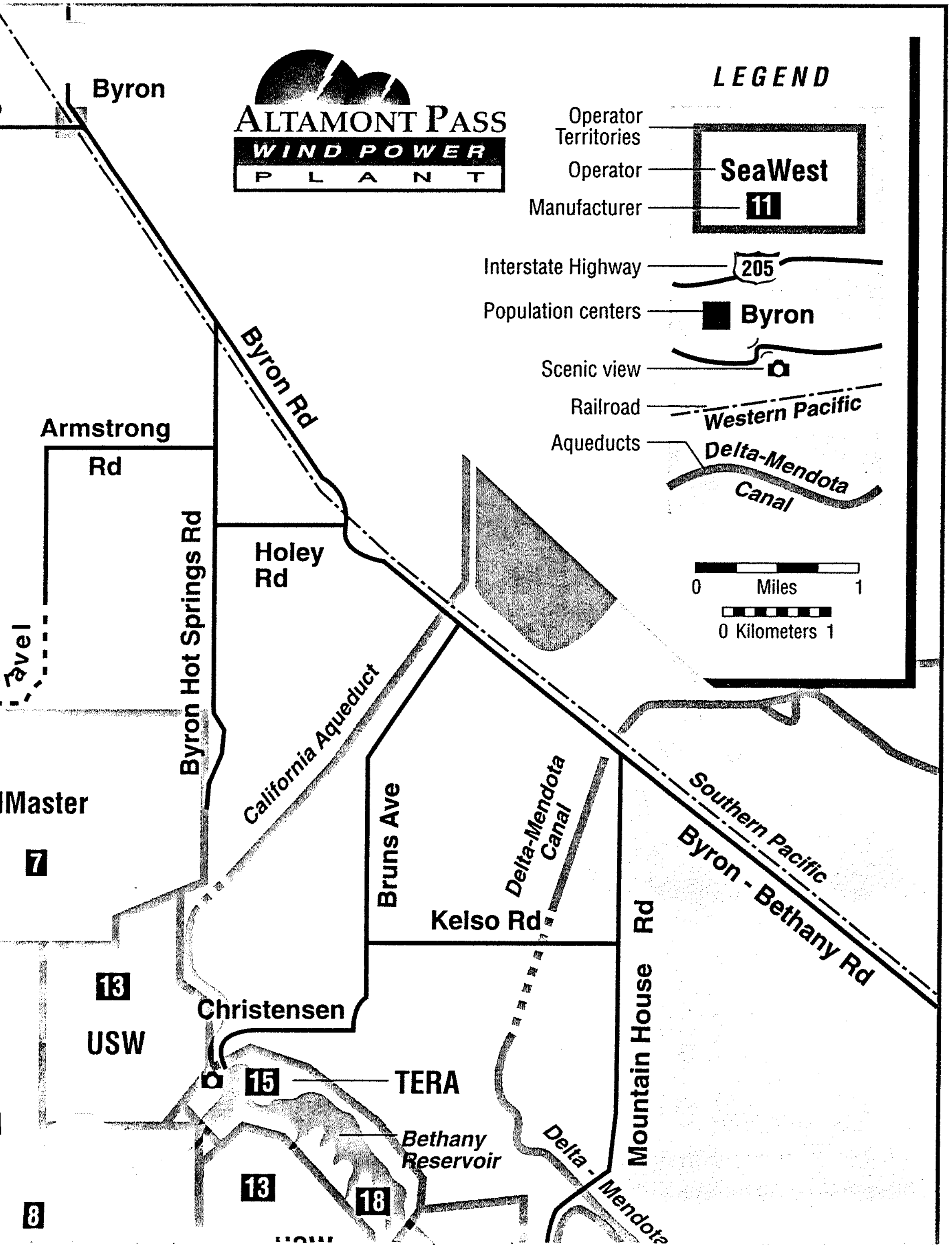
19

| | |
|---|---|
| Manufacturer: | **ALTERNERGY/ AEROTECH** (Danish) |
| Size of Turbine: | 75 kW |
| Rotor Diameter: | 51 ft. |
| Cut-in Speed: | 8.6 mph |
| Rated Wind Speed: | 30 mph |
| Cut-out Speed: | 66 mph |
| Number Installed: | 4 |
| Description: | Upwind, tubular tower with inside ladder to nacelle |
| Operator: | Tempest, Inc. |

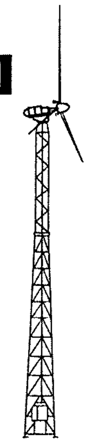


20

| | | |
|---|---|---|
| Manufacturer: | **W.E.G.** (British) | |
| Size of Turbine: | 250 kW | 300kW |
| Rotor Diameter: | 82 ft. | 108ft. |
| Number of Blades: | 3 | 2 |
| Cut-in Speed: | 11 mph | 11mph |
| Rated Wind Speed: | 30 mph | 26mph |
| Cut-out Speed: | 56 mph | 56mph |
| Number Installed: | 20 | 1 |
| Description: | Upwind, tubular tower, variable pitch | |
| Operator: | U.S. W.E.G. | |

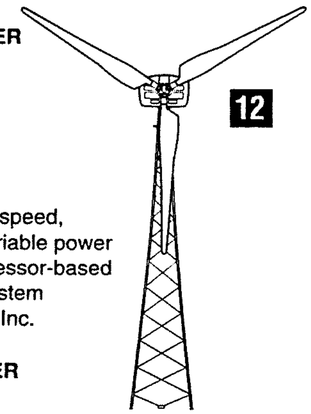



**11**



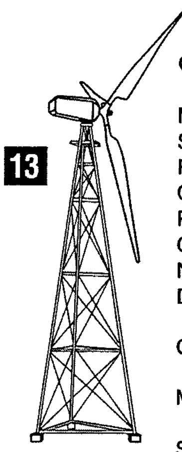
Manufacturer: **WIND POWER SYSTEMS**
Size of Turbine: 40 kW
Rotor Diameter: 39 ft.
Cut-in Speed: 11 mph
Rated Wind Speed: 30 mph
Cut-out Speed: 60 mph
Number Installed: 20
Description: Downwind, tilt-down lattice tower, no nacelle
Operator: American Windpower, Inc.

**12**



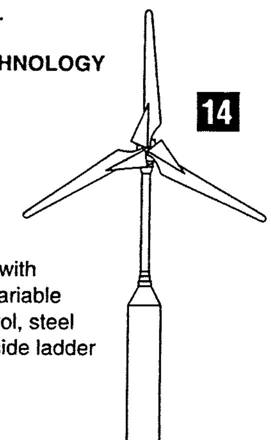
Manufacturer: **U.S. WINDPOWER**
Size of Turbine: 300 kW - 400kW
Rotor Diameter: 108 ft
Cut-in Speed: 9 mph
Rated Wind Speed: 29 mph - 32 mph
Cut-out Speed: Variable
Number Installed: 22
Description: Upwind, variable speed, variable pitch, variable power factor, microprocessor-based turbine control system
Operator: U.S. Windpower, Inc.

**13**



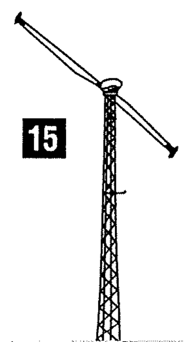
Manufacturer: **U.S. WINDPOWER**
Size of Turbine: 100 kW
Rotor Diameter: 56 ft.
Cut-in Speed: 12 mph
Rated Wind Speed: 29 mph
Cut-out Speed: 44 mph
Number Installed: 3,500
Description: Downwind, free yaw, variable pitch blades, remote computer control, tripod tower
Operator: U.S. Windpower, Inc.

**14**



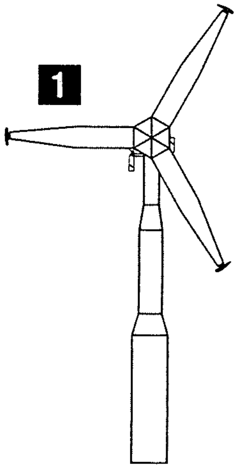
Manufacturer: **DANISH WIND TECHNOLOGY** (Danish)
Size of Turbine: 300 kW
Rotor Diameter: 97 ft.
Cut-in Speed: 12 mph
Rated Wind Speed: 30 mph
Cut-out Speed: 56 mph
Number Installed: 3
Description: Downwind, free yaw with hydraulic damping, variable pitch, computer control, steel tubular tower with inside ladder to nacelle
Operator: Atkinson Mechanical

**15**



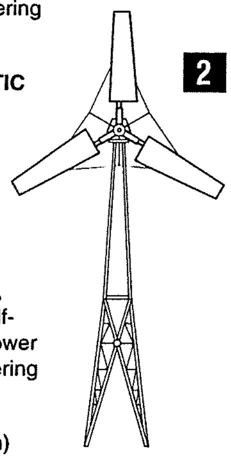
| | | | |
|---|---|---|---|
| Manufacturer: | **ENERGY SCIENCES, INC.** | | |
| Size of Turbine: | 50 kW | 65 kW | 80 kW |
| Rotor Diameter: | 54 ft. | 54 ft. | 54 ft. |
| Cut-in Speed: | 14 mph | 11 mph | 11 mph |
| Rated Wind Speed: | 30 mph | 40 mph | 37 mph |
| Cut-out Speed: | 55 mph | 55 mph | 55 mph |
| Number Installed: | 99 | 96 | 109 |
| Description: | Downwind, blade tip brakes, free yaw, tilt-down lattice tower | | |
| Operator: | Altamont Energy Corp. | | |

**1**



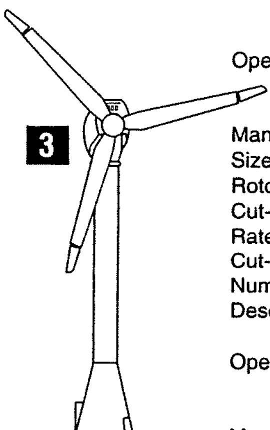
Manufacturer: **HOLEC/POLENKO** (Dutch)
Size of Turbine: 100 kW
Rotor Diameter: 59 ft.
Cut-in Speed: 14 mph
Rated Wind Speed: 31 mph
Cut-out Speed: 67 mph
Number Installed: 12
Description: Upwind, fixed pitch, dual yaw rotors, self-supporting tubular tower
Operator: Thompson Engineering Management

**2**



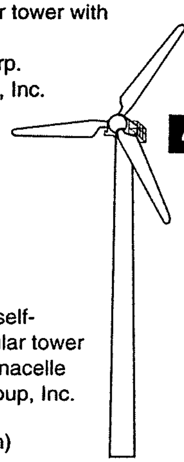
Manufacturer: **HOLEC/WINDMATIC** (Danish)
Size of Turbine: 65 kW
Rotor Diameter: 48 ft.
Cut-in Speed: 12 mph
Rated Wind Speed: 35 mph
Cut-out Speed: 56 mph
Number Installed: 26
Description: Upwind, fixed pitch, dual yaw rotors, self-supporting lattice tower
Operator: Thompson Engineering Management

**3**



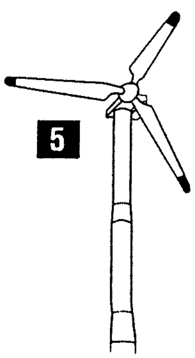
| Manufacturer: | **HOWDEN** (Scottish) | |
|---|---|---|
| Size of Turbine: | 330 kW | 750 kW |
| Rotor Diameter: | 102 ft. | 149 ft. |
| Cut-in Speed: | 11 mph | 12 mph |
| Rated Wind Speed: | 27 mph | 29 mph |
| Cut-out Speed: | 55 mph | 58 mph |
| Number Installed: | 85 | 1 |
| Description: | Upwind, steel tubular tower with conical base | |
| Operator: | Altamont Energy Corp. Howden Wind Parks, Inc. | |

**4**

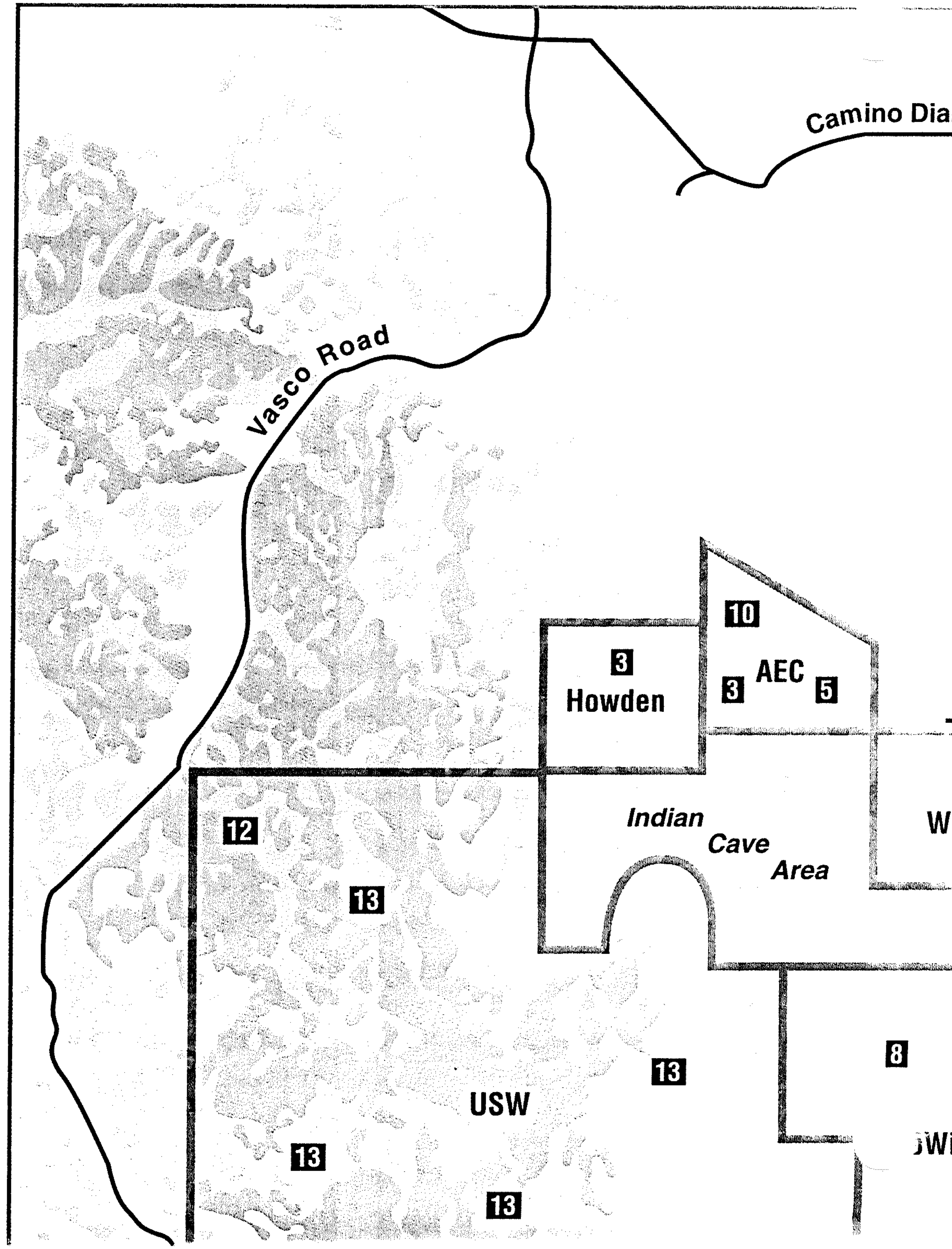


Manufacturer: **MICON** (Danish)
Size of Turbine: 60 kW
Rotor Diameter: 52 ft.
Cut-in Speed: 9 mph
Rated Wind Speed: 34 mph
Cut-out Speed: None
Number Installed: 221
Description: Upwind, fixed pitch, self-supporting steel tubular tower with inside ladder to nacelle
Operator: SeaWest Energy Group, Inc.

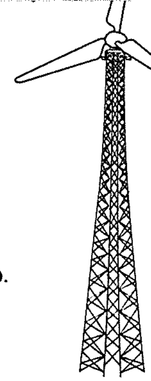
**5**



Manufacturer: **NORDTANK** (Danish)
Size of Turbine: 65 kW
Rotor Diameter: 52 ft.
Cut-in Speed: 8 mph
Rated Wind Speed: 34 mph
Cut-out Speed: None
Number Installed: 394
Description: Upwind, fixed pitch, steel tubular tower
Operator: Altamont Energy Corp.

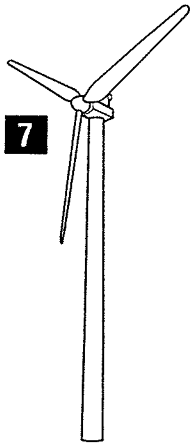


Wintec Ltd.



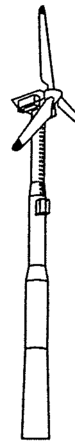
6

| | | |
|---|---|---|
| Manufacturer: | **VESTAS** (Danish) | |
| Size of Turbine: | 65 kW | 100 kW |
| Rotor Diameter: | 50 ft. | 56 ft. |
| Cut-in Speed: | 7 mph | 8 mph |
| Rated Wind Speed: | 34 mph | 42 mph |
| Cut-out Speed: | 50 mph | 62 mph |
| Number Installed: | 2 | 200 |
| Description: | Upwind, lattice tower | |
| Operator: | Altamont Energy Corp.<br>Zond Systems, Inc. | |



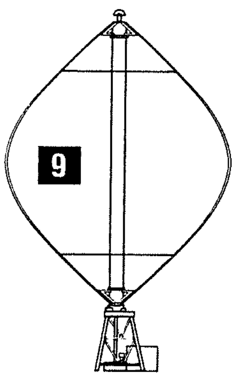
7

| | | | | |
|---|---|---|---|---|
| Manufacturer: | **HMZ-WINDMASTER** (Belgian) | | | |
| Size of Turbine: | 75 kW | 200 kW | 250 kW | 300 kW |
| Rotor Diameter: | 72 ft. | 72 ft. | 76 ft. | 82 ft. |
| Cut-in Speed: | 10 mph | 11 mph | 11 mph | 11 mph |
| Rated Wind Speed: | 20 mph | 33 mph | 32 mph | 34 mph |
| Cut-out Speed: | 50 mph | 50 mph | 56 mph | 56 mph |
| Number Installed: | 5 | 129 | 30 | 15 |
| Description: | Upwind, hydraulically pitched blades, tubular tower with inside ladder to nacelle | | | |
| Operator: | WindMaster | | | |



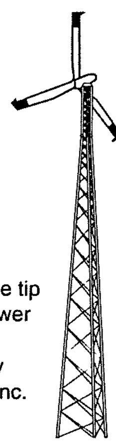
8

| | | | |
|---|---|---|---|
| Manufacturer: | **DANREGN VIND KRAFT/BONUS** (Danish) | | |
| Size of Turbine: | 65 kW | 120 kW | 150 kW |
| Rotor Diameter: | 50 ft. | 63.5 ft. | 76 ft. |
| Cut-in Speed: | 9 mph | 9 mph | 9 mph |
| Rated Wind Speed: | 40 mph | 40 mph | 40 mph |
| Cut-out Speed: | 67 mph | 67 mph | 67 mph |
| Number Installed: | 211 | 250 | 100 |
| Description: | Upwind, fixed pitch, self-supporting steel tubular tower | | |
| Operator: | LFC Power Systems Corp.<br>Weta3 | | |



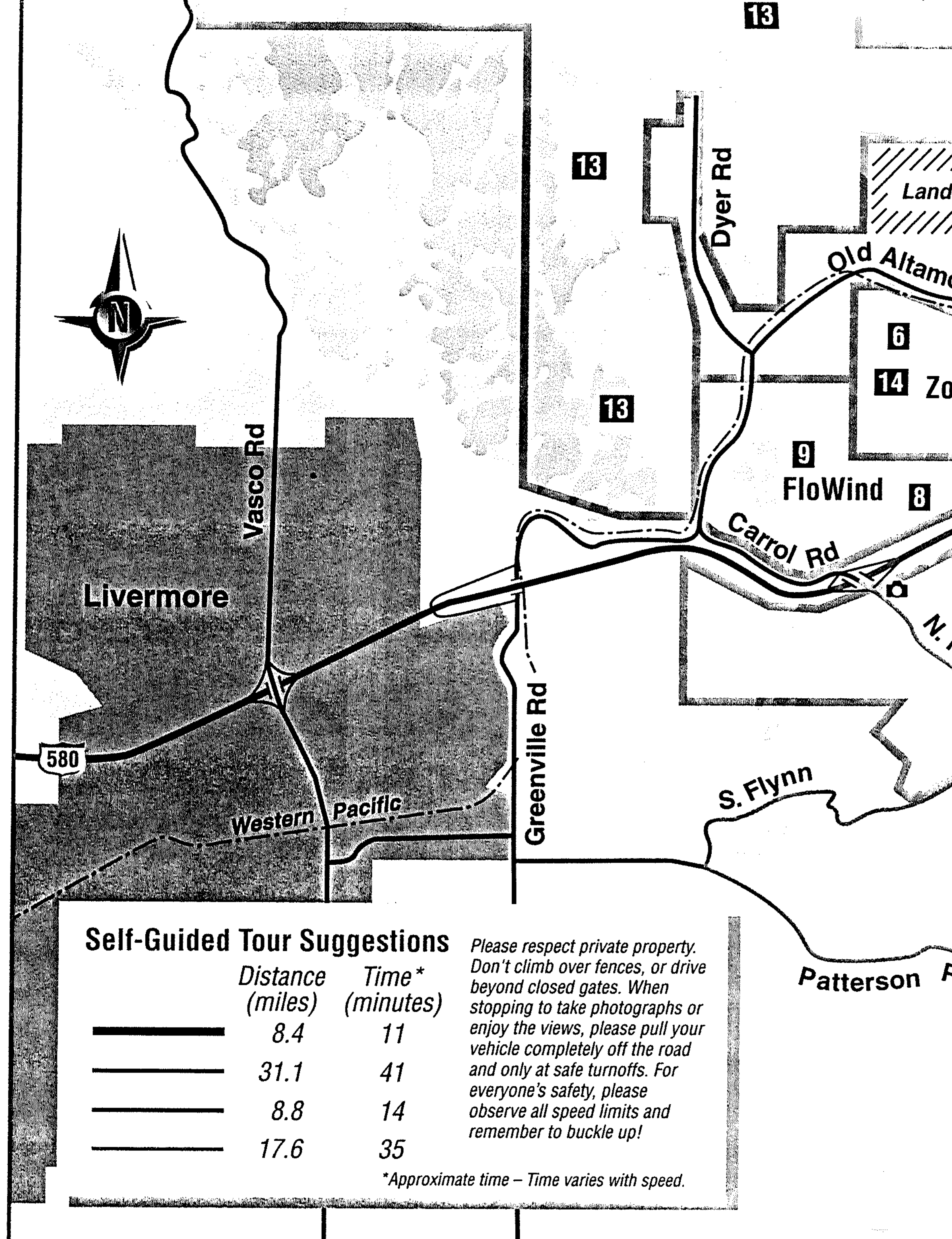
9

| | | |
|---|---|---|
| Manufacturer: | **FLOWIND** | |
| Size of Turbine: | 150 kW | 250 kW |
| Rotor Diameter: | 56 ft. | 62 ft. |
| Cut-in Speed: | 12 mph | 14 mph |
| Rated Wind Speed: | 38 mph | 38 mph |
| Cut-out Speed: | 60 mph | 60 mph |
| Number Installed: | 148 | 21 |
| Description: | Vertical axis | |
| Developer: | FloWind Corp. | |



10

| | | |
|---|---|---|
| Manufacturer: | **ENERTECH** | |
| Size of Turbine: | 40 kW | 60 kW |
| Rotor Diameter: | 44 ft. | 44 ft. |
| Cut-in Speed: | 8 mph | 10 mph |
| Rated Wind Speed: | 30 mph | 35 mph |
| Cut-out Speed: | 50 mph | 60 mph |
| Number Installed: | 192 | 36 |
| Description: | Downwind, free yaw, blade tip brakes, self-supporting tower | |
| Operator: | Altamont Energy Corp.<br>Altamont Power Company<br>SeaWest Energy Group, Inc. | |




## Self-Guided Tour Suggestions

| | Distance (miles) | Time* (minutes) |
|---|---|---|
| (thick line) | 8.4 | 11 |
| (line) | 31.1 | 41 |
| (line) | 8.8 | 14 |
| (line) | 17.6 | 35 |

*Please respect private property. Don't climb over fences, or drive beyond closed gates. When stopping to take photographs or enjoy the views, please pull your vehicle completely off the road and only at safe turnoffs. For everyone's safety, please observe all speed limits and remember to buckle up!*

**Approximate time – Time varies with speed.*

FOR A TIME DURING THE 1980s, when wind turbines were going up on the blustery ridges of California at a rate of nearly 2000 per year, it appeared as if interest in wind power had reached its peak in the United States. But a recent gust of activity among utilities in different parts of the country has signaled the beginning of what many experts believe is a revival of wind power projects—with interest even more widespread than before, and with more intimate involvement from utilities.

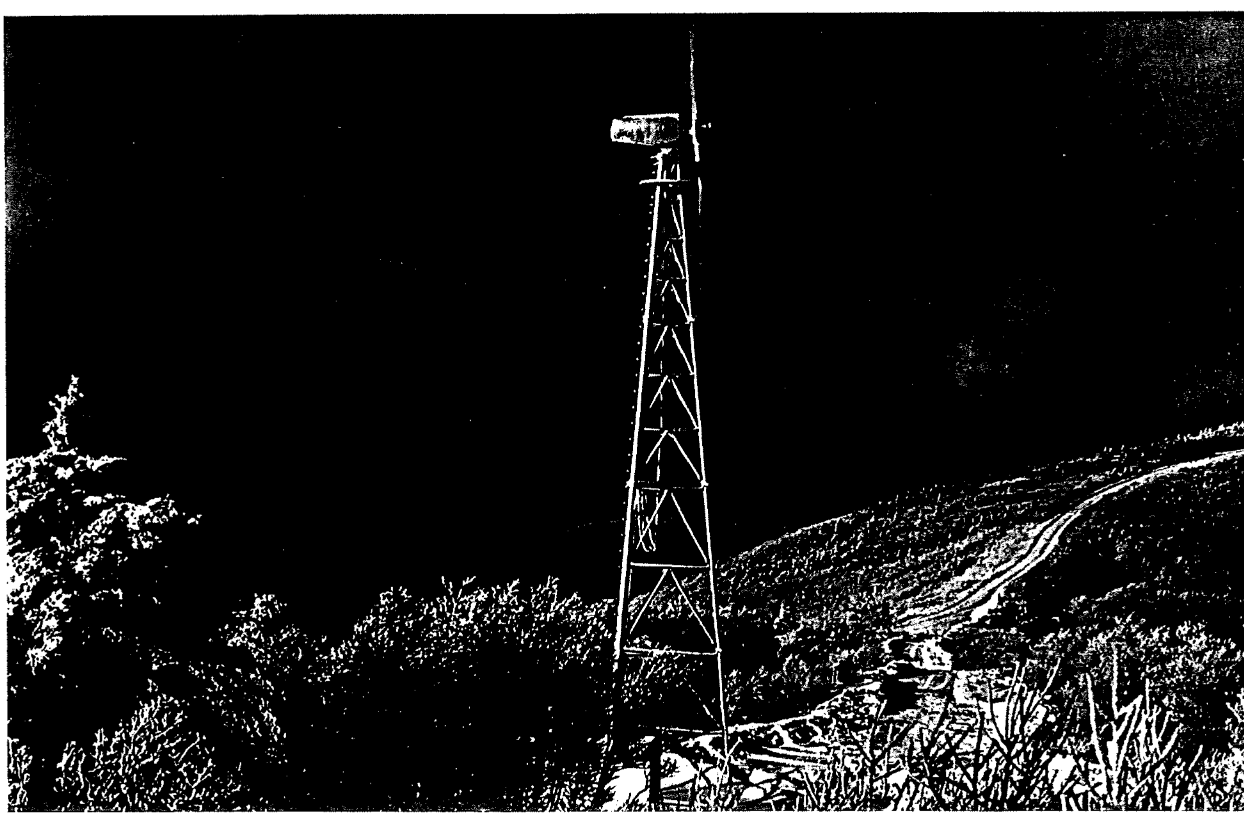
Here are some examples of the attention utilities have given to new wind projects within the past year. Northern States Power Company has announced plans to bring a total of 100 MW of wind power on-line by 1997. Puget Sound Power & Light Company, in conjunction with three other utilities, plans to bring 50 MW of wind turbines on-line by 1996 in the Pacific Northwest's first large-scale wind generating project. The Bonneville Power Administration has put out for bid 50 MW of wind power it plans to bring on-line in 1996. Pacific Gas and Electric Company, a major player in earlier wind developments, has filed for a permit to install 7 MW of next-generation wind turbine prototypes between 1994 and 1996. Niagara Mohawk Power Corporation installed two turbines near Lake Ontario in November—the first utility-grade commercial turbines in the state of New York. And in the Midwest, the unregulated subsidiary of Iowa-Illinois Gas and Electric Company has formed a joint venture with the largest U.S. wind turbine manufacturer to market wind power to utilities in that region.

"In the early 1980s we witnessed a surge of utility involvement in wind power projects, but technological progress fell short of expectations," says Edgar DeMeo, who oversees EPRI's program for solar and wind power. "Now, 10 years later, technological progress has caught up with and even exceeded the early expectations, and as a result, the activity among utilities is expanding more rapidly than ever before." DeMeo notes that today's wind power development is geographically more widespread, too. "People used to think wind power was something that only Californians were into," he says. "But today, most of these projects are being undertaken in other parts of the country."

In a major departure from past practices, some of the utilities establishing new wind farms plan to own the wind turbines directly, rather than buying the power from a developer who owns the machines. DeMeo credits significant advances in technology for this increased interest in direct ownership. "The technology has reached a sufficient level of maturity for utilities to consider owning the turbines," he says. "It's not as risky as it was 10 years ago, before the industry settled on a preferred turbine size range and before we

The power of wind on Buffalo Ridge, Minnesota, prevents this boy from falling over. (Photo courtesy of John R. Dunlop)

A lone turbine in the picturesque mountains of Vermont churns on despite its frigid environment.



ıe millions of hours of operating experience that have since offered critical feedback to improve turbine reliability."

Also, growing public concern about the environment has led to regulatory incentives that are encouraging wind projects. For example, the use of environmental externalities in utility resource planning is making renewable energy technologies like wind power more attractive. The confidence inspired by technological advances in wind turbines has prompted the implementation of other types of financial incentives, including a 1.5¢/kWh production incentive, part of the federal energy bill signed by President Bush in October. In addition, EPRI and the U.S. Department of Energy (DOE) have initiated a major program to accelerate the commercialization of wind turbines.

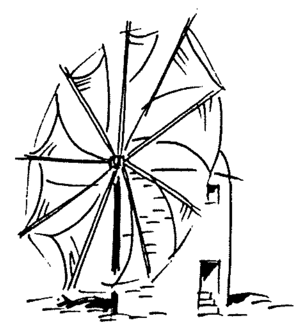
Today there are more than 16,000 wind turbines installed in this country—nearly all of them in California—with an aggregate power rating of nearly 1500 MW. These turbines generated some 2.7 billion kWh of electricity in 1991, enough energy to meet the residential needs of a city the size of San Francisco. But this country's abundance of high-wind regions (those with an average annual wind speed of 16 miles per hour or higher) offers the potential for thousands of additional wind projects. According to a study conducted for DOE by Battelle, Pacific Northwest Laboratory, if today's wind turbine technology took full advantage of these high-wind regions, it could generate 20% of the country's electricity. With the anticipated improvements in wind turbine technology, an even greater contribution could be achieved, says DeMeo.

Many of the best locations for wind projects lie outside California, with Montana, Wyoming, North Dakota, South Dakota, and Minnesota possessing a large chunk of the choice wind regions. The Northeast also claims considerable wind resources. In all, about 14 states possess wind energy potential that is equal to or greater than that of California.

### To own or not to own?

Except for one wind power installation in Hawaii, all of the major utility-scale wind projects have been undertaken by independent developers who in turn sell the electricity to utilities. This is largely because in the past wind turbine technology was still in the research and development phase. Also, the financial incentives offered by the federal and state governments were available only to nonutility developers (i.e., independent power producers).

But much has changed since then. Perhaps most significantly, the major U.S. wind turbine manufacturer, U.S. Wind-



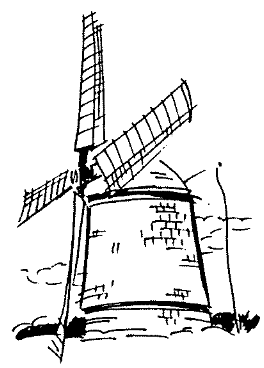
power, has developed a variable-speed turbine with support from members of the Variable-Speed Wind Turbine Development Alliance, established by EPRI and joined by Niagara Mohawk and Pacific Gas and Electric. The breakthrough turbine, the first prototype of which was field-tested in the spring of 1991, is expected to produce electricity for a record low cost of 5¢/kWh, given an average annual wind speed of 16 miles per hour. The new turbine is capable of producing electricity at varying rotor speeds. By contrast, virtually all other turbines on the market must operate at constant rpm to produce utility-grade (60-Hz ac) power. Because the extra torque generated by wind gusts must be absorbed by the drivetrains of constant-speed wind turbines, they require heavier designs than comparable variable-speed models.

While a few other variable-speed turbines have been developed in recent years, U.S. Windpower's model offers a much more advanced electronic system—including a sophisticated controller and converter—that does not send objectionable current distortions back onto the utility line. Because of its variable-speed capability, the new machine is rated at 350-kW. According to Kingsley E. Chatton, president of Kenetech/Windpower, the manufacturing arm of U.S. Windpower, the machine operates at wind velocities ranging from 9 to 60 miles per hour. Last summer U.S. Windpower undertook a major program, testing 22 of the new machines at the Altamont Pass in California. Data gathered from the tests are providing statistical information on the turbine operating and maintenance requirements and are helping to improve the technology's design. Any improvements will be incorporated into commercial units to be installed in the fall of 1993.

U.S. Windpower's achievement not only has pushed utility turbines beyond the R&D level, it has bumped them into a cost-effective price range for utilities. And with the availability of many turbines on the market now routinely running at or above 95% (compared with 50–60% in the early 1980s), there are a number of advantages to utilities' owning the machines. To start with, points out Earl Davis, EPRI's manager of wind power integration, utility ownership is cheaper because utilities, which have access to much more capital, can get lower financing rates than the smaller, independent developers and entrepreneurs, who are viewed as a riskier investment. In addition, because more middlemen are involved in financing the projects of independent developers, their up-front financing costs are greater and add to the total installed cost. In the end, the cost of energy from a wind power plant owned by an independent power producer could be 30–40% greater than that of energy from the same plant if owned by a utility.

Northern States Power, which in August announced its plans to install 100 MW of wind generation, plans to own the first 25 MW. The remaining 75 MW will be put out to bid and may be owned by NSP or by an independent power producer, says Glynis Hinschberger, the utility's manager of energy resource planning. "The reason we want to own the initial block of turbines is to get some operating experience for ourselves," Hinschberger says. "We have experience with other generation technologies, and we'd like to get [illegible] with this one. If this is a technology we're going to be relying on in the future, we'd like to get some idea of how it works."

Melanie Granfors, spokeswoman for Puget Sound Power & Light, says Puget and the other utilities involved in the Pacific Northwest project (Idaho Power, Portland General Electric, and PacifiCorp) chose to own the turbines simply "because it was the least-cost option." Explains Granfors, "It was less expensive to own



the turbines than to purchase power from them." Benton County Public Utility District has been invited to join the project, but at press time the utility had not responded with a final answer. While details of the agreement with the turbine manufacturer, U.S. Windpower, are still under negotiation, the utilities plan to contract with the company to operate and maintain the turbines for a certain period early in the project. The plan is for utility staff members to gain experience with operation and maintenance before taking over these responsibilities.

Regardless of whether utilities interested in wind power own their turbines directly or purchase power from developers, they face some major challenges. One of these is the issue of land use. Unlike the early wind power developers in California, who had access to large tracts of land—typically measuring 2–10 square miles and owned by a single farmer—the Midwest utilities are dealing with smaller tracts, very similar to those in Europe, which have been divided into several sections (typically four owners for every square mile of farmland). Whereas the California land is generally used for dry

## Development

Davis stresses that utilities need to get professional assistance from experts they may not have in-house, such as wind energy meteorologists. "Wind energy meteorology is a new specialty," Davis says. "A very limited number of people have had the opportunity for experience in this area." Al Manning, former president of Hawaiian Electric Renewable Systems (HERS), agrees, noting that boundary-layer meteorologists, who specialize in the interactions between terrain and the air masses above it, should be involved in the early planning phases. HERS is a subsidiary of Hawaiian Electric Industries, the only utility in the country with experience in owning substantial wind-powered generation capacity.

Since the mid-1980s, Hawaiian Electric Industries has owned and operated over 12 MW of wind capacity. Acknowledging an announcement in October of this year that HERS plans to shut down its major wind installation, consisting of 16 wind turbines on Oahu, because of chronic mechanical problems and poor financial performance, Manning noted the significant differences between these projects and those being pursued by utilities today. One of the turbines to be shut down is the largest horizontal-axis wind turbine in the world, a 3200-kW machine installed in 1987. The remaining 15 are 600-kW units. "These machines were the only ones of their kind in the world," Manning says. "When parts were needed for these turbines, we frequently had to have them made."

Having replacement parts custom made meant that the machines were out of commission for relatively long periods. In addition, the turbines were much more expensive to start with—about four to five times the cost of turbines on the market today, Manning says. The crane required to erect the biggest machine was larger than anything available from the construction industry in Hawaii; it had to be shipped from the U.S. mainland and returned after the installation was completed. "These turbines were created when the industry was still experimenting with turbine size," says Manning. "Today's turbines offer a more realistic capacity range."

Two types of forums are available to utilities that are interested in learning more about wind power technology and logistics. The Utility Wind Interest Group, which receives support from EPRI and the U.S. Department of Energy, helps keep its members informed on the status of wind turbine technology and produces brochures on the use and development of wind power. Currently, 12 utilities from across the country belong to the interest group. Also helpful are the Advisory Councils for Wind Energy, through which utilities that are seriously pursuing wind power can exchange experiences and information on issues—such as system integration, wind resource valuation, and land use—that must be addressed throughout the wind farm development process. At present there are two of these advisory councils, one for the Northwest and one for the Southwest. Davis is exploring the possibility of establishing similar councils for the Midwest and Northeast regions of the country.

"One message we are trying to get across is that utilities do not have to repeat the mistakes others have already made. We have learned from past experience and can help our members through the process. They do not have to do this on their own." Davis encourages utilities who need assistance to contact him at (415) 855-2256. □

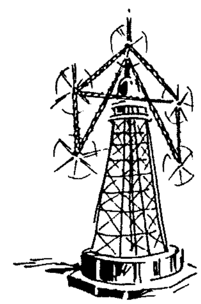
·ming and cattle grazing, the Midwest ·es have been planted with crops, a use that can pose some obstacles to the installation of turbines and access roads. Davis views the European utilities' experience as a valuable complement to U.S. experience and is working with EPRI members to make the best use of knowledge gleaned from the overseas industry.

### Incentives: the ups and downs

Substantial tax credits at both the state and federal levels played a crucial role in California in offsetting what was viewed as the considerable financial and technical risk of early utility-scale wind turbine development. While these credits were not available to utilities, independent developers were eligible to receive them, and the incentive did much to encourage the installation of wind turbines. Turbines began sprouting up in the late 1970s, primarily in California but also in other parts of the country. Many of these early machines were prototypes, and testing and engineering were typically performed in the field. The resulting high failure rate tarnished the reputation of wind power. Nevertheless, buoyed by support from the federal and state governments, and encouraged by tentative interest from some utilities who viewed wind as a future opportunity, the initiation of wind projects continued.

In 1985 the federal tax credits expired, followed a year later by California's tax credits. However, significant improvements in turbine technology, together with the continuation of another type of incentive in California, known as Standard Offer 4 contracts, made possible the financing and installation of thousands more turbines, even in the face of falling fossil fuel prices. Standard Offer 4 contracts essentially guaranteed a minimum price for wind energy over a period of years, enabling wind farm developers to obtain the financing they needed. As more turbines went up, much-needed operating experience was gained, system reliability improved, and the cost of installed projects decreased dramatically, from more than $2000/kW in the early 1980s to about half that by the end of the decade. This brought the cost of wind energy down from 25–30¢/kWh to 7–9¢/kWh, assuming an average annual wind speed of 16 miles per hour. Starting in the mid-1980s, no further Standard Offer 4 contracts were issued. As a result, the installation rate slowed considerably, causing some observers to wonder whether the golden age of wind power had already come and gone.

Technological progress is the engine driving today's activity in wind power.



But new types of incentives are beginning to come to life, and they are expected to add fuel to the wind power movement. Largely reflecting a revival of interest in and commitment to renewable energy technologies, the incentives are propelled primarily by environmental concerns, but also by a desire for national energy stability—an interest that was reinforced during the recent war in the Persian Gulf. Among other factors that are making wind power attractive for more utilities is the need to use environmental externalities in developing plans for future power generation.

Environmental externalities are impacts —both positive and negative—that are not reflected in the market prices of generation options. For instance, releases of carbon dioxide and nitrogen oxides are negative externalities associated with burning coal. Such externalities might be added to the cost of using coal, or instead a credit might be given to renewable energy resources, such as wind power, for *not* generating such emissions. As a result, utilities, which typically use a least-cost method for selecting future generation, will take these factors into account, since they are reflected in the bottom-li re for each option. New York, Wisconsin, Vermont, and Oregon are just some of the states whose utilities are including externalities in the generation planning process. Other states, like Minnesota, have adopted different incentives, including sales and property tax exemptions.

Meanwhile, the federal government has renewed its own incentives. In October President Bush signed an energy bill that includes a 1.5¢/kWh production incentive. For investor-owned utilities this incentive comes in the form of a tax credit. For tax-exempt utilities (including municipals and cooperatives), it comes in the form of a payment, dependent on the annual appropriations of the U.S. Congress. The incentive will go to the owners of wind plants that are brought on-line between January 1, 1994, and June 30, 1999. The credit will be available for the first 10 years of a wind plant's operation and will be adjusted annually for inflation. As Davis points out, this production incentive may further encourage utilities to purchase their own turbines, since they are the ones likely to benefit most. For instance, a 1.5¢/kWh credit on a 40-MW project, which would typically produce 100,000,000 kWh per year, would result in tax savings of $1.5 million. Private developers would be unlikely to reap the full benefits of such a tax break, since their tax bills are typically well under $1 million, which is less than the allowable tax credit. An investor-owned utility's tax bill, on the other hand, may well amount to several million dollars, so the tax credit is a good financial incentive for utilities—a benefit that also flows through to the customer by reducing energy costs.

### Winds of Europe

The use of incentives in European countries has proceeded at a much more even pace, illustrating a steadily increasing commitment to wind power. And while the world's attention in the 1980s was fixed on the hills of California, it appears that Europe will soon steal the show and far surpass the United States in turbine installations. According to Michael Marvin, director of government and public affairs



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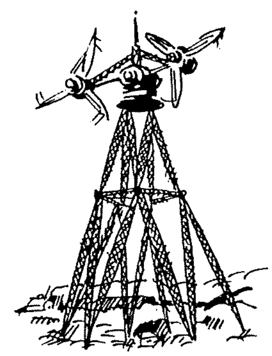
ιυ. the American Wind Energy Association, "By the end of the decade, unless current trends change, Europe will dominate world production of wind-generated electricity."

Government policies are the driving force behind Europe's increased commitment to wind power. The ministries of energy, environment, and research and industrial development in various countries have established long-term energy and environmental policy plans. Combined, the European programs call for the installation of at least 4000 MW of wind capacity by the year 2000. The United States, meanwhile, has set no national goals for the implementation of wind technology. Among the European countries expected to be most active in wind power this decade are England, Denmark, Germany, and the Netherlands. Significant activity will also be occurring in Alberta, Canada.

The OEM Development Corporation, which compiled a soon-to-be-published EPRI report (TR-101391) on wind technology in Europe, points out that the European commitment to wind projects in the 1990s more than doubles the 1600 MW of wind capacity that exists in the United States. "While some of these goals may not have the force of law, it is clear that European governments are serious about wind and are attempting to give this and other renewables every chance to be implemented on a significant scale," according to Jamie Chapman, author of the OEM report. The European Wind Energy Association projects the installation of 11,500 MW of wind capacity by 2005, 25,000 MW by 2010, and 100,000 MW by 2030.

What's prompting European countries to leap so confidently onto the wind bandwagon? They are reacting to factors similar to those propelling the U.S. market for wind power: uncertain oil prices, mistrust of nuclear power (a growing unease that was precipitated by the Chernobyl accident), and increasing damage to the environment from the use of fossil fuels. DeMeo of EPRI points out that environmental concerns clearly dominate. "A number of European countries have come to the conclusion that they need to do something not only to reduce acid rain but to minimize greenhouse gases as well. Wind is a favorite option for them because most of the European countries have good wind resources and because of the status of the technology."

DeMeo sums up the difference between the European and the U.S. perspectives today as follows: "In this country, utilities are trying to decide whether they should use wind power and under what conditions it is going to make sense. In the European countries, the decision to use wind



power has already been made by the government and the people, so the question the utilities there face is *how* they are going to use it, not *whether* they are going to use it."

One strength of the European movement is that it represents many sectors of society, including government bodies, utilities, academic institutions, and manufacturers. The Commission of the European Communities and the national government programs are the major forces supporting advances in the technology—facilitating and even mandating the involvement of utilities, demonstrating new turbines, and stimulating the market. Of great significance with respect to utility participation, European utilities—unlike their counterparts in the United States during the 1980s—have been allowed to receive tax credits and other financial incentives.

The European government programs have also been of major benefit to European turbine manufacturers. In fact, so strong is governmental support that subsidies have led to the development of machines far more expensive than those produced in the United States. While U.S.-manufactured turbines now cost less than $1000/kW installed, European machines typically cost 50% more and weigh about twice as much. Although European turbines may not be cost-competitive with American-made models, some of them offer extremely attractive features, points out DeMeo. In particular, he says, several machines produced by Danish manufacturers offer high reliability, and a German manufacturer has produced a variable-speed turbine similar to U.S. Windpower's. The heavy subsidies in Europe—inspired by governmental desire to foster domestic industry—certainly make the European market hard to break into. But U.S. Windpower did just that last summer, winning a bid to sell 25 MW of wind power to a utility in Holland.

## Competition on the rise

While U.S. Windpower clearly dominates the wind power market in the United States, other domestic manufacturers are producing advanced turbines that are expected to become competitive within the next few years. In fact, the U.S. Department of Energy, through its Advanced Wind Turbine Program, is sponsoring the development of five turbines in an effort to provide wind power for 5¢/kWh, assuming sites with an average annual wind speed of 13 miles per hour, by 1995.

Among the most promising machines in the DOE program is R. Lynette & Associates' two-bladed turbine, rated at a capacity of 275 kW. A very lightweight machine, it is expected to weigh about half as much per kilowatt as most of the three-bladed commercial turbines available today. Because the machine is so light, it should be inexpensive to build. It employs advanced blades, designed by DOE's National Renewable Energy Laboratory, that increase energy capture. The control system takes advantage of the aerodynamic nature of the blades, so they automatically stall in high wind to ensure that the maximum power rating is not exceeded. This machine is to be available for initial commercial delivery in 1994.

Another promising machine selected for funding through the DOE program is Northern Power Systems' turbine, which



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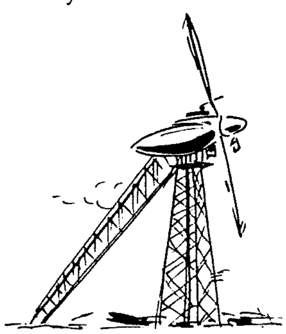
is expected to provide 250 kW of capacity. Also a two-bladed, lightweight design, this turbine employs aileron controls and a teetering rotor, which allows the blades to rock back and forth to adapt to uneven wind pressures. The ailerons, similar to those on the wings of an airplane, represent a major advance in wind turbine technology. The adjustable flaps can regulate how fast the rotor spins and are used to control the starting and stopping of the machine. This turbine is expected to be commercially available in 1995.



DOE's Advanced Wind Turbine Program, established in 1990, is a major part of a larger federal wind program and is intended to bolster the U.S. industry. "We believe a strong manufacturing base with multiple players will lead toward a healthy industry," says Ron Loose, director of the federal Wind Energy Program. "We feel that for wind to be accepted by utilities as a domestic energy option, we must have a diverse supply of quality domestic turbines."

To further advance the development of emerging turbine technologies, EPRI and DOE have established the Utility Wind Turbine Performance Verification Program. Created through a memorandum of understanding signed by the two organizations in September, the program aims to accelerate wind power commercialization and facilitate utility involvement. The program's long-term objective is to ensure the commercialization, by the year 2003, of field-verified, state-of-the-art, utility-grade wind power systems capable of delivering electricity for 4¢/kWh (in 1992 dollars), given 13-mile-per-hour winds. This represents a more than 20% decrease in the cost of energy produced by today's state-of-the-art technology.

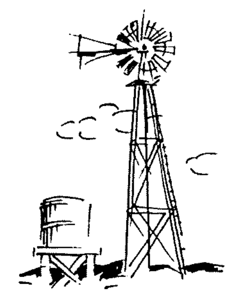
Arrangements established through the memorandum of understanding call for DOE—as is consistent with its Advanced Wind Turbine Program—to fund the development and initial testing of advanced wind turbines. EPRI and the participating utilities will provide the testing ground for the turbines. Four utilities are each expected to install and operate 20 or more commercial prototype turbines, including at least 10 of each turbine type. EPRI is currently seeking members from different parts of the country to act as host utilities for the program and is encouraging interested utilities to get others involved as cosponsors.

The machines will be deployed and evaluated for three years, enough time to allow a thorough assessment of their energy cost and suitability for large-scale application. The turbine testing will get under way in 1994. As DeMeo points out, the data gathered will provide valuable experience and feedback on the turbines' operating performance and maintenance requirements—the kind of information required before a major installation. The program's capital expenses are expected to run about $10 million per host utility site, with half to be provided by the host and the remainder by EPRI, partner utilities, and DOE. EPRI's portion includes an estimated $1.5 million for basic program support, excluding tailored collaboration funds that are available to member utilities.

Although DOE is sponsoring the testing of U.S. machinery only, EPRI funds are available for both foreign and U.S. turbines. The decision on which machines to employ is left to the host utilities. Currently available machines are eligible for the program, but the major emphasis will be on emerging turbines. Nevertheless, as DeMeo points out, most of the existing turbines have been field-tested only in California and Hawaii. "When you get into the vast expanses of Wyoming with 10 feet of snow on the ground, wind turbine performance is a whole different story."

"The early commercialization of a product is critical to its success," says Davis, noting that the program will help manufacturers receive early orders for commercial turbines and thus help to drive down the cost of the machinery. "An equally important objective," he says, "is to allow pioneering utilities to gain experience in operating turbines without having to assume the entire risk associated with a new power generation technology."

Marvin of the American Wind Energy Association believes the EPRI-DOE program will help pack much-needed power



into the U.S. turbine-manufacturing muscle. According to him, "U.S. Windpower's breakthrough was only the beginning. Now we'll begin to see some more competition emerge. I think the mid-nineties are going to be a tremendously exciting time for the wind power industry. The best in wind is yet to come." ■


**Further reading**

Utility Wind Interest Group brochures: *Economic Lessons from a Decade of Experience*, August 1991; *America Takes Stock of a Vast Energy Resource*, February 1992; *Integrating an Ever-Changing Resource*, July 1992.

*Assessment of Wind Power Station Performance and Reliability*. Prepared by R. Lynette & Associates, Inc. June 1992. EPRI TR-100705.

*An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States*. Prepared for the U.S. Department of Energy by Battelle, Pacific Northwest Laboratory. August 1991. PNL-7789.

"Excellent Forecast for Wind." *EPRI Journal*, Vol. 15, No. 4 (June 1990), pp. 14–25.

*Siting Guidelines for Utility Application of Wind Turbines*. Prepared by Battelle, Pacific Northwest Laboratory. January 1983. EPRI AP-2795.



Background information for this article was provided by Earl Davis and Edgar DeMeo, Generation & Storage Division.




1-23

# Some Advice on Wind Farm

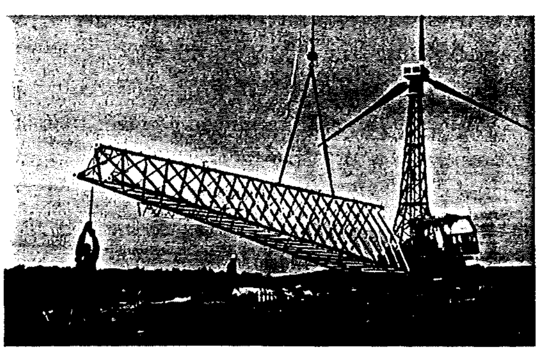
Because only a handful of electric utilities in the country have actually owned their own wind turbines, there is a limited amount of documented experience available for utilities to take advantage of. Earl Davis, EPRI's manager of wind power integration, is working to fill this knowledge gap, in part by developing a primer on wind farm development. This handbook is scheduled to be published next year.

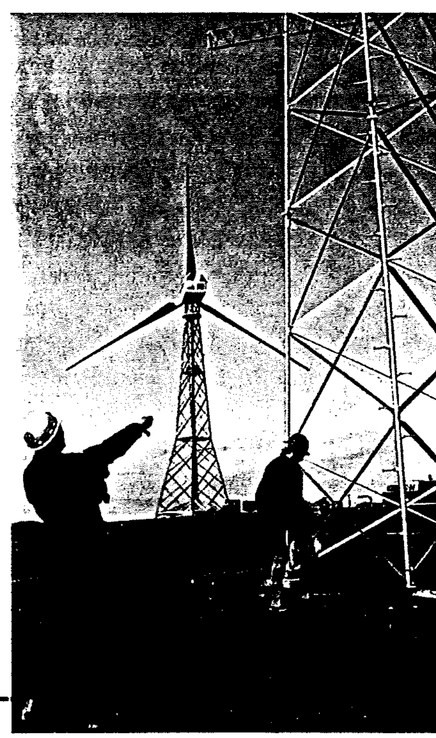
"Certainly utilities have a number of challenging issues to deal with if they want to own their own turbines," says Davis. "But there are a number of benefits as well, including the ability to have greater control of the turbine operations and of the way this energy resource is going to be integrated with their other generation sources."

Davis recommends that utilities considering direct ownership of wind machines first thoroughly measure their wind resources to determine what wind conditions prevail in the areas of specific interest to them. Next, they should analyze available turbine technology to find out which machines are most appropriate for their weather conditions. Before making any commitment to install the technology, utilities should examine the potential for snow, ice, heavy rainfall, tornadoes, and other extreme weather conditions that may affect the maintenance and operation of the turbines. Also important is investigating whether any endangered or sensitive species inhabit potential wind farm sites. According to Davis, utilities should address existing land use as well, taking into account whether a given site has been cultivated and whether there are houses nearby.

Land ownership is another issue to consider. There are several options. A utility might buy one large block of land to accommodate several clusters of wind turbines, or it might purchase only the specific ridges on which the turbines would be located. Similarly, the utility could lease the entire parcel or just those sections needed for tapping the wind resources. A third option is leasing the "wind rights" to the land, which would allow the present owner of the land to continue using it while simultaneously offering the utility the rights to install wind turbines, access roads, transmission lines, and other equipment required to operate and maintain a wind farm.

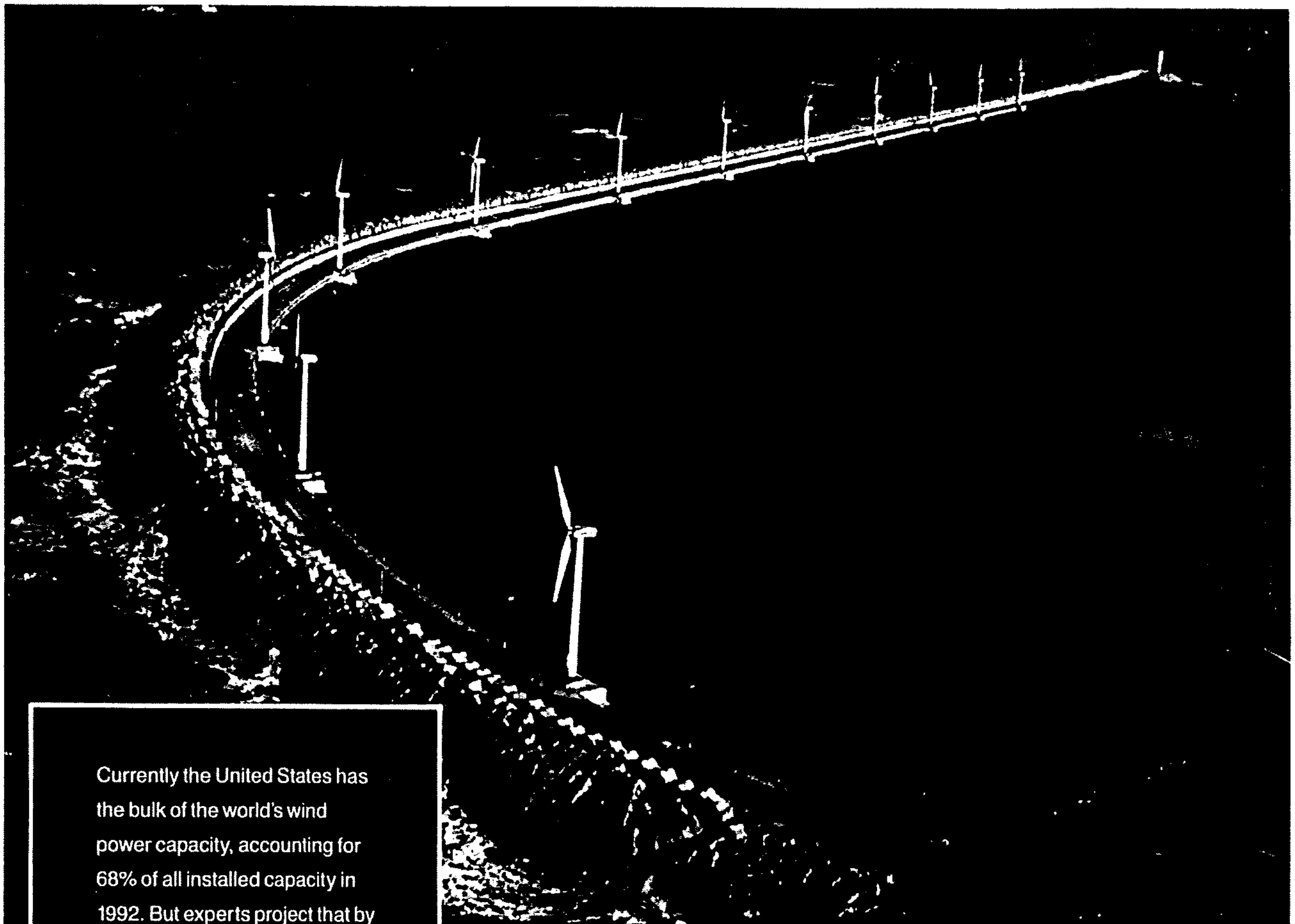
During the preliminary, feasibility phase of a wind farm project, the utility should lay out a plan to collect the electricity produced by the turbines and transmit it to the utility grid, says Davis. In addition to the technical considerations, the utility must look at the staffing requirements for the wind plant, determining where and how it will be operated and how to monitor its performance. Because many wind plants are located in remote areas, often a local office must be established. Finally, the utility should establish a performance verification program to determine the percentage of the available energy that is actually captured and to identify ways to improve the energy production.





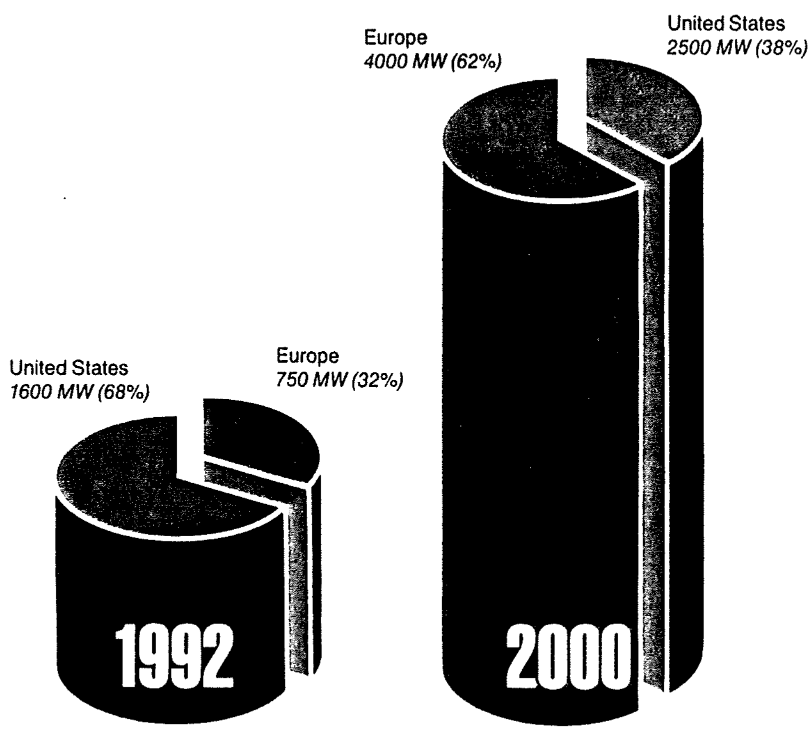
Workers erect two wind turbines near Lake Ontario for Niagara Mohawk Power Corp.

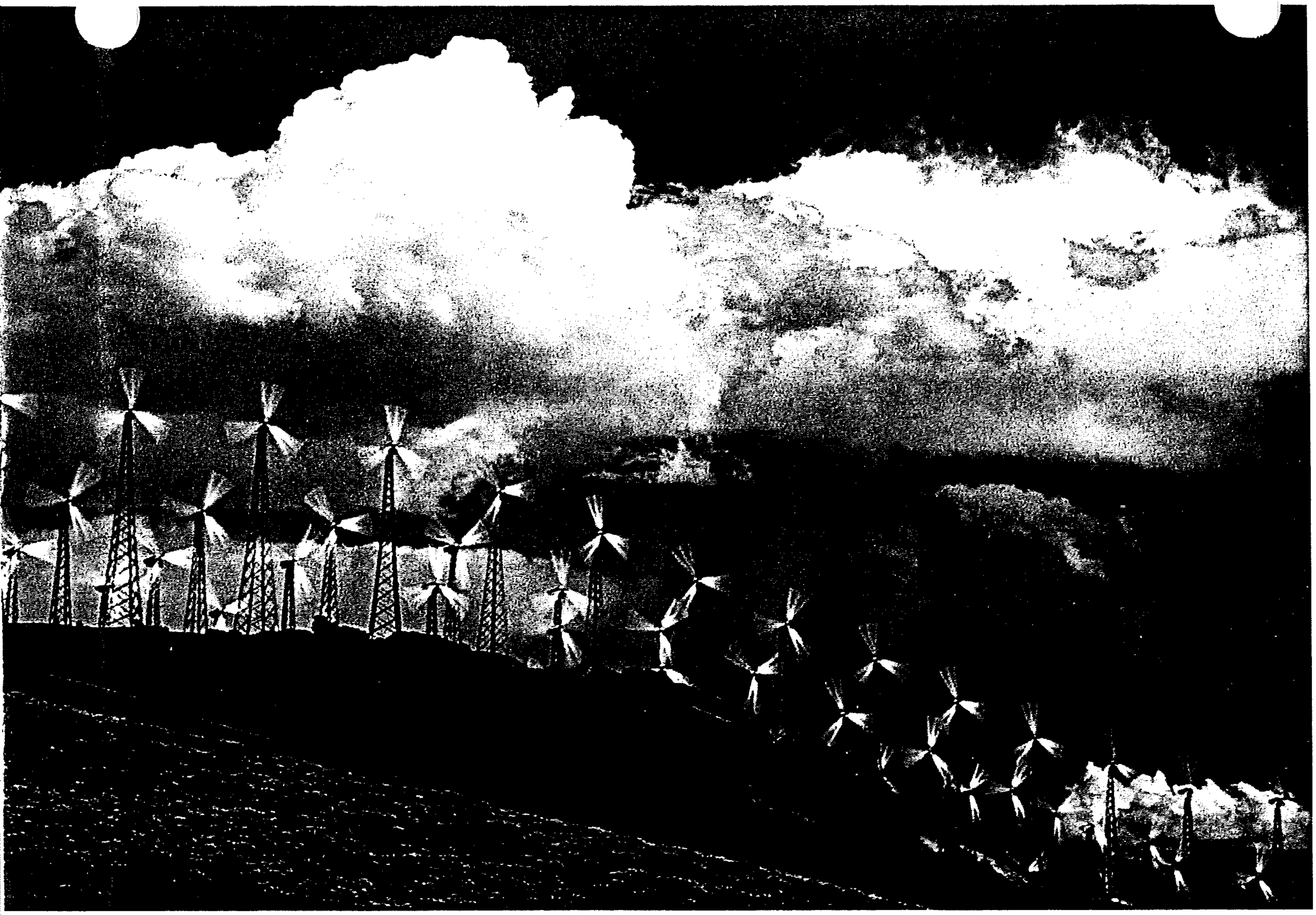
# THE WORLD ACCORDING TO WIND POWER



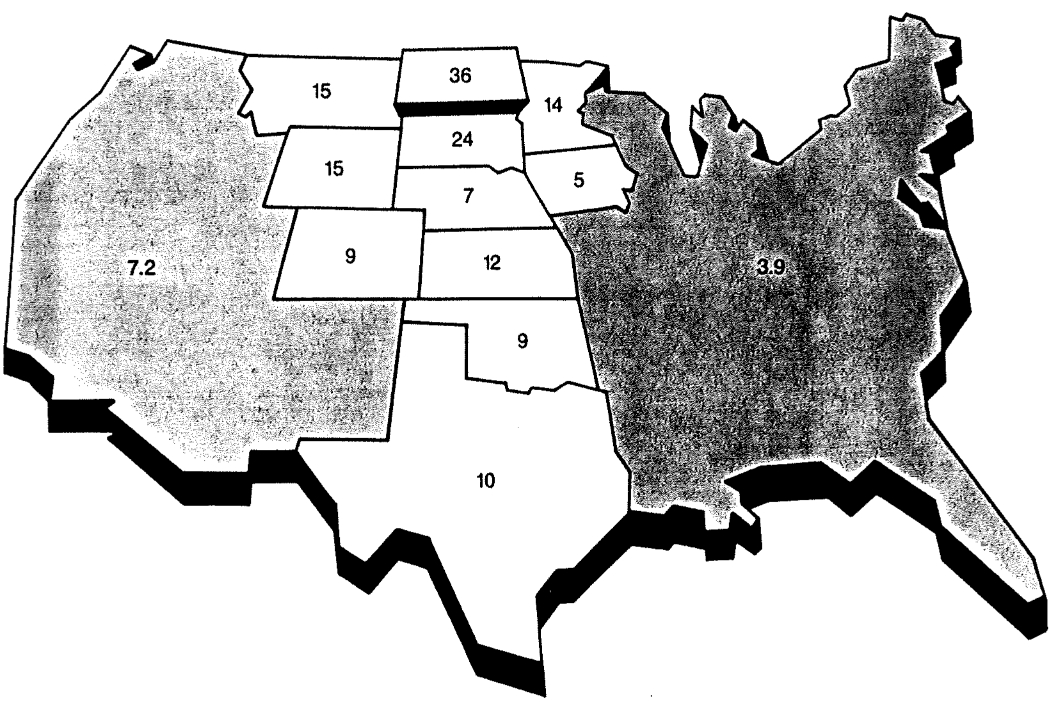
Currently the United States has the bulk of the world's wind power capacity, accounting for 68% of all installed capacity in 1992. But experts project that by the end of the decade, Europe will be the dominant force in wind power, accounting for 62% of the total installed wind power capacity worldwide. Aggressive government programs that set national goals for wind turbine installation and subsidize wind power projects are the driving force behind Europe's increased commitment to wind power. Other countries, such as India, have also installed wind turbines, but their activity is negligible in comparison with U.S. and European involvement.

*Wind farm at the outer harbor of Zeebrugge, Belgium*





Troops of wind turbines are as common as the California poppy on some Golden State hillsides.




**WIND RESOURCES, COAST TO COAST**

While ample wind resources are dispersed across the United States, the prime location for wind farm development is the central, Great Plains region. The numbers on this map represent the percentage of the 1990 electricity needs of the lower 48 states that could be met through wind power, given the wind resources available in the specified regions. For instance, North Dakota alone has enough wind resources to supply 36% of the electricity consumed by the contiguous 48 states in 1990. However, only a fraction of this wind power potential can be exploited economically.



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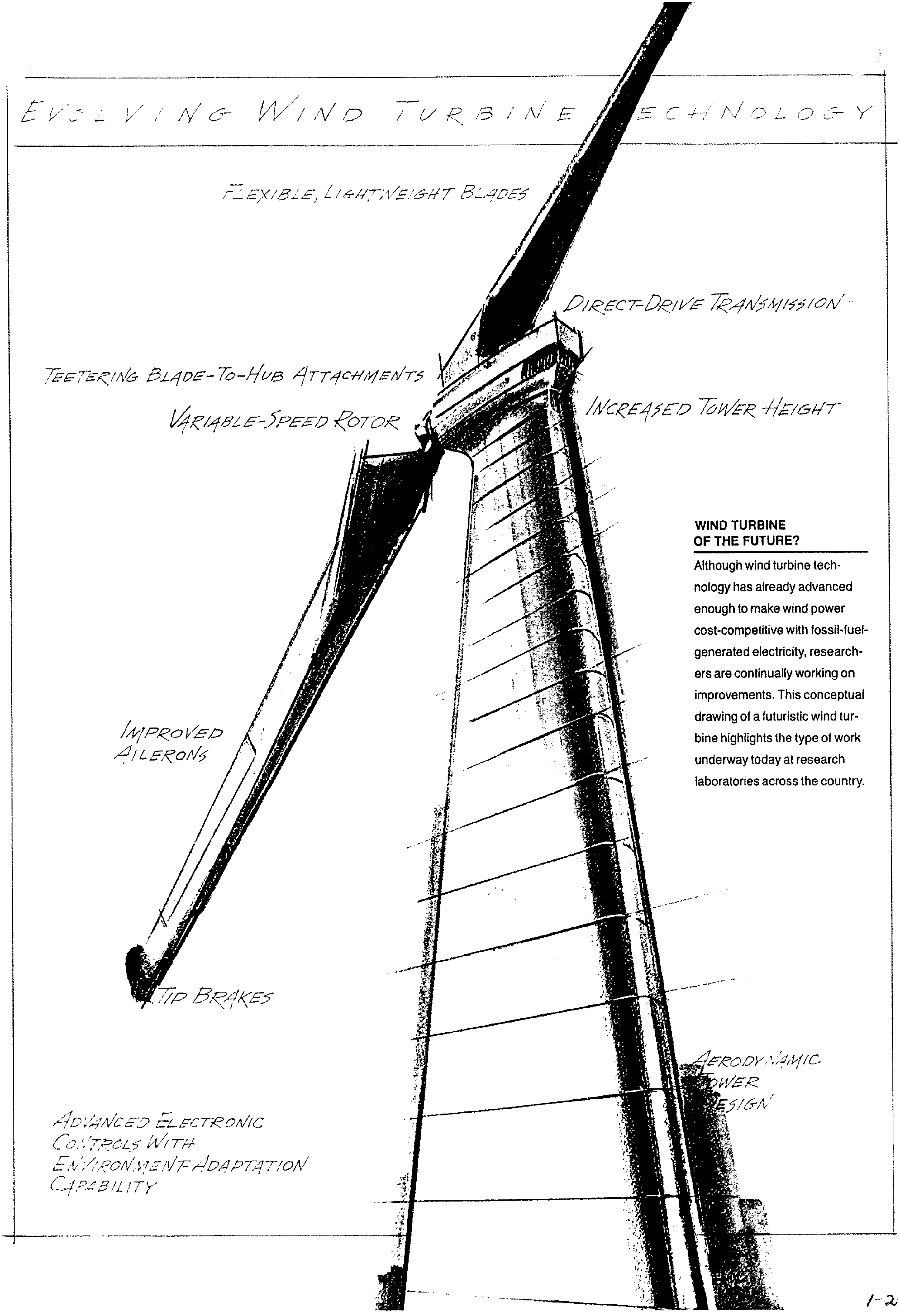



**WIND TURBINE OF THE FUTURE?**

Although wind turbine technology has already advanced enough to make wind power cost-competitive with fossil-fuel-generated electricity, researchers are continually working on improvements. This conceptual drawing of a futuristic wind turbine highlights the type of work underway today at research laboratories across the country.

# Reaping the Wild Wind

JUDGES

| | |
|---|---|
| Kathryn Fuller | President and chief executive officer, World Wildlife Fund. |
| Jay D. Hair | President and chief executive officer, National Wildlife Federation. |
| Denis Hayes | Chairman of the board, Green Seal; president, Bullitt Foundation; organizer of Earth Day 1970 and Earth Day 1990. |
| Fred Krupp | Executive director, the Environmental Defense Fund. |
| Thomas Lovejoy | Assistant secretary for external affairs, the Smithsonian Institution. |

It's hard not to be mesmerized while watching a wind farm generate electricity—a sea of blades pinwheeling madly or twirling lazily as the breeze picks up and slackens. Stand below the spinning rotors, and as the blades rev up to a whine and slow to a whisper you can hear the wind's capriciousness.

And therein lies the weakness of the wind turbine. Until recently, turbines were designed to operate at a single, ideal speed. The two- or three-blade rotors are geared to spin the shaft of a generator at a fixed clip, so that it cranks out an alternating current at 60 cycles per second, the standard utility-grid frequency. If a sudden gust tries to whirl the blades any faster, the generator shaft strains against the added torque. Not only does wind energy go to waste, but the unwanted torque shortens the machinery's lifetime.

This drawback has forced engineers to either build wind turbines out of costly heavy-duty components or keep replacing parts. That's one key reason electric utilities have shied away from the wind turbine's nonpolluting, renewable energy.

But technology has finally caught up with the wind. A new variable-speed wind turbine, the 33M-VS, is proving that wind farms can compete with conventional fuel-burning power plants. The turbine was developed by the Palo Alto–based Electric Power Research Institute (EPRI), the research and development arm of the electric utility industry, and U.S. Windpower.

Unlike previous turbines, the 33M-VS is rigged to roll with the wind's punches. When gusts whip the rotor, the generator shaft is free to speed up in response. As the shaft's rotation speed changes with the wind, the alternating current that flows from the generator swings up and down in frequency.

But between the generator and the utility grid lies an electronic power converter. This device first converts the variable-frequency current to direct current, then switches it back to alternating current at a fixed 60 cycles per second. So the generator feeds an even current to the utility grid. And the wind gust problems—wear and tear and wasted energy—have all but blown away.

Edgar DeMeo, who manages EPRI's research efforts in solar and wind power, realized in the early 1980s that power converters could smooth out the wind turbine's growing pains. Back then, as tax credits nurtured the technology's initial development spurt, engineers were coming to grips with the mechanical fatigue that plagued conventional turbines. But the cost of power converters—made from extra-large silicon chips to handle high currents—was prohibitive.

Like so many electronic products, however, power converters began to tumble in price. "In the mid-eighties," recalls DeMeo, "wind turbine technology was coming along, and with big advances in power electronics, we asked if it made sense to look at a marriage." EPRI had already played a role in developing power converters for huge adjustable-speed industrial motors. To bootstrap the technology onto wind turbines, in 1988 EPRI joined forces with Oakland-based U.S. Windpower, the nation's biggest wind-turbine manufacturer. In 1990, after some successful tests, EPRI brought the Pacific Gas & Electric Company and Niagara Mohawk Power Corporation into the consortium.

In late 1990, the consortium—known as the Variable-Speed Wind Turbine Development Alliance—began redesigning U.S. Windpower's existing 100-kilowatt turbine to demonstrate the new variable-speed technology. Its blades sweeping more than three times the area of the 100-kilowatt model, the prototype was designed to generate between 300 and 400 kilowatts—enough to power 150 or so typical homes for a year.

By the end of 1991, the turbine was spinning away at U.S. Windpower's headquarters near blustery Altamont Pass, just east of San Francisco Bay. EPRI calculates that if planted in a spot where annual wind speeds average 16 miles per hour, the turbine could generate electricity at five cents per kilowatt-hour. That's about on par with the generating costs of a newly built coal- or gas-fired plant, and two to four cents cheaper than traditional wind turbines. Last year U.S. Windpower ran 22 more test models for a season at Altamont Pass, then took them apart to look for mechanical wear. "We believe we're beyond the threshold of competing economically with traditional fossil-fuel technologies," says company president Dale Osborn. And that means the world's windiest landscapes may soon sprout fields of wheeling, whispering rotors.

## Finalists

**TRELIANT FANG**, member of the technical staff at **AT&T** in Princeton, New Jersey, for the development of a technique using the chemical compound n-butyl butyrate as a nonpolluting solvent in the manufacture of integrated circuits. This chemical is environmentally benign and nontoxic and can be easily recycled in the manufacturing process. It serves as a substitute for ozone-layer-damaging trichloroethane (traditionally used in electronics manufacturing) and is currently being used to produce AT&T's multichip modules.

**DAVID F. THOMPSON**, senior development associate at **Corning** in Corning, New York, for an electrically heated catalytic converter. The converter helps reduce automobile exhaust emissions during the first two minutes of operation, when up to 90 percent of all pollutants are emitted. In the Corning system, exhaust gases are heated to over 400 degrees Celsius so they can be converted to harmless gases within five seconds of engine ignition. Without affecting vehicle performance, Corning's technology easily surpasses California's 1997 ultralow vehicle emission standards, which are more restrictive than federal requirements and are gradually being adopted by other states.

**ROGER LONG**, president of **Envirosafe Solutions** in Schuylkill Haven, Pennsylvania, for a nontoxic, Teflon-based barrier that is too slippery for fire ants, roaches, caterpillars, and many other kinds of insects to walk across. Called Envirosafe, it was developed with the assistance of Du Pont and is a safe alternative to pesticides. It is available as a spray and in tape form.

**ANTHONY BARKET**, president of **21st Century Water Systems** in Morro Bay, California, for the Divert-It water efficiency system. Every time you run the shower or a faucet while waiting for the water to get hot, approximately one to three gallons of cold water are wasted. With the push of a valve, the Divert-It system channels this water into a pressurized storage tank hidden under the sink; the toilet, when flushed, then draws water first from the tank. If a community of 10,000 people used Divert-It, which is inexpensive and easy to install, more than 20 million gallons of water a year would be conserved.

# *1993 FACTS ABOUT WIND ENERGY*

## WIND ENERGY IS COST EFFECTIVE

- KENETECH/Windpower's latest generation variable-speed wind turbine (Model 33M-VS) incorporates state-of-the-art engineering and captures significantly more energy than existing constant speed technologies at a lower cost. The 33M-VS is designed to generate power at roughly 5 cents per kilowatt-hour (kWh).
- The California Energy Commission has calculated that wind energy is less costly than gas, nuclear and coal when capital, fuel and operating expenses are counted over the life of a power plant.
- Under the Clean Air Act Amendments of 1990, wind power helps utilities save SO2 emission allowances. The value created ranges from approximately 0.2¢/kWh to over 1¢/kWh for typical utilities.
- As regulators in many states begin to insist that electricity costs reflect the health and social value of avoiding air pollution, the power produced by non-polluting wind turbines could become more cost-effective.

## WIND ENERGY IS PROVEN

- The 3.8 billion kWh produced worldwide by wind turbines is enough electricity to meet the residential requirements of 1.6 million North Americans.
- KENETECH/Windpower is the world's largest wind energy company. KENETECH/ Windpower's turbines have delivered more than 4.4 billion kilowatt-hours since 1982.
- In 1992, KENETECH/Windpower's turbines delivered 800 million kilowatt-hours, enough electricity for 130,000 average households.
- KENETECH/Windpower has manufactured, installed, and is operating more than 4,200 wind turbines, logging over 79 million hours of operation.

## WIND ENERGY HELPS THE ENVIRONMENT

- The near 3 billion kilowatt-hours of electricity generated by California wind turbines in 1992 offset the emission of 16 million pounds of nitrogen dioxide, sulfur dioxide and particulates.
- For every kilowatt-hour generated by a wind turbine instead of fossil fuels, between 1 to 2 pounds of carbon dioxide, a chief "greenhouse" gas, are avoided.
- Wind turbines currently offset the emission of 2.7 billion pounds of carbon dioxide annually.
- If world-wide wind energy's 3.8 billion kilowatt-hours were generated from the combustion of oil, it would require 5.4 million barrels of oil, or a fleet of 41,000 oil tanker trucks.

# Business Day

D1

TUESDAY, SEPTEMBER 8, 1992

The New York Times


# A New Era for Windmill Power

## High-Tech Models Attracting Utilities

By MATTHEW L. WALD

Special to The New York Times

LIVERMORE, Calif. — A new generation of windmills that Don Quixote could never tilt at is ready to take its place as an economical and important source of the nation's energy.

Because of striking improvements in technology, the commercial use of these windmills, or wind turbines as the builders call them, has shown that in addition to being pollution free, they can now compete with fossil fuels in the cost of producing electricity.

As a result, officials of utility companies from around the world have come, cash in hand, to California to inspect the tops of the ridges here at the Altamont Pass, for example, where new machines that look like sideways helicopters married to computers are harnessing the wind.

In recent months, utilities serving upstate New York Illinois, Iowa, California and the Netherlands have decided to try to use the wind to produce electricity commercially.

**Competing With Fossil Fuels**

Kingsley E. Chatton, president of U.S. Windpower, which operates 22 new-generation windmills here, said the economics of wind power was at the point where it "will compete with fossil fuel." Others agree.

Edgar A. DeMeo, in charge of renewable-energy research at the Electric Power Research Institute, a nationwide research consortium based in Palo Alto, Calif., said the work in California represented a significant advance. Mr. DeMeo's organization, which is supported by dues from utilities, carries out wide-ranging investigations on new technologies and ways to improve existing technologies involving all sorts of power sources.

"We're beyond Kitty Hawk and into the jet age," he said.

The turbines are a successor to the thousands of crude, flimsy windmills put up by optimistic pioneers of the early 1980's, machines that generated more tax credits than electricity and by now have largely disappeared.

**Capturing More Energy**

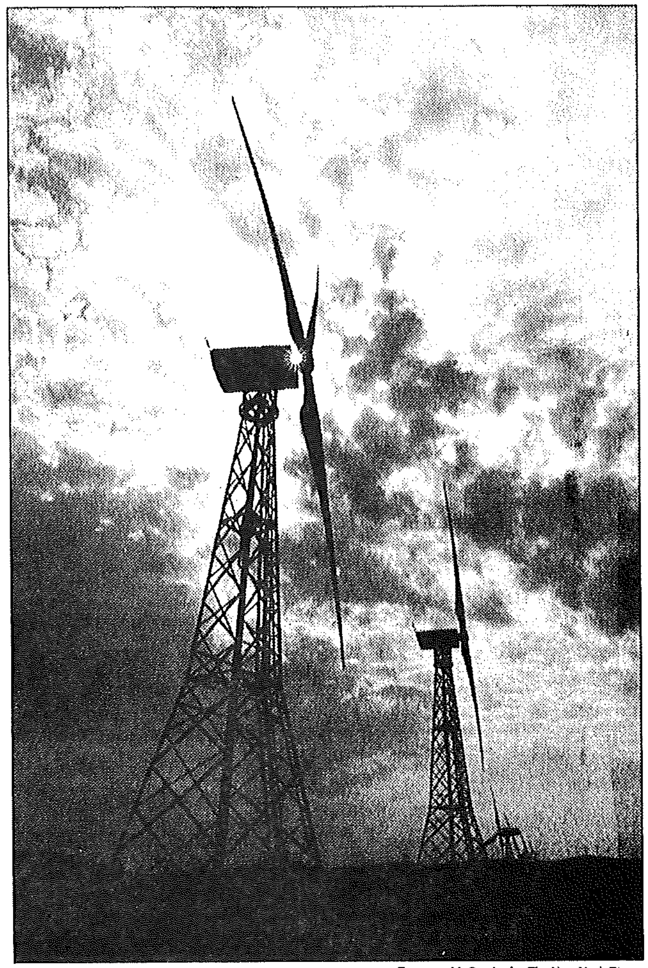
The new windmills capture far more of the wind's energy — a surprisingly tricky feat. Wind varies greatly, but electricity must be so uniform that a user can, for example, set a clock by it. Uniformity has been largely achieved with durable, high-technology adjustable fiberglass propeller blades directed by computers.

Wind turbines cannot replace fuel-burning plants completely because the wind cannot be ordered to blow. But it can be counted on enough over time to produce substantial amounts of energy and thus reduce conventional generation with its emissions of sulfur dioxide, which causes acid rain, and carbon dioxide, the biggest greenhouse gas.

Wind can also be used to save the water behind hydroelectric dams to last through dry seasons. In some locations, wind is reliable enough to be counted on at certain hours of the day or seasons of the year.

The newest generation of windmills

Continued on Page D4

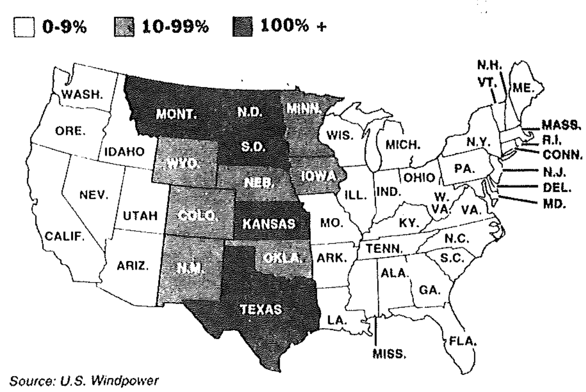


Terrence McCarthy for The New York Times

A new generation of windmills is poised, supporters say, to compete with fossil fuels in the production of electricity. These new "wind turbines" in Livermore, Calif., are controlled by computers to help produce a steady voltage regardless of changes in the wind's speed.

### Where the Winds Are

Map shows the wind potential of the 48 contiguous states, according to what percentage of the nation's electricity needs could be generated by the winds in each state over the course of a year.




Source: U.S. Windpower

The New York Times

# Windmills Enter New Era With Help of High Technology

*Continued From First Business Page*

thus crosses an economic threshold that will allow their use in many areas of the country, although it will take several years before they produce a large fraction of the nation's electricity. Mr. DeMeo said he would not be surprised to see windmills generate 10 percent in 30 years — about equal to the share now produced by hydroelectricity.

He predicted that successive generations of windmills, building on the combination of sophisticated blades and computer control, would be bigger and would not need costly items like gearboxes, lowering costs further.

**A Cold, Noisy Wind**

On a recent morning here atop the Altamont Pass, about 30 miles east of San Francisco, the wind, at 30 miles an hour, was strong enough to whip open a car door as soon as the passenger began to open it. The turbines whined at different pitches, while the cold wind whistled through the 80-foot towers covering the bare hills. None of this seemed to bother the cows or the ground squirrels, but for a visitor it was altogether eerie.

"Kind of a nice day, isn't it?" Chuck Ferguson, a field engineer, said as he opened the power electronics box at the base of one tower. It was generating enough electricity to run about 80 houses with their central air-conditioners going, meaning the 22 machines here can power thousands of homes and businesses.

That's a lot of tilting.

Mr. Chatton of U.S. Windpower said the cost of wind-turbine production, from capital investment to operation and maintenance, was about five cents a kilowatt-hour, roughly half the average retail price for power nationwide. A kilowatt-hour is enough electricity to light 10 100-watt bulbs for an hour. At an oil-fired plant, that much electricity costs about 5 cents in fuel alone, apart from capital investment, operation and maintenance expenses. So a power company that now uses oil could save money by building windmills.

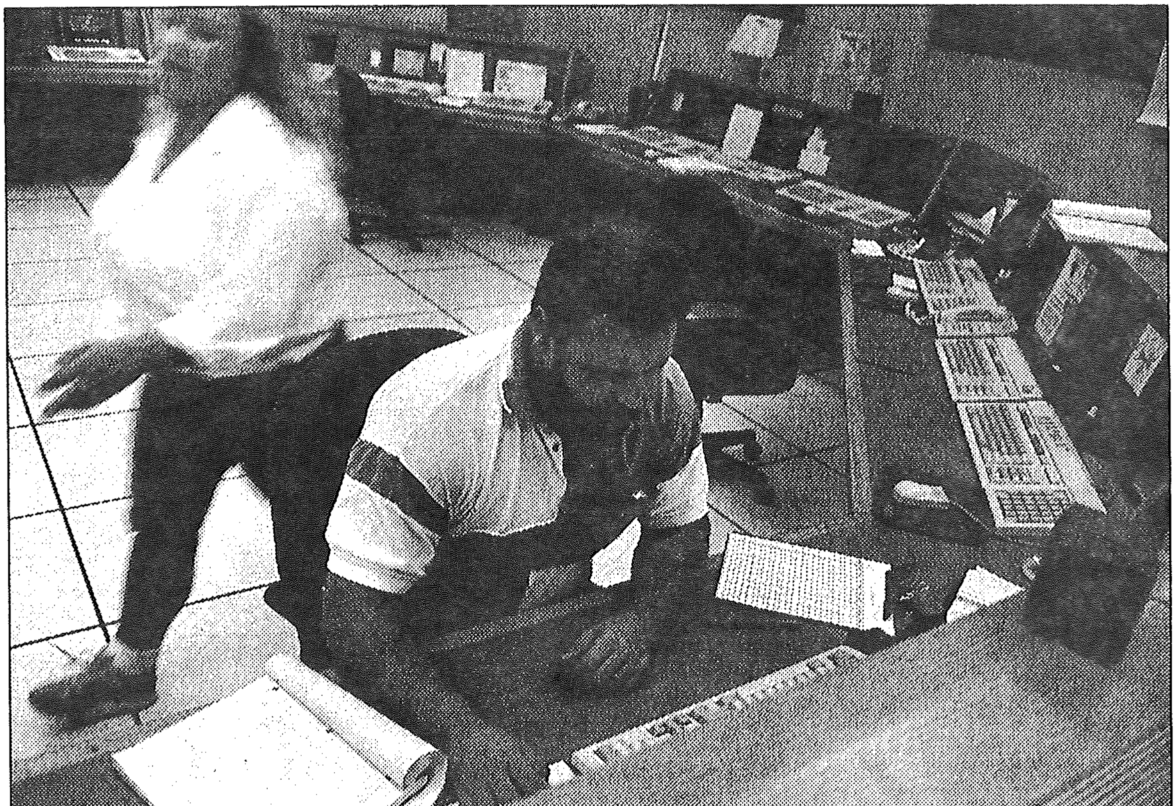
**Cheaper to Build Windmills**

At existing plants that run on coal and natural gas, generation costs are lower, and the money to build the plants has already been spent. But in many locations, building new wind turbines may be cheaper than building new fossil-fuel-burning plants.

Coal-burning utilities with no need for new capacity also have an incentive to turn to wind. The Federal Clean Air Act limits their sulfur dioxide emissions, often requiring them to buy cleaner fuel at a premium, or to buy "emissions allowances" from utilities that are cleaner than the standard required. Windmills do not pollute.

Not that they are completely benign. Some complain that windmills clutter up the landscape. And in some places, environmentalists have said windmill blades have killed birds.

Here at Livermore, U.S. Windpower has painted some blades with a striped pattern to see if this will keep birds away. Company officials say they have not found dead birds at any of the machines, striped or not.



Terrence McCarthy for The New York Times

U.S. Windpower operates 22 new-generation windmills at Altamont Pass, about 30 miles east of San Francisco. From a control room, Kevin Coleman monitors computers that adjust the windmills' propellers.

Still, windmill use is spreading. U.S. Windpower, a subsidiary of the Kenetech Corporation, has recently announced these projects:

¶A joint venture with the Iowa-Illinois Gas and Electric Company to develop 250 megawatts worth of windmills, that is, about 600 windmills. A megawatt is a thousand kilowatts.

¶The sale of a 50-megawatt plant to the Sacramento Municipal Utility District, which is seeking to replace the output of a retired nuclear plant.

¶The construction of a 25-megawatt plant in Holland, with the power to be bought by Energiebedrijf voor Groningen en Drenthe, known as E.G.D., and the sale of a 50-megawatt plant to four utilities in the Pacific Northwest.

U.S. Windpower also plans to have two turbines installed by Nov. 1 for the Niagara Mohawk Power Corporation in upstate New York, to see how they work in cold weather.

**The Last Windmill Maker**

The Iowa-Illinois and Pacific Northwest deals are particularly significant because of the role utilities will play, as owners or co-owners, rather than buyers of power. The utilities can also supply money for capital costs at far lower rates than start-up high-technology companies can obtain.

U.S. Windpower, the only American company that builds windmills, has outlasted the others and has 138 patents on its equipment. Some smaller concerns, however, do assemble windmills from imported components. U.S. Windpower's parent, Kenetech, is owned in part by its management and in part by the Hillman Company, Allstate Insurance, F. H. Prince & Company and a variety of other, smaller investors. Last year, the company had revenues of about $350 million.

To produce alternating current at precisely 60 cycles a second, the standard for this country since early in the century, most traditional windmills have been designed to turn at only one speed. If the wind is not strong enough to turn the blades at that speed, no power is produced. If the wind blows more strongly, anything above the minimum amount of energy needed to produce electricity is wasted by the blades. Worse, on a really windy day the machines cannot work at all because they would be damaged.

**Combining Two Technologies**

The new generation of machines is a marriage of aerodynamics and microelectronics. U.S. Windpower adapted the idea of variable-pitch blades from airplanes and developed a system to let the blades and the generator turn at whatever speed the wind allows. Computers open and close electronic circuits to smooth out the air flow over the blades and create electric current that alternates at the right cycles.

The result: while older machines produce no power until the wind reaches 14 miles an hour, the new ones start making electricity at 9 miles an hour. The older ones shut down at 45 miles an hour; new ones work at up to 60.

Another innovation is size, with new machines having a bladespan of about 100 feet, up from 56 feet in previous designs. That means four times as much power, at a total cost only about two and a half times more. There have also been improvements in the blades, which are now 2,000-pound fiberglass structures derived from sailboat masts.

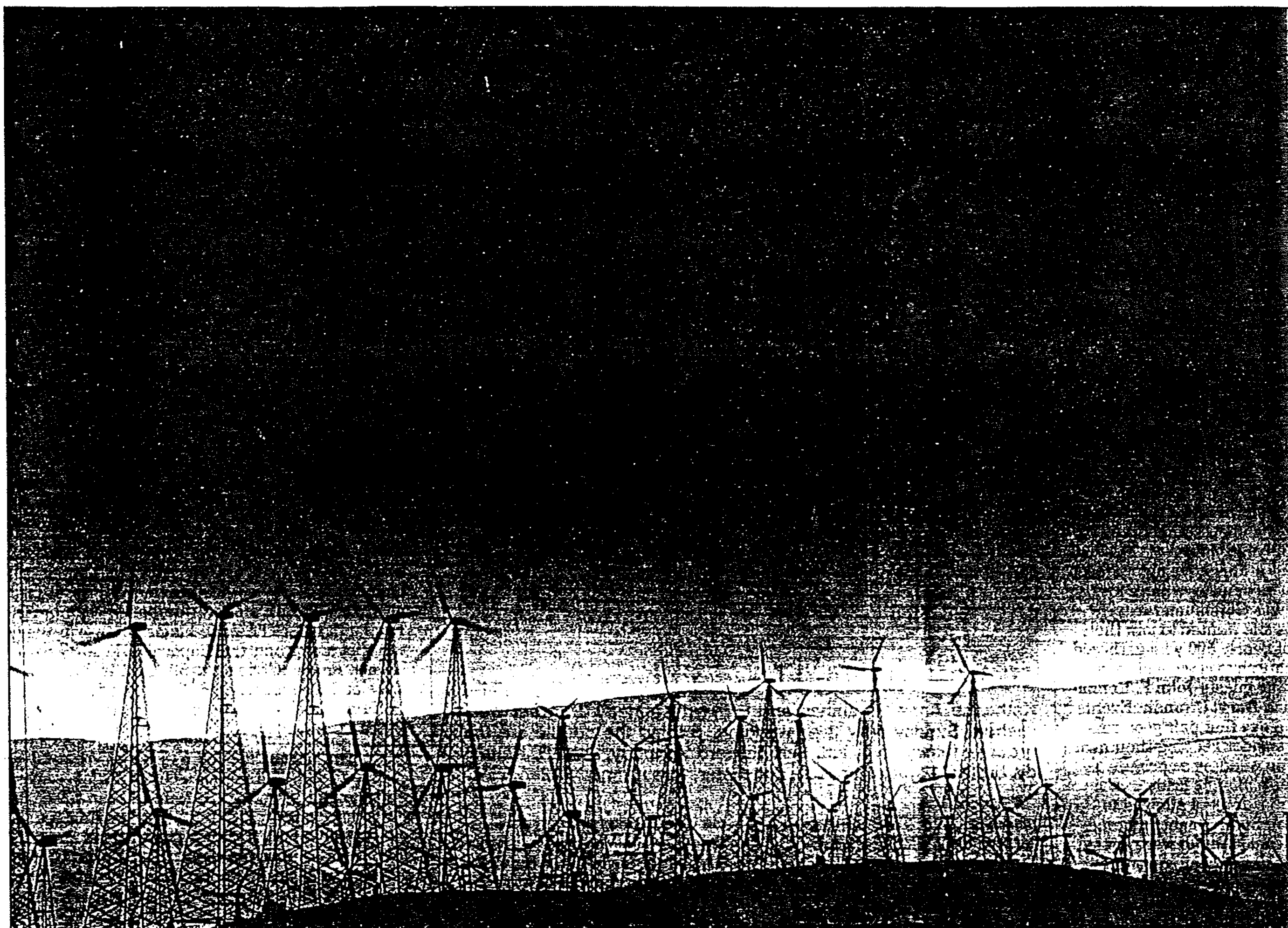
The ridges where U.S. Windpower's turbines stand are between California's sunny central valley and the cloud-bound coast. Every day, the sun warms the air in the valley and as the hot air rises, cooler air from the coast rushes in to fill the void. This gives the site more predictable winds than most other places.

But the "wind resource," as proponents call it, is not peculiar to California. In fact, by national standards, California is not particularly windy: a strip of states from North Dakota to Texas has far more wind. And although electricity is usually generated within a few hundred miles of where it will be consumed, Texas alone could, theoretically, generate 36 percent more kilowatt-hours from wind than are used in the entire continental United States.

The Sacramento Bee

Monday, October 11, 1993

## Winds of change



Bee/Michael A. Jones

Dark clouds loom over some of the more than 7,000 windmills in Altamont Pass, but wind has a bright future as an energy source, specialists say.

# Windmills turn into major power source

By Dale Vargas
Bee Staff Writer

LIVERMORE – It's enough to send Don Quixote over the edge.

If Cervantes' fictional character who thought windmills were monsters rode into Altamont Pass today, he would be surrounded by more than 7,000 spinning wind turbines that look a bit like alien creatures clawing the sky.

**DISCOVERY**

Unlike their ancestral brethren that pumped water or ground grain, today's wind machines make electricity.

Once considered little more than a Fantasyland idea for electricity production, wind has joined the ranks of solar and biomass as a viable possibility in alternative fuels. And wind power is now a multimillion-dollar industry that could have a profound effect on the environment.

The 17,000 wind turbines in the United States today produce about 1,700 megawatts. California, the birthplace of the wind energy industry, still holds 95 percent of that power capacity. Projects are under way or being considered in other areas in the Midwest, the Northwest, Texas and elsewhere.

By 2000, there could be an increase – more turbines with bigger capacities – to 10,000 megawatts, according to the American Wind Energy Association. If that ambitious goal is reached, the industry could produce 22 billion kilowatt hours a year – or enough power for regular residential use by nearly 5½ million people.

While those figures represent

1-32

# Windmill: Turbines could cut dependence on foreign oil

Continued from page A1
something less than 2 percent of the country's projected power needs, they could mean the elimination of 5.5 million tons of emissions from fossil fuel-burning power plants each year, according to the association.

Wind is looked to increasingly as a means toward less dependence on foreign oil products and smaller bills for rate-payers.

Since California's first wind farm in 1981, the cost of produce a kilowatt hour has declined 75 percent, from between 25 cents and 35 cents to less than 10 cents, said Randall Swisher, executive director of the wind energy association.

That makes it competitive with other power sources, such as nuclear and coal, experts said.

"We are confident that wind energy provides an environmentally preferred method of generating electricity," said Clarence R. Grebey III, a Washington, D.C., spokesman for Kenetech Corp., the parent company of Livermore-based U.S. Windpower Inc.

U.S. Windpower – which owns half of the turbines in an 80-square-mile area in Altamont Pass – is the biggest wind turbine manufacturer and developer in the world. It is involved in wind projects throughout the world, including one in Ukraine that will accelerate the decommissioning of the Chernobyl nuclear plant, said Grebey.

Among the new U.S. Windpower projects is a planned 50-megawatt wind "farm" in Solano County for the Sacramento Municipal Utility District.

"It is a tremendously important option. ... If you think of the air-quality problems we have, the global warming, you've got to be for wind power," said SMUD General Manager S. David Freeman.

Pacific Gas and Electric Co., which has been involved in wind-power projects for more than a decade, plans to increase the current 800 megawatts of wind power it has on line, said Bob Haywood, the utility's power system vice president.

"It is free energy, if you will," Haywood said of the technology his company invested $114 million in last year.

Southern California Edison also uses wind power, to the tune of 960 megawatts a year from huge wind farms in the Tehachapi Mountains and in the desert near Palm Springs, said Edison official Ron Luxa.

Wind power is not without its detractors or problems.

A comprehensive study done between 1989 and 1991 by the California Energy Commission declared "an unexpected impact of widespread wind turbine development in California has been the death of birds from collisions with turbines."

The study turned up 182 dead birds in sampled areas. Sixty-five percent of the dead birds were raptors, or birds of prey. Some of the casualties are protected or endangered species.

State researchers concluded that 567 raptors were killed in the Altamont Pass wind-farm during a two-year period ending in 1991. The report labels its findings "cause for concern."

Most of the deaths, and some injuries, occurred when the birds flew into the turning blades of the turbines atop 20-to-30-meter-high towers. Some larger birds, like red-tailed hawks, golden eagles and common ravens, were electrocuted when their wings turned them into electric circuits at riser poles.

U.S. Windpower's Grebey said his company has invested $1 million in looking for ways to fix the bird-collision problem. PG&E, which now has 72 wind projects, also is looking into the issue, an official said.

A draft environmental impact report for SMUD's Solano wind farm said the effect of windmills on birds could be significant – particularly in terms of electrocutions or collisions with turbines. The report lists several actions or design details, such as insulated wires and "on-site bird avoidance research," that might reduce possible harm.

"Environmentalists like things in black and white," said Rich Ferguson of the California Sierra Club. But, he said, "it's not that easy."

On the bird-death problem, Ferguson said, it appears officials are taking the issue seriously and the Sierra Club has adopted a wait-and-see attitude.

Wind industry officials said the electrocution problem has been virtually eliminated by altered wiring, but the blade deaths remain a puzzle. So far, it has been difficult to tell the exact reasons for the birds' apparent inability to sense the turning blades. Possible solutions being considered or tested include painting of the blades and installing noise makers.

Generally, the machines are relatively quiet.

"You get where you don't hear it at all," said Lois Combs, who for 12 years has lived with her family on 150 acres dotted with wind turbines. The hum of the nearby machines is audible from the Combs home on North Flynn Road, but the noise is not distracting or overwhelming.

Another issue that caused some concern this summer was grass fires sparked by twisted cables on the turbines. U.S. Windpower officials acknowledge the problem, but say they are working with the equipment to eliminate the problem.

Technology has overcome many of the problems associated with early efforts at harnessing wind power during late 1970s and early '80s, when turbines were prohibitively expensive and "were breaking down all the time," said Swisher.

Wind power is most efficient in areas where the wind farms operate during peak energy usage times. Computer-controlled wind turbines are turned off when the wind is too weak or too strong to warrant capturing its power.

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