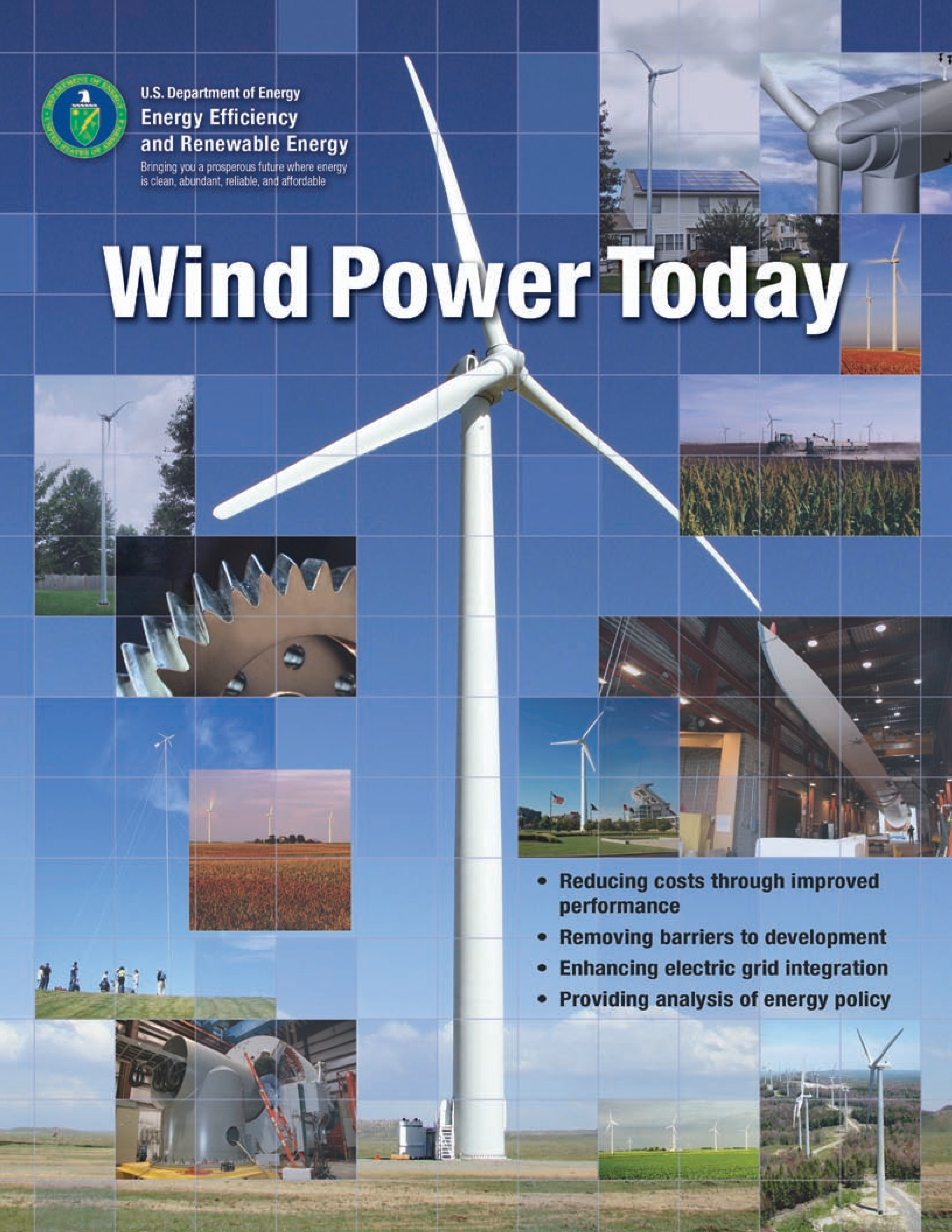
U.S. Department of Energy
Energy Efficiency and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Wind Power Today



- **Reducing costs through improved performance**
- **Removing barriers to development**
- **Enhancing electric grid integration**
- **Providing analysis of energy policy**

Leading the Nation’s Wind Energy R&D

Wind energy technology has come a long way over the past decade. In 1996, the average utility-scale wind turbine was almost as tall as a 12-story building and it produced enough electricity to power about 125 average American homes. At the time, these turbines were considered by some to be quite large, but by today’s standards, they would be considered small for utility-scale production. The average turbine installed in 2006 (rated at 1.5 MW) was twice as tall as the ’96 model. It is almost as tall as the Statue of Liberty and has a rotor large enough to sweep a football field. A 1.5-megawatt (MW) turbine produces enough electricity to power almost 500 homes, and again, that might be considered small when compared to the 3- to 5-MW machines being developed today that will generate enough power for more than 1,300 homes. A 3.6-MW machine has a rotor diameter large enough to park 24 cars in end to end, and a 5-MW machine is as tall as the Space Needle in Seattle, Washington.

The U.S. Department of Energy (DOE) has worked with industry for more than 25 years to bring the technology to where it is today, developing larger machines that are more efficient and that capture more energy from the wind. As the machines have increased in size and performance, the cost of producing energy has dropped—from $0.80 (current dollars) per kilowatt-hour (kWh) in 1980 to about $0.04/kWh today—so that in some areas of the Nation, utility-scale wind power is the most cost-effective form of new generation available.

DOE has also been working to improve the performance and reduce the costs for small and distributed wind energy systems. These systems show great potential for engaging local populations in addressing America’s energy future. Advances in small wind technology have produced quieter and more reliable systems that are easier to install and cost less to operate.

The wind energy industry has become the fastest growing utility-scale energy resource in the Nation, growing from 1,800-MW of capacity in 1996 to more than 11,600 MW in 2006. 2006 was a record-breaking year with new installations of more than 2,400 MW and a 27% annual growth rate. The new generating capacity installed in 2006 represents a capital investment of almost $4 billion, more than 10,000 new job-years nationwide (10,000 one-year jobs or 1,000 ten-year jobs), and more than $5 to $9 million in annual payments to landowners. The land payments and jobs provide a much needed economic boost to America’s struggling rural economies.

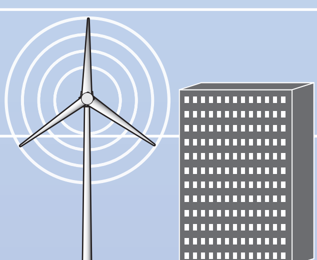
As a clean, domestically produced renewable energy resource, wind energy also contributes to our Nation’s energy security and environmental quality. The current capacity will generate more than 30 million megawatt-hours (MWh) and displace approximately 18 million metric tons of carbon dioxide per year.

Although 11,600 MW is enough capacity to power about 3 million average homes, it still constitutes a very small share of the total U.S. generation. According to the Energy Information Administration,

600’
500’
400’
300’
200’
100’
0’

1996

The 550-kW Zond Z-40, commonly installed in 1996, has a 131-ft (40-m) hub height and is as tall as a 12-story building.



2006

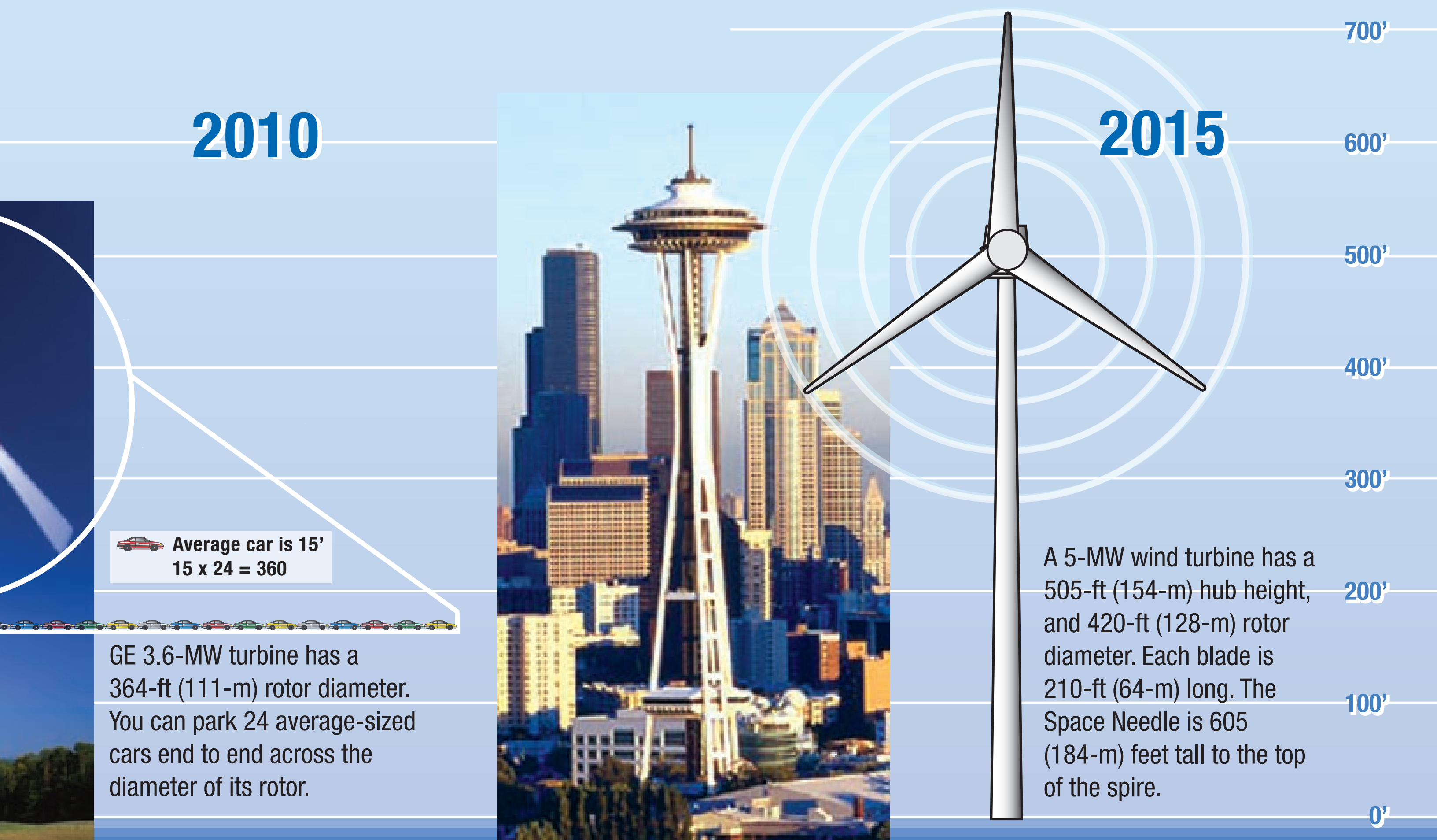
The GE 1.5-MW wind turbine, commonly installed in 2006, has a 275-ft (84-m) hub height and is almost as tall as the Statue of Liberty, which is 305 feet (93-m) tall from the ground to tip of torch.

as of October 2006, wind accounted for only 0.7% of the national electric supply. Coal-fired plants generate the majority (48.5%) of the Nation's electrical energy, followed by natural gas (20.5%) and nuclear plants (19.2%). Conventional hydroelectric, petroleum-fired plants, and other renewables constitute the remaining generation sources.

To accelerate the development and use of advanced clean energy technologies, President George W. Bush launched an Advanced Energy Initiative in 2006. According to the Initiative, areas with good wind resources have the potential to supply up to 20% of the electricity consumption of the United States. The DOE Wind Energy Program is collaborating with industry and stakeholders to analyze credible scenarios for high levels of wind energy use, and determine what actions will best address the technology, market, and policy challenges to maximizing the Nation's opportunity for harnessing its immense wind resources. To provide 20% of the Nation's electricity supply, U.S. wind capacity would have to increase from its current 11,600 MW to more than 325,000 MW. Incorporating this amount of wind generated electricity in the Nation's electricity portfolio could avoid emission of 3,500 million metric tons of carbon equivalent through 2050—equivalent to the amount of carbon produced by the entire transportation sector over 3-1/2 years. This would also lead to approximately $332 billion in economic investment and more than 3,725,000 full-time equivalency job years for construction and plant operation, largely focused in rural areas.

To provide greater support for the President's initiative, in 2006, the DOE Wind Energy Program shifted the emphasis of its activities to accelerate the market penetration of wind technology. Shifts in program activities include:

1. Supporting the development of 20% U.S. energy by wind.
2. Increasing the program's efforts to overcome near-term deployment barriers to wind projects.
3. Collaborating with the DOE Office of Electricity Delivery and Energy Reliability to ensure that wind energy is appropriately represented in grid expansion and modernization efforts around the Nation and conducting outreach to Federal, state, and local organizations and utilities.
4. Expanding work in the area of turbine performance and reliability to mitigate risk to investors, developers, and operators.
5. Expanding program activities in the distributed wind technology market sector (residential, farm, small business).



WIND ENERGY PROGRAM SUPPORT

Sandia National Laboratories developed an advanced data acquisition system (ATLAS II) on a GE Wind 1.5-MW wind turbine. The turbine is part of a cooperative activity involving SNL, GE Wind, and NREL.

Sandia researchers work with industry partners to develop the advanced materials and manufacturing processes required by longer blades.

The NWTC's resonance blade test system uses a 1000-pound (454-kg) weight housed in a stand attached to the end of the blade. The system allows researchers to apply 3 million cycles of fatigue test to a blade in 50 days rather than the 116 days required by the previous test system.

The NWTC has two dynamometer test facilities—a 2.5-MW and a 225-kW—to help its industry partners conduct a wide range of tests on wind turbine drivetrains and gearboxes.

The DOE Wind Energy Program is one of 10 clean energy technology programs within the Department of Energy. It is managed by program staff at DOE Headquarters in Washington, D.C., and its Project Management Center (PMC) in Golden, Colorado, manages the financial assistance, provides program support, and conducts outreach activities. The program provides funding to a wide range of public and private sector partners, with primary focus on the National Renewable Energy Laboratory's (NREL) National Wind Technology Center (NWTC) near Boulder, Colorado, and Sandia National Laboratories (SNL) in Albuquerque, New Mexico. NREL and SNL conduct wind energy research with industry partners and researchers from universities nationwide to advance wind energy technologies. Each laboratory is extensively equipped with a unique set of skills and capabilities to meet industry needs.

As the lead research facility for the program, NREL's NWTC conducts research across the complete spectrum of engineering disciplines that are applicable to wind energy, including: atmospheric fluid mechanics and aerodynamics; dynamics, structures, and fatigue; power systems and electronics; and wind turbine engineering applications. The center also provides design reviews and analysis; dynamometer, field, and blade testing services; and field verification for wind turbines that range in size from 400 watts to 2.5 MW. The NWTC is the Nation's only wind energy technology test facility accredited to International Electrotechnical Commission (IEC) standards. Industry partners may use the center's facilities to conduct atmospheric, static-strength, and fatigue tests on turbines and components, including its 2.5-MW dynamometer, to conduct lifetime endurance tests on a wide range of wind turbine drivetrains and gearboxes. In addition, the NWTC completed construction of a 225-kW dynamometer in 2005 that will aid development of advanced generators and power electronics for small wind systems. The NWTC also has two permanently installed advanced wind turbines to test new control schemes and equipment, and sites for testing industry prototype wind turbines.

SNL specializes in all aspects of wind-turbine blade design and system reliability. Activities at SNL focus on reducing the cost of wind generated electricity and improving the reliability of systems operating nationwide. Research disciplines include: materials, airfoils, stress analysis, fatigue analysis, structural analysis, and manufacturing processes. By partnering with both universities and industry, SNL has advanced the state of knowledge in the areas of materials, structurally efficient airfoil designs, active-flow aerodynamic control, and sensors. Researchers at the laboratory are currently investigating integrated blade designs where airfoil choice, blade planform, materials, manufacturing process, and embedded controls are all considered in a system perspective. By collaborating with operators, developers, and manufacturers, SNL evaluates known reliability problems and develops tools and methods to anticipate and investigate future reliability issues.

TECHNOLOGY ACCEPTANCE

In support of Advanced Energy Initiative objective to expand the use of wind energy, the Wind Energy Program is increasing its efforts to overcome near-term deployment barriers to wind by enhancing public acceptance, promoting supportive public policies, engaging key stakeholders, and addressing siting and environmental issues.

In 1999, only four states boasted more than 100 MW of installed wind capacity. By the end of 2006, 16 states had more than 100 MW and six more states are expected to reach that capacity by the end of 2007. The goal of the DOE Wind Powering America (WPA) project is for 30 states to have 100 MW of wind installed by 2010.

To achieve its goal, WPA supports the formation of state wind working groups, providing stakeholders with timely information on the current state of wind technology, economics, state wind resources, economic development impacts, and policy options/issues. Group members include landowners and agricultural sector representatives, utilities and regulators, colleges and universities, advocacy groups, and state and local officials. In 2006, WPA launched four new state wind working groups in Illinois, Indiana, Missouri, and New Jersey, bringing the total number of state wind working groups to 29. WPA also supported events in 11 states and convened its 5th annual All-States Summit in Pittsburgh, Pennsylvania. The summit provided participants with an opportunity to share strategies and lessons learned and to visit with experts on topics such as avian and wildlife issues, siting, transmission, community wind, small wind, Native American projects, operating impacts, utility myths, regulators, radar, interconnection, and wind resources and mapping.

Rural Economic Development

Rising fuel costs, low commodity prices, and a lack of jobs are just a few of the economic issues faced by rural communities nationwide. To address these issues, WPA works with rural community leaders, U.S. Department of Agriculture local and national representatives, state and local officials, the Farm Bureau, the Farmers' Union, representatives of growers associations, agricultural schools, and the local financial community to explore wind development options, benefits, and barriers. Achieving the goals of WPA during the next 20 years will create $60 billion in capital investment in rural America, provide $1.2 billion in new income for farmers and rural landowners, and create 80,000 new jobs.

Wind Power for Native Americans

The United States is home to more than 700 Native American tribes located on 96 million acres (39 million hectares), much of which have excellent wind resources that could be commercially

The new wind generating capacity installed in 2006 (2,454 MW) represents $5 to $9 million in annual payments to rural landowners.

developed to provide electricity and revenue to the reservations. Before these resources can be fully realized, many issues need to be resolved. These include the lack of wind resource data, tribal utility policies, sovereignty, perceived developer risk, limited loads, investment capital, technical expertise, and transmission to markets.

To support the development of Native American wind resources, WPA provides a wide range of technical assistance and outreach activities to more than 20 tribes from 13 states. To help tribes understand their wind resource and potential development options, WPA administers a Native American Anemometer Loan Program. In 2006, WPA helped install four 40- to50-m (130 to 165 ft) towers and one 20-m (65 ft) tower. Installation of two to four more of the tall towers is anticipated in 2007.

WPA also provides wind energy training for Native Americans through the DOE-supported Wind Energy Applications and Training Symposium (WEATS) at the NWTC. Training sessions in the 2006 symposium included Wind Applications, Wind Fundamentals, Small Wind (on- and off-grid applications), Site Selection and Wind Resource Assessment, Land Agreements/Environmental Review, Permitting, Interconnection and Transmission, and Wind Integration. Participants also toured the NWTC and the Ponnequin Wind Farm.

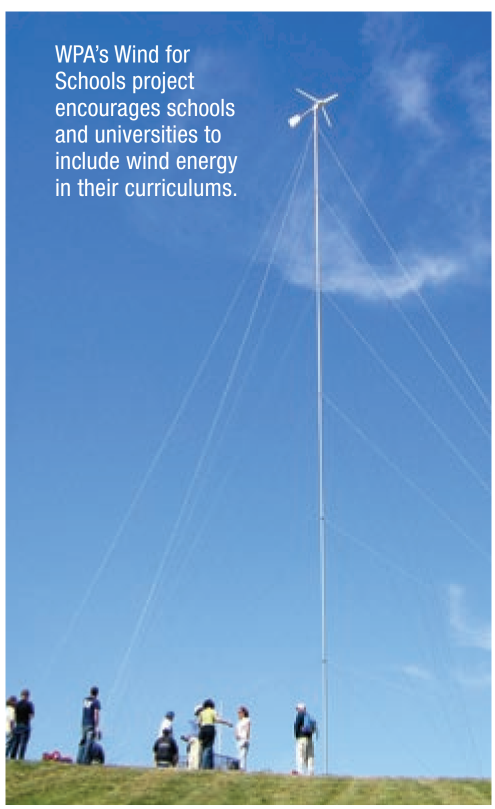
Wind for Schools

At a grass-roots level, WPA is engaging rural America in a discussion of wind energy while developing a knowledge base through its Wind for Schools (WfS) project. The objectives of the project are to:

1. Engage rural school teachers and students in wind energy education
2. Equip college students in wind energy applications and education to provide the growing U.S. wind industry with interested and equipped professionals
3. Introduce wind energy on a small scale in rural communities, starting a discussion of the benefits and issues in using wind energy

To accomplish its objectives, the WPA team at NREL assists schools with the installation of a small wind turbine through a coordinated community effort. Team members include a WfS facilitator within each state; a wind application center at a state-based university or college to provide technical assistance; a school, science teacher, school administration, and community to host or own the wind turbine; a green tag marketer to assist with the sale of the green attributes of the turbine to defray system costs; a wind turbine manufacturer to provide the wind turbine system; the local utility or energy cooperative; and the state energy office.

WPA launched it first WfS project in Colorado in 2006 and plans to replicate the process in Nebraska, Kansas, South Dakota, Montana, and Idaho in 2007-2008.



WPA's Wind for Schools project encourages schools and universities to include wind energy in their curriculums.

The Grassland Shrub Steppe Species Collaborative – a 4-year effort to study the impact of wind turbines on prairie chicken habitats in Kansas, is one study being conducted with program support to help understand wind-wildlife interactions.

Environmental Assessment

WPA also works with universities and non-government organizations to address wind turbine siting issues such as aesthetics, radar interference, and wind-wildlife interactions. In 2006, the program worked with AWEA, the National Wind Coordinating Committee (NWCC), and other federal agencies on wind power-radar interaction issues that affected more than 1000 MW of planned installations.

Wind power-radar interaction issues gained national attention in 2006 due to the potential for radar operations to be affected by wind turbines. Interference occurs when radar signals are reflected back by wind turbines causing clutter on the radar screens. In July, more than 100 experts, including representatives from AWEA, DOE, the Department of Defense, and the Federal Aviation Administration attended a Wind Power and Radar Issue Forum brief convened by the NWCC to discuss the influence of wind energy on aviation radar and possible mitigation strategies. This collaboration and follow-on interaction helped facilitate the approval of 950 MW of wind projects.

To help resolve wind-wildlife interactions, the program supported two collaborative efforts, the Grassland Shrub Steppe Species Collaborative—a 4-year effort to study the impact of wind turbines on prairie chicken habitats in Kansas—and the Bat and Wind Energy Collaborative that investigates bat and wind turbine interaction. In addition, the NWCC hosted its sixth Wildlife Research Meeting in Texas. The purpose of the meeting was to bring participants up-to-date on research being conducted to understand the interaction of birds, bats, and other wildlife with wind energy development, examine what has been learned about ways to minimize or mitigate wind energy's impacts on wildlife, and identify gaps in knowledge and research needs.

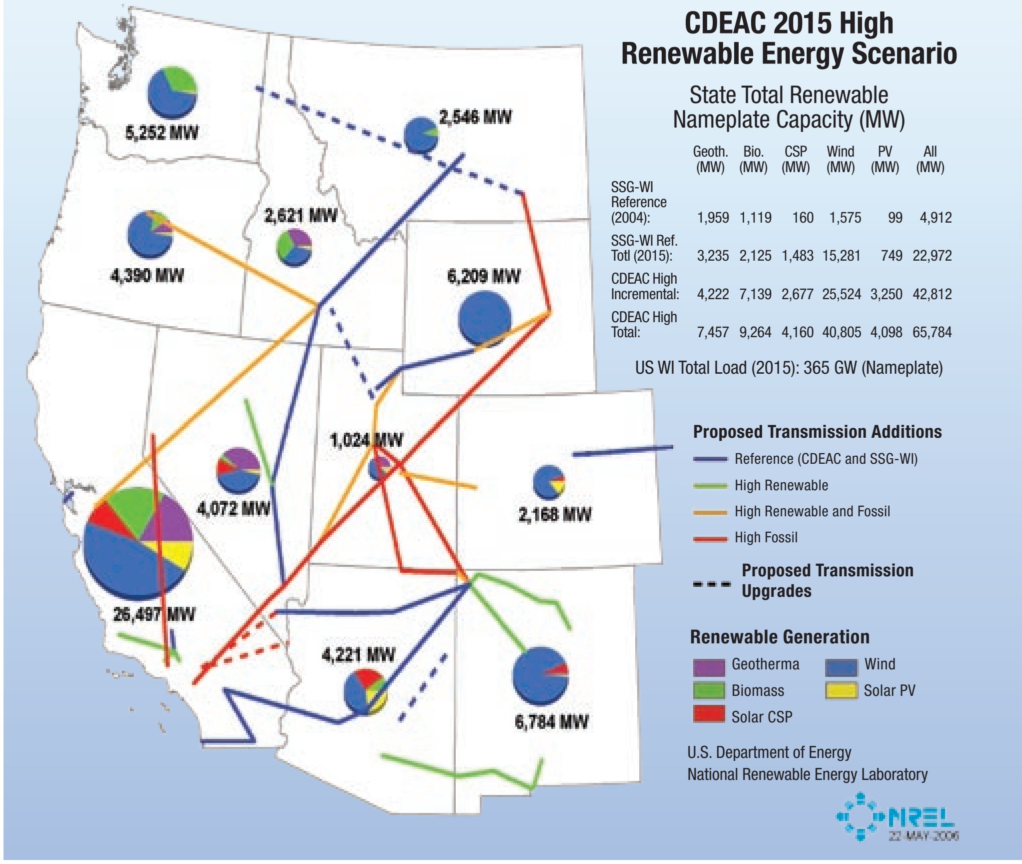
FACILITATING INTEGRATION OF WIND ON THE GRID

Systems Integration

The natural variability of the wind resource can present challenges to grid system operators and planners with regard to managing regulation, load following, scheduling, line voltage, and reserves. While the current level of wind penetration in the United States and around the world has provided substantial experience for successful grid operations with wind power, many grid operators need to gain a better understanding of the impacts of wind on the utility grid before they can feel comfortable increasing the percentage of wind in their energy portfolios. The goal of the program's systems integration research is to address interconnection impacts, electric power market rules, operating strategies, and system planning needed for wind energy to compete without disadvantage to serve the Nation's energy needs.

In 2006, the Wind Energy Program conducted a number of studies to provide states and utilities with the information and tools they need for wind energy development. For example, the program provided extensive GIS-based wind resource and transmission data to help the Western Area Governors Association (WGA) and the Clean and Diversified Energy Advisory Committee (CDEAC) to identify 30 GW of clean power that could be developed by 2015. In 2006, the CDEAC Wind Task Force developed a set of supply curves based on this data. The findings of the study indicate that the wind resource in the WGA region is more than enough to economically achieve the WGA 30-GW target for clean energy development.

Additional 2006 system integration activities included a study that provided the Western Farmers Electric Cooperative with a systems integration and wind power data analysis, a wind integration study for the state of Minnesota, and a study for Xcel Energy in Colorado that provided the company with the data it needs to assess the technical and economic impact of adding a significant amount of wind generation to its energy portfolio.



The Wind Energy Program provided the Western Area Governors Association and the Clean Diversified Energy Advisory Committee with extensive wind map GIS and transmission data to help them determine if there is enough wind resource to help them achieve 30 GW of clean power by 2015.

NREL Supplies WAPA with Wind Farm Training Simulator

The Western Area Power Administration (WAPA) provides electric power system operations training to power system operators and dispatchers throughout the United States and Canada at its Electric Power Training Center (EPTC) in Golden, Colorado. A significant portion of this training is performed with the Miniature Power System (MPS), an actual power system consisting of three synchronous generators (scaled up to 500 MW total), five loads, two ties to the western electrical grid, and a simulation of more than 500 miles of transmission lines. To enable WAPA to integrate wind energy into its training program, NREL's NWTC supplied WAPA with a wind farm simulator in 2006 that successfully simulated power delivery to the MPS grid from a time-series file of real wind-farm data for a 50-MW wind farm.

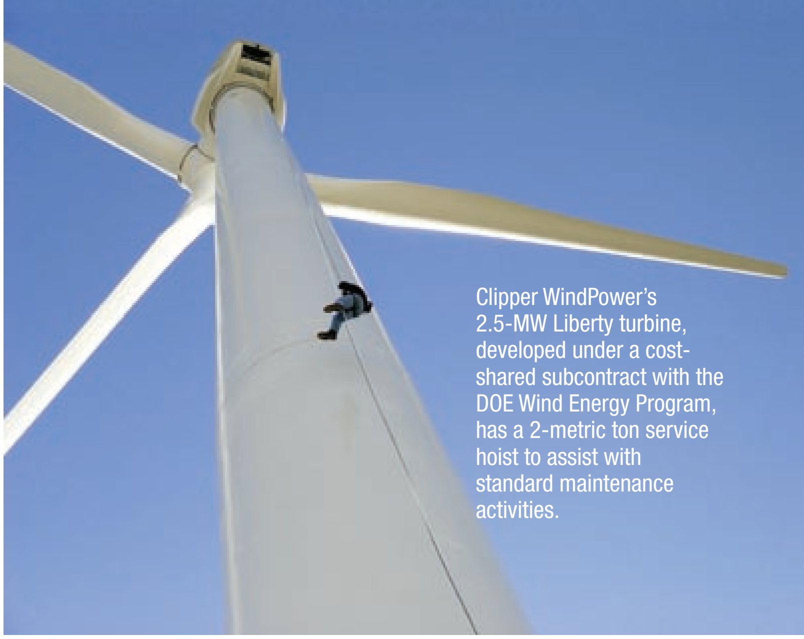
Enhancing Critical Energy Infrastructure

Transmission is a key energy infrastructure element critical to tapping our national wind resource and moving electricity to market, much as the interstate highway system does for the Nation's transportation needs. Much of the Nation's best wind resources cannot be tapped to meet our increasing energy demands without new transmission system capacity. The development of new transmission is challenged by many regulatory, jurisdictional siting, and cost allocation barriers. The program is working with state and Federal energy offices as well as regional organizations and utilities to support appropriate representation of wind energy characteristics and opportunities in energy infrastructure planning processes underway across the nation.

The development of new transmission corridors requires the coordination of many different organizations and groups from the Federal, regional, state, and local levels. Upgrading the Nation's transmission system, like upgrading the interstate highway system, will have substantial costs and will cross many organizational boundaries.

The Wind Energy Program is working closely with the DOE Office of Electricity Delivery and Energy Reliability to effectively coordinate the Department of Energy's contributions to the transmission planning efforts. This joint program effort will focus on linking remote regions with low-cost wind power to urban load centers, allowing thousands of homes and businesses access to abundant renewable energy

REDUCING COSTS THROUGH IMPROVED PERFORMANCE



Clipper WindPower's 2.5-MW Liberty turbine, developed under a cost-shared subcontract with the DOE Wind Energy Program, has a 2-metric ton service hoist to assist with standard maintenance activities.

Large Wind Technologies

Although research efforts for the past two decades have led to dramatic reductions in the cost of wind energy, continued incremental improvements to wind turbine performance will lower system costs even further while improving system integration and enhancing technology acceptance.

The Wind Energy Program focuses its cost energy reduction efforts on improving wind turbine components. For example, gearboxes comprise 35% to 40% of the total wind turbine system cost. To help industry identify opportunities for improved gearbox design, the program initiated a long-term industry collaboration. NREL sponsored a drivetrain workshop in 2006 to jointly identify research needs under a multilateral industry-driven test program at the NWTC. For more information, contact Sandy Butterfield at 303-384-6902 or sandy_butterfield@nrel.gov.

Extending the fatigue life of system components like the drive-train, blades, and tower will play an important role in reducing system costs. As wind turbines become larger and taller, they become more flexible and susceptible to fatigue. To design fatigue-resistant wind turbines, the program is investigating ways to gain better control of the way the components interact and move. Control systems that regulate turbine power and maintain stable closed-loop behavior in the presence of turbulent wind inflow are critical to today's large wind turbine designs. NREL is developing and testing control systems that maximize energy capture while reducing structural dynamic loads that cause turbine parts to wear out thus increasing the cost of operation and maintenance.

To better understand improvement opportunities for wind turbine availability, SNL hosted a Wind Turbine Reliability Workshop in Albuquerque, New Mexico in October, 2006. More than 90 partici-pants, representing wind farms, service companies, consultants, manufacturers, universities, and laboratories listened to presentations on topics ranging from hardware reliability (gearboxes, generators, pitch systems, blades, and condition monitoring) to stakeholder perspectives (owners, operations, maintenance, and user groups). The workshop also addressed planning for the characterization and reduction of operating and maintenance costs, data information sharing, and the establishment of user groups to address pressing common issues. SNL is planning another technical session in September 2007, and is currently working with the American Wind Energy Association (AWEA) Operations and Maintenance Working Group and others to begin a systematic data collection effort to collect, analyze, and report on issues affecting turbine reliability and availability. For more informa-tion contact Roger Hill, (505) 844-6111, rrhill@sandia.gov.

To help increase the performance of wind turbine blades, program researchers have tested new blade designs and materials at NREL's NWTC for the past decade using fatigue and static strength tests. However, the rapid growth in wind turbine size has recently out-stripped the capacity of the blade test facilities. In 2006, the program announced a CRADA seeking partners to design, construct, and assist in operating wind turbine blade test facilities capable of testing blades up to at least 70 m (230 ft) in length. The Wind Energy Program will contribute capital equipment and provide NREL staff and expertise to help develop and operate the facility. Massachusetts and Texas were chosen as the two finalists from six applications. The partners in Massachusetts include the Massachusetts Technology Collaborative, the University of Massachusetts, and the Massachusetts Executive Office of Economic Development. In Texas, the Lone Star Wind Alliance, led by the University of Houston and the Texas General Land Office, is partnering with Texas A&M University, Texas Tech University, University of Texas-Austin, West Texas A&M University, Montana State University, Stanford University, New Mexico State University, Old Dominion University, and the Houston Advanced Research Center.

Distributed Wind Technologies

Distributed wind systems have been traditionally defined as wind turbines rated at 100 kW or less installed at remote locations. The Wind Energy Program has supported efforts to increase the reliability and performance of distributed wind turbines with a goal of produc-ing electricity at between 10 and 15 cents/kWh in a Class 3 wind resource (5.3 m/s at 10 m) by 2007. As achievement of the program's distributed wind technology (DWT) goal draws near, the program is expanding its activities and its definition for distributed applications to include wind turbines that are installed remotely or connected to the grid at the distribution system, including behind the customer meters. An independent assessment of the various segments of the distributed wind market is in progress.

NWTC team member, Garth Johnson, works in the rotor's hub after it is installed on the turbine.

The Controls Advanced Research Turbine (CART) at the National Wind Technology Center (NWTC) received a facelift in 2006 when an NWTC team replaced its 2-bladed rotor with a new 3-bladed rotor obtained from GE. The new 40-m rotor (trimmed down from 47 meters to fit the machine) will allow NREL researchers to test new control schemes applicable only to 3-bladed machines. Control schemes are used to reduce wind turbine loads and increase energy capture. Although many of the schemes tested in the past at the NWTC are applicable to both 2 and 3-bladed machines, because most of the turbines in commercial use today are 3-bladed, the upgrade to the CART will enable NREL to better meet industry research needs.

Successful 2006 LWT Projects

One program R&D project that shows potential for demonstrating a significant increase in overall system performance is the 2.5-MW Liberty wind turbine developed by Clipper Windpower. Clipper completed its prototype in 2005 after only 3 years of R&D. The new machine's innovative distributed-path powertrain design incorporates four permanent-magnet generators, and advanced variable-speed controls. According to U.S. Department of Energy Secretary Samuel W. Bodman, "Clipper's Liberty Turbine is not only one of the most advanced wind turbines ever produced, it may well be the most efficient wind turbine in the world." Successful field-tests conducted by Clipper with assistance from NREL and intensive component testing at the NWTC helped Clipper put the Liberty series turbine into production in the summer of 2006. Clipper's 2006 transaction announcements represent firm commitments of 875 MW of turbines and more than 5,000 MW of contingent orders for delivery through 2011.

Northern Power Systems (NPS) produced an award-winning power electronics package that can be scaled for use in a wide range of wind turbines, from small to multimegawatt systems. According to NPS, the new converter improves wind turbine reliability, energy capture, and grid performance. The project team was chosen by the American Wind Energy Association for its 2006 Technical Achievement Award. Tests completed in 2006 on both the converter and a 1.5-MW direct-drive generator, also developed with program support, demonstrated high-quality power output.

Knight & Carver is developing a 27.5-m (90-ft) replacement blade for a 750-kW turbine. The "STAR" (which stands for sweep twist adaptive rotor) blade is the first of its kind ever built. Its most distinctive characteristic is a gently curved tip, which prompts the blade to respond to high winds such that adverse loads are attenuated. This allows the blade length to be extended with no weight penalty and augments energy capture in low-wind-speed resource areas.

Global Energy Concepts (GEC) worked with program researchers to fabricate a 1.5-MW, single-stage drivetrain with a planetary gearbox and a medium-speed, permanent-magnet generator. The simple gearbox design and moderate-sized generator show potential for reducing tower-head weight and drivetrain costs. The company completed initial testing of this drivetrain at NREL's 2.5-MW dynamometer test facility. The generator is currently being upgraded, and a second phase of testing is planned for 2007.

Genesis Corporation is testing a new tooth form for gearboxes that promises major improvements in power density while reducing the costs of these devices. The company completed the first round of testing with positive results and is now working to refine its design through further targeted testing.

Knight & Carver's new blade design is curved to take maximum advantage of all wind speeds while passively reducing loads.

International Collaborations

International Research

The Wind Energy Program supports international wind energy research efforts as a member of the International Energy Agency (IEA) Wind Energy Executive Committee and by providing operating agents for several IEA Tasks. The United States participates in the five tasks listed below, is the operating agent for three of the tasks, and provides technical experts for the Topical Expert meetings held under Task 11: Base Technology Information Exchange.

- Task 19: Wind Energy in Cold Climates
- Task 20: HAWT Aerodynamics and Models from Wind Tunnel Measurements – Operating Agent
- Task 21: Dynamic Models of Wind Farms for Power Systems Studies
- Task 23: Offshore Wind Energy Technology and Deployment – Operating Agent
- Task 24: Integration of Wind and Hydropower Systems – Operating Agent
- Task 25: Power System Operation with Large Amounts of Wind Power

For more information on IEA activities, visit the IEA web site at www.ieawind.org

International Standards

NREL also plays an active role in the development of international standards by working with AWEA and the International Electrotechnical Commission Working Groups. International standards provide a critical link to cutting edge research which forms the basis for and harmonization of international design requirements. NREL's participation in the working groups provides consistent representation for U.S. industry, thus ensuring that standards to do not impede international industry development and trade opportunities while ensuring that environmental, safety, and health interests of industry employees, utility personnel, and the general public are maintained. NREL participates in the following active IEC Working Groups:

IEC 61400-1, Wind Turbine Safety and Design Requirements

IEC 61400-2, Small Turbine Safety and Design Requirements

IEC 61400-3, Offshore Design requirements

IEC 61400-4, Wind Turbine Gearbox Requirements

IEC 61400-11, Wind Turbine Noise Measurement

IEC 61400-12, Wind Turbine Power Performance Measurement

IEC 61400-21, Power Quality

IEC 61400-22, Certification Requirements

IEC 61400-23, Blade Structural Testing

IEC 61400-24, Lightning Protection Guidelines

IEC 61400-25, Communications and SCADA

The program is also continuing its efforts to increase the performance and reliability of small wind turbines. In 2007, the program will launch an effort to establish a small turbine testing and certification program. The program will partner with industry to test a number of small turbines to International Electrotechnical Commission (IEC) and draft AWEA standards. The project will provide high-quality, detailed, and independent test results and allow small businesses the opportunity to earn a certification granted by an independent certification body. The certification body is in the process of being formed by the Interstate Renewable Energy Council (IREC)—the Small Wind Certification Corporation.

Successful 2006 Small Wind Projects

Southwest Windpower conducted performance optimization and blade-fatigue tests at the NWTC on its new Skystream wind turbine. The 1.8-kW turbine, developed in partnership with DOE, won the Best of What's New Award from *Popular Science Magazine* and was listed as a best invention for 2006 by *Time* magazine. The new turbine has fully integrated electrical components, costs less, is easier to install, and more quiet to operate.

Northern Power Systems (NPS) is reconfiguring its 100-kW cold weather turbine for agricultural and community applications in temperate climates. The company began building its new machine in 2007 and plans to start testing the prototype at the NWTC before the end of the year. The machine will cost less to produce, and it shows good potential for filling a market gap in mid-sized wind turbines.

Windward Engineering produced a new 4.25-kW machine called the Endurance. The turbine is sized to offset the energy consumption of an average U.S. home (~11,000 kWh/yr) when installed in a Class 3 wind regime (5 m/s at a height of 10m). It employs an induction generator to simplify grid compatibility and a brake that is capable of stopping the rotor on command in any wind condition—a unique feature for a small wind system. Windward used off-the-shelf components from other industries to reduce system cost. The Endurance is currently being tested at the NWTC to IEC standards for duration, power performance, and acoustics.

Southwest Windpower's 1.8-kW Skystream turbine.

Windward Engineering's 4.25-kW Endurance wind turbine

WIND ENERGY FOR THE NEXT DECADE

For the past two years, the wind industry has enjoyed record-breaking growth, and industry experts predict that with the extension of the PTC through 2008, the next two years will be record-breakers as well. The challenge for industry is to maintain the long-term wind energy growth required to fulfill the expectations of the President's Advanced Energy Initiative. AWEA and the Wind Energy Program have formed a collaborative with 75 participating companies and organizations to evaluate credible scenarios for providing 20% of U.S. electric demand with wind and identify strategic actions that include:

- Participating in collaborative partnerships with industry that will result in turbine technology with higher reliability, expanded performance and a more competitive cost of energy
- Increasing its outreach and education efforts
- Investigating ways to increase and make transmission more accessible
- Addressing environmental issues
- Providing support for national and state policies that enable robust growth of wind energy.

The program also supports the development of expanded testing capabilities to support larger wind turbine R&D. The CRADA issued in 2006 that seeks partners to build a blade test facility capable of testing blades up to at least 70 m (230 ft) in length is one area targeted for expansion. The program is also exploring options for construction of a new drivetrain test facility of at least 11 MW in capacity.

For distributed wind technologies, the program will support potential markets by investigating applications such as off-grid water pumping for crop irrigation, residential-scale wind turbines, community wind, and hybrid wind/diesel applications.

To ensure long-term wind growth, the program is also investigating emerging applications for wind energy such as offshore installations, hydrogen production, and the production and delivery of clean water.

Hydrogen production offers an opportunity for wind to provide low-cost, clean energy for the transportation sector. NREL, in partnership with Xcel Energy, launched a wind-to-hydrogen demonstration project at the NWTC that will investigate the potential of using wind energy to produce hydrogen. The project will use two wind turbines (a 10-kW and a 100-kW), two proton-exchange membrane electrolyzers, and one alkaline electrolyzer to produce hydrogen from water. The hydrogen will be compressed and stored for later use in a hydrogen internal combustion engine where it will be converted into electricity and fed into the utility grid during peak demand hours. For more information visit http://www.nrel.gov/hydrogen/proj_wind_hydrogen.html

The program is also investigating wind energy applications that can ease the demands on the Nation's water resources. As the U.S. population grows, it places greater and greater demands on water supplies, wastewater services, and the electricity needed to power the growing water services infrastructure. Water is also a critical resource for thermoelectric power plants. Wind offers an energy source that uses limited water when compared to thermoelectric generation, and it can play a role in supplying energy for municipal water supplies and processes.

All of these applications present new challenges to the wind community, and cost and infrastructure barriers are expected to be significant. The program's vision is that this evolution pathway will begin to have an impact on the marketplace in the post-2020 timeframe.

This wind-to-hydrogen animation at http://www.nrel.gov/hydrogen/proj_wind_hydrogen.html demonstrates how electricity from wind turbines is used to produce hydrogen at NREL's National Wind Technology Center.

Key Contacts

Steve Lindenberg
Acting Program Manager
Office of Wind and Hydropower Technologies
Energy Efficiency and Renewable Energy
1000 Independence Ave., SW, Washington, D.C. 20585

Robert Thresher, Director
National Renewable Energy Laboratory
National Wind Technology Center
1617 Cole Blvd, MS. 3811
Golden, Colorado 80401

Brian Smith, Technology Manager
Wind and Hydropower Technologies
National Wind Technology Center
1617 Cole Boulevard, Golden, CO 80401

Jose R. Zayas, Manager
Sandia National Laboratories
Wind Energy Technology Department
P.O. Box 5800, Albuquerque, NM 87185-1124

Wind Energy Web Sites

U.S. DEPARTMENT OF ENERGY WIND AND HYDROPOWER TECHNOLOGIES PROGRAM
http://www1.eere.energy.gov/windandhydro/

AMERICAN WIND ENERGY ASSOCIATION
http://www.awea.org/
windmail@awea.org

NATIONAL RENEWABLE ENERGY LABORATORY NATIONAL WIND TECHNOLOGY CENTER
http://www.nrel.gov/wind/

SANDIA NATIONAL LABORATORIES
http://www.sandia.gov/wind/

NATIONAL WIND COORDINATING COMMITTEE
http://www.nationalwind.org/

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