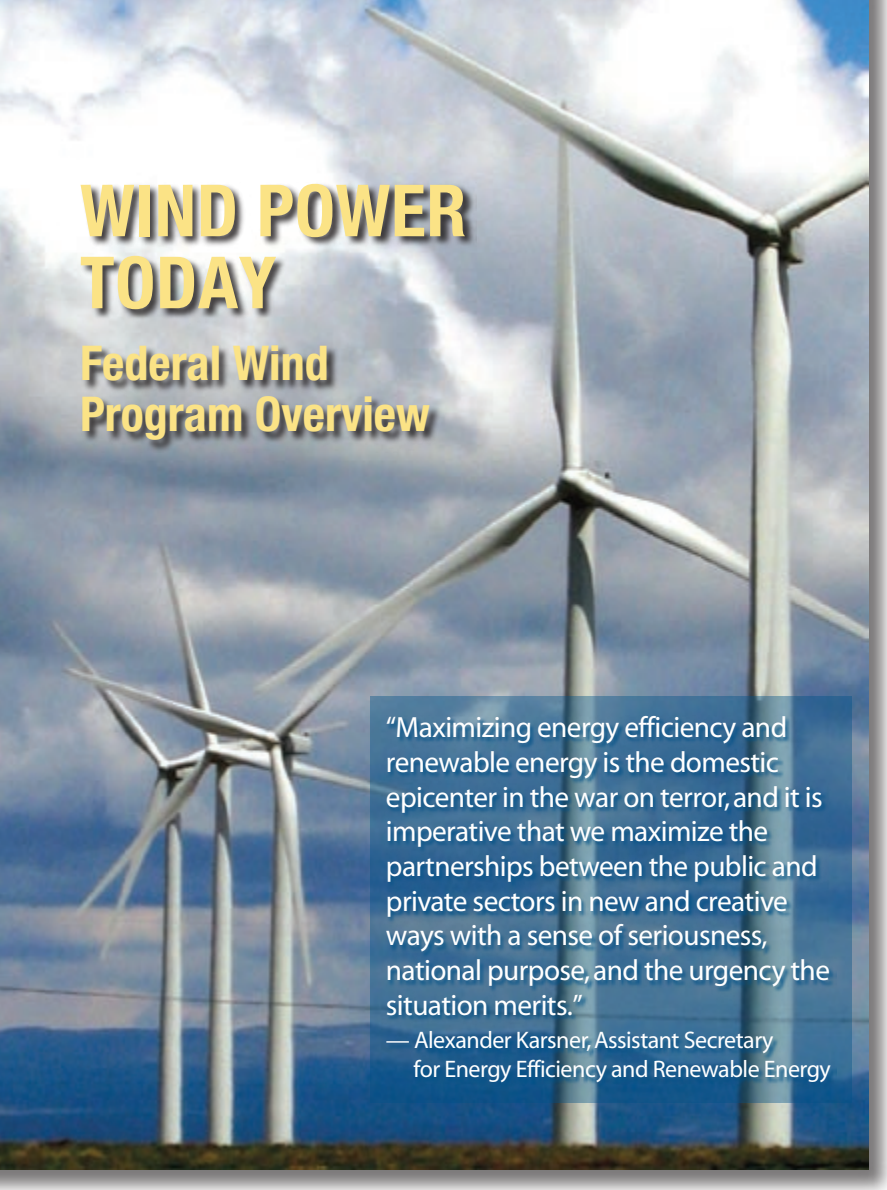
U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Wind Power Today



Fossil Gulch Wind Park, Hagerman, Idaho

To help meet America's increasing energy needs while protecting our nation's energy security and environment, President George W. Bush launched the Advanced Energy Initiative in January 2006, that calls for the accelerated development and use of advanced clean energy technologies. In his State of the Union Address, the President said that one way we can address energy challenges is by changing the way we power our homes and businesses. On a recent tour to promote the new initiative, the President stated, "If the technology is developed further…it's possible we could generate up to 20% of our electricity needs through wind…"

For more than 25 years, the U.S. Department of Energy (DOE) Wind Energy Program has worked with partners in the wind energy industry to develop clean, innovative, cost-effective wind energy technologies. This effort has culminated in some of industry's leading products today and a record-breaking year for wind energy installations; in 2005, the United States installed more new wind energy capacity than any other country in the world. The new capacity, totaling 2,431 megawatts (MW), was worth more than $3 billion in generating equipment, and it brought the total national wind energy capacity to 9,149 MW, enough electricity to power 2.3 million average American households. Although that seems like a lot of electricity, it still represents less than 1% of the total national generation sources.

Before wind energy can claim a larger percentage of our national electricity generation, the wind industry must overcome significant technology and application barriers, one of which is cost. While research conducted under the Wind Program has helped industry to greatly reduce the cost of wind energy over the past two decades, to ensure continued growth, wind technologies need to become as cost effective in lower wind speed areas of the country as it currently is in the higher wind speed areas where most development occurs today. Low wind speed areas are 20 times more common than higher wind areas and they are five times closer to load centers. In the years to come, developing our rich coastal wind resources that are often close to major population centers is another significant national energy opportunity, but developing technologies suitable for harsh marine environments presents even greater technology challenges.

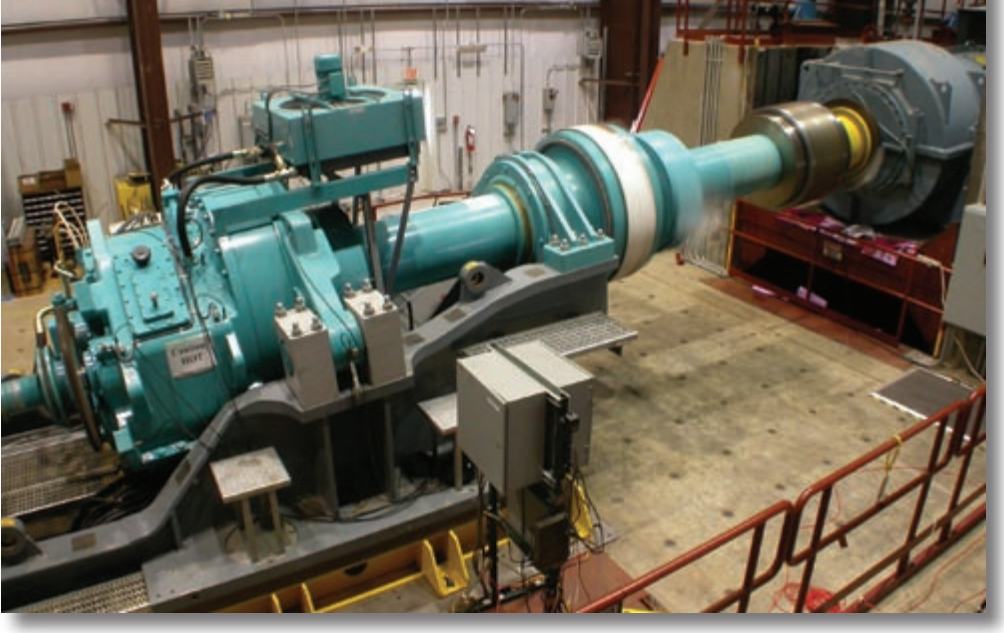
Technology application barriers include grid integration and technology acceptance. To ensure equitable treatment of wind energy in the national grid, the Wind Program is conducting research to demonstrate that wind can be smoothly integrated into the electrical grid with minimal, if any, impact on cost and reliability. To enhance technology acceptance and facilitate greater development on state and regional levels, the program provides technical and outreach support to utilities, electric cooperatives, rural agencies, Native American groups, state and local energy offices, and other Federal agencies through its Wind Powering America project.

To ensure long-term industry growth, the Wind Program is also researching new applications such as the use of wind energy to clean and move water and to produce hydrogen, as well as use of wind with other renewable energy technologies such as hydropower.

Successfully implemented, the Wind Program will help produce outcomes that contribute to our national security and economy while minimizing environmental impacts. Our abundant homeland wind resources offer homegrown energy that can increase our national energy security, strengthen our energy infrastructure and stabilize electricity prices by diversifying our energy supplies. Reliance on

Wind Program Goals

- By 2007, reduce the cost of electricity from distributed wind systems to 10-15 cents/kWh in Class 3 wind resources.
- By 2010, facilitate the installation of at least 100 MW of wind energy in 30 states.
- By 2012, reduce the cost of electricity from large wind systems in Class 4 winds to 3.6 cents/kWh for onshore systems.
- By 2012, complete program activities addressing electric power market rules, interconnection impacts, operating strategies, and system planning needed for wind energy to compete without disadvantage to serve the Nation's energy needs.
- By 2014, reduce the cost of electricity from large wind systems in Class 6 winds to 5 cents/kWh for shallow water (depths up to 30 meters) offshore systems (from a baseline of 9.5 cents/kWh in 2005).
- By 2016, reduce the cost of electricity from large wind systems in Class 6 winds to 5 cents/kWh for transitional (depths up to 60 meters) offshore systems.



NREL's 2.5-MW dynamometer conducts lifetime endurance tests on a GE 1.5-MW drivetrain.

indigenous resources also reduces the balance of payments that threatens our national economic security. Because wind energy's fuel is free, it reduces the risk associated with volatile fossil fuel prices. Wind often displaces electricity that would otherwise be produced by burning natural gas, thus helping to reduce gas demand and limit gas price hikes. According to the American Wind Energy Association, the 9,149 MW of installed wind energy capacity at the end of 2005 will save more than half a billion cubic feet (Bcf) of natural gas per day in 2006. The United States currently burns about 13 Bcf/day for electricity generation, which means during 2006, wind power will reduce natural gas use for power generation by approximately 5%. For more information on DOE's Wind Program, visit www.eere.energy.gov/windandhydro/.

Research Facilities and Industry Services

To accomplish the Wind Program's research and development (R&D) goals, researchers at the National Renewable Energy Laboratory's (NREL) National Wind Technology (NWTC) near Boulder, Colorado, and at Sandia National Laboratories (SNL) in Albuquerque, New Mexico, work with industry partners and researchers from universities nationwide to develop advanced wind energy technologies. Each laboratory is extensively equipped with a unique set of skills and capabilities to meet industry needs. SNL conducts research in advanced manufacturing, component reliability, aerodynamics, structural analysis, material fatigue, and control systems. 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. NWTC researchers provide technical support in the form of design review 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.

NWTC's industry partners may use the Center's facilities to conduct atmospheric, static-strength, and fatigue tests on turbine components, and 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 on a 225-kW dynamometer in 2005 that will aide in the development of advanced generators and power electronics for small wind systems. The NWTC also has two permanently installed advanced wind turbines that can be used to test new control schemes and equipment and test pads that manufacturers can use to test their prototype machines.

In 2005, NWTC researchers worked with Germanischer Lloyd of Hamburg, Germany, to approve NREL's wind turbine design codes for calculating onshore wind turbine loads for design and certification. Although many U.S. wind turbine manufacturers have relied on these design codes to estimate the design loads of their turbines in the past, until recently the codes were not accepted by certifying agencies in Europe. For information on working with the NWTC visit www.nrel.gov/wind/working.html.

The NWTC is extensively equipped to conduct a wide range of wind system tests and wind energy research.

DEVELOPING LOW WIND SPEED TECHNOLOGIES

Most of the wind farms that exist today are built on America's prime wind sites (Class 6 sites with wind speeds of 6.7 meters per second [m/s] at a 10 m height) that are near transmission lines. As the wind industry grows and the prime sites are developed, it becomes imperative for industry to develop technologies that can operate cost effectively in the widespread lower wind speed regions (Class 4 with wind speeds of 5.8 m/s at a 10 m height).

Current wind technology can operate economically on Class 4 sites with the support of the Federal production tax credit (PTC). The PTC provides a 1.9 cent per kWh tax credit for electricity produced by commercial wind generation plants for the first 10 years of production. Originally enacted in 1992, the PTC has expired three times in the past six years, and industry growth slowed drastically between each expiration and re-enactment. Although the Energy Policy Act of 2005 extended the PTC through December 2007, there is no certainty of a long-term extension. To help industry develop more economic technologies, NWTC and SNL researchers work with industry through cost-shared partnerships. The industry partners lead new technology designs and make commercial decisions while the laboratories provide theoretical and technical support through applied research and performance testing.

DOE issued solicitations for low wind speed turbine (LWST) partnerships in 2001 and 2003 and plans to issue another in the future. Solicitations offer bidders an opportunity to participate in one of three technical areas: concept and scaling studies, component development, or LWST prototype development.

For more information about the Wind Program partnerships with industry, visit www.nrel.gov/wind/wind_project.html.

U.S. Department of Energy, Wind Energy Program Technology Portfolio

Concept Design Studies

- Advanced Energy Systems, Inc. – Independent Pitch Control
- AWS Truewind, LLC – Techniques to Evaluate Designs and Operating Environments of Offshore Wind Turbines
- Behnke, Erdman and Whitaker Engineering – Medium-Voltage, Variable-Speed Drive Technology
- Berger/Abam Engineers, Inc. – Hybrid Steel/Concrete Wind Turbine Towers
- Concept Marine Associates, Inc. – Semisubmersible Platform and Anchor Foundation System
- Global Energy Concepts LLC
  - Rotor Aerodynamics Control
  - Operation and Maintenance Cost Model
- General Electric Global Research – Wind Energy/Desalination System
- Massachusetts Institute of Technology – Offshore Floating Wind Turbine Concepts
- Native American Technologies Company – On-site Tower Fabrication
- Peregrine Power – Power Electronics from Silicon Carbide
- QinetiQ – LIDAR Wind Speed Sensing

Component Development

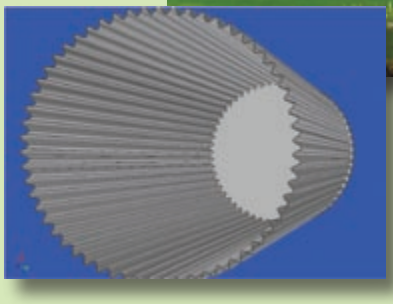
- Northern Power Systems, Inc.
  - Direct-Drive, Permanent-Magnet Generator
  - Advanced Power Converter
- Genesis Partners LP – Convoloid Gearing
- Knight and Carver – Blade

Prototype Development

- General Electric Wind Energy LLC – Multimegawatt Wind Turbine
- Clipper Windpower Technology Inc. – 2.5-MW Liberty Wind Turbine
- Northern Power Systems – 2-MW Wind Turbine

Concept Designs

The prototype turbines and components undergoing tests today started as concept design studies, some of which were developed under earlier Wind Program projects. More than half-a-dozen concept studies were underway or completed in 2005. Three of the concept studies investigated technologies for offshore applications while two of the studies explored alternative approaches to power conversion. One study considered a method to form and fabricate towers on site to reduce fabrication and transportation costs, and another examined concepts for integrating reverse-osmosis desalination with wind energy that included cost of water modeling. Yet another investigated the potential of laser anemometry (LIDAR) systems for sensing turbine inflows and attenuating adverse loads when integrated with appropriate controllers and actuators.



QinetiQ investigates the potential of LIDAR systems for sensing turbine inflows and attenuating adverse loads.

Native American Technologies explores a method to form and fabricate towers on site.

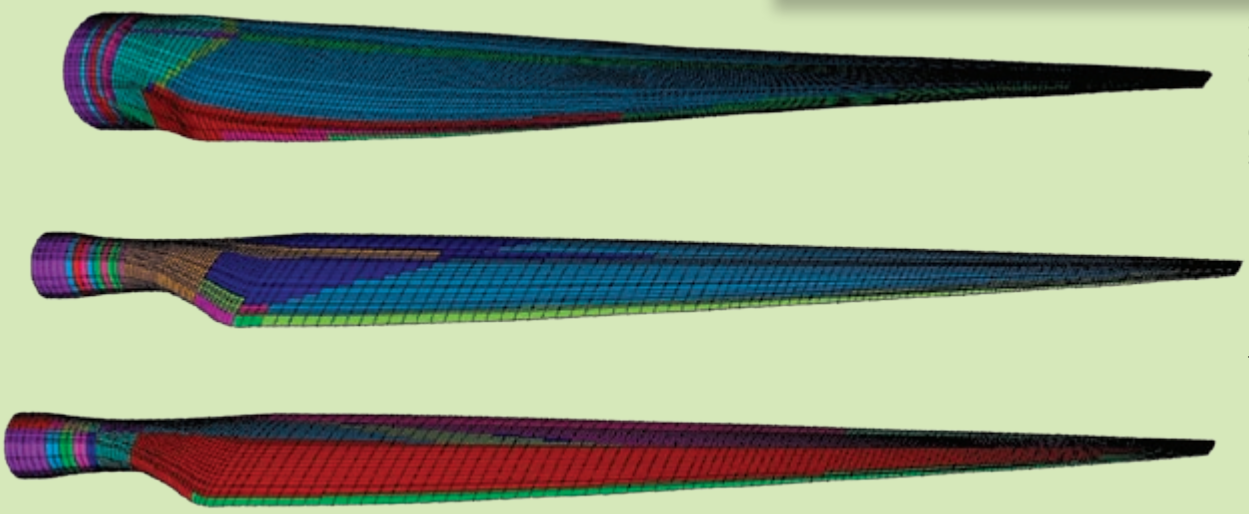
Components

DOE is working with several companies to reduce the cost of wind energy by reducing component costs and increasing efficiency. Under a subcontract with Genesis Partners LLP, the program is working on a new tooth form that promises major improvements in the power density of wind turbine gears while lowering the cost of these devices. Under another subcontract, Northern Power Systems has developed components that also show promise for cost reductions. Tests conducted at the NWTC in 2005 indicated that the combination of the Northern Power Systems 1.5-MW permanent-magnet direct-drive prototype generator with closely integrated power electronics may gain a significant reduction in the cost of energy.

The goal of the rotor development research conducted at Sandia National Laboratories (SNL) is to develop larger rotors (longer blades) to increase energy capture and reduce the cost of energy without increasing system loads. Rotor design studies conducted in 2001 concluded that designs for larger rotors would require improved designs, materials, and manufacturing processes. Extensive studies also revealed the load attenuating potential of aeroelastic tailoring, which could be achieved either by material twist coupling or blade sweep. Based on these early studies, SNL developed an integrated design and manufacture process for blades that incorporates advanced aerodynamic and structural designs, lightweight carbon-fiber, and innovative manufacturing processes. For more than a decade, SNL has worked with Montana State University to conduct thousands of tests on 175 different materials, and working with Global Energy Concepts under a WindPACT study, identified one carbon-glass material that demonstrated excellent compressive as-built strength. Since 2003, SNL has worked with TPI Composites to develop and manufacture several new blades that incorporate different aspects of the integrated approach. All of these efforts culminated in the production of a 9-m subscale blade in 2006 that demonstrates significant reductions in weight and cost while increasing strength.

The NPS 1.5-MW permanent-magnet direct-drive prototype generator tested at NREL.

SNL produced a 9-m subscale blade in 2006 that demonstrates significant reductions in weight and costs while increasing strength.



Finite element models of three experimental blades

In 2005, SNL also worked with Knight and Carver to develop a 28-m, sweep-twist coupled blade that will passively reduce loads, thereby allowing a larger, more productive rotor. The new design uses outer blade sweep to create twist coupling without the use of angled fiber. This concept also shows potential for significant cost and manufacturing advantages.

The initial mold fabrication for Knight and Carver's sweep twist blade.

Prototypes

In 2005, DOE worked with three U.S. manufacturers to develop low wind speed multi-megawatt prototypes; Clipper Windpower, General Electric (GE) Wind Energy, and Northern Power Systems. As a result of Wind Program efforts and the accelerated testing capabilities at the NWTC, Clipper Windpower completed the fabrication of its first multimegawatt prototype in record time. From drawing board to field tests, it took Clipper only three years to produce its 2.5-MW turbine that incorporates a highly innovative multiple-drive path gearbox feeding four advanced permanent magnet generators. The multiple-drive path design radically decreases individual gearbox component loads, which reduces gearbox weight and size. Clipper began commercial production of the new machine at the end of 2005.

GE Wind Energy is developing an advanced multimegawatt prototype turbine to achieve significantly reduced energy costs in low wind speed environments. The company plans to pursue an evolutionary path that benefits from technology demonstrations of hybrid composite blades and advanced controls.

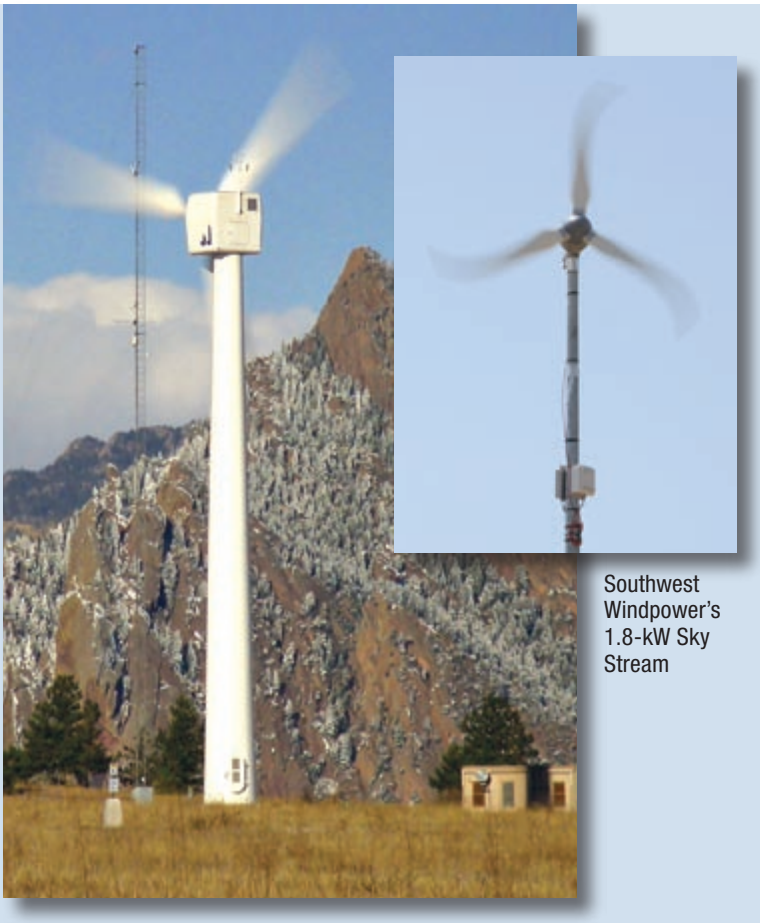
In July 2005, DOE subcontracted with Northern Power Systems to design, build, erect, and test a 2-MW wind turbine that integrates several technologies developed during earlier phases of the LWST project. The new design will include two of the technologies previously developed: a high-energy-density, permanent-magnet, direct-drive generator and an advanced power converter. The project is scheduled for completion in 2008.

Clipper Windpower 's 2.5-MW C-93 Liberty turbine

DISTRIBUTED WIND ENERGY TECHNOLOGIES

DOE is also working with several small wind turbine companies to develop more efficient, cost-effective machines. NPS is developing a design to modify its 100-kW cold weather turbine for farm and community applications. Southwest Windpower is currently conducting acoustic, performance, and load tests on its new 1.8-kW prototype at NREL. Abundant Renewable Energy is working on a concept design for a 10-kW system that will produce electricity for 11 cents/kWh in moderate wind resources, and Wetzel Engineering is working on a concept design for a 6-kW system that will produce electricity for 8 cents/kWh in low wind speed resource areas.

To develop more efficient components for small wind systems, the program is working with Composite Engineering to develop a 7.5-m turbine blade that will be constructed of low-cost, industrial-grade carbon spars. The new blade will be suitable for use as a retrofit and on new machines. Princeton Power Systems developed a novel AC-link converter designed for wind turbines rated at less than 100 kW with permanent-magnet generators. The design offers scalability, high power quality, and high reliability. Two 50-kW prototypes were successfully tested at the SNL Distributed Energy Technology Laboratory.



Southwest Windpower's 1.8-kW Sky Stream

NPS100-kW cold weather turbine

WIND-GRID INTEGRATION: GAINING EQUITABLE TREATMENT FOR WIND

The variable nature of the wind resource, the relatively low capacity factor of wind plants, the generally remote locations of good wind sites, and the fact that utilities cannot turn the wind on when needed, are the major differences from conventional generation sources that result in barriers to wind deployment. The Wind Program conducts systems integration research to provide real operational data and mitigation strategies to reduce these barriers and to ensure that wind energy is treated in a fair manner. The goals of the wind-grid integration effort are to complete the data collection and develop the tools and techniques and transfer this information in coordination with DOE's Office of Electric Delivery and Energy Reliability to electric utilities, regional and transmission system operators, state and Federal regulators, the wind industry, and other stakeholders by 2012.

This effort has three thrusts: 1) Technology Characterization and Data Collection, which includes development of wind turbine generator models and wind plant performance data; 2) Tools and Methods Development for assessing ancillary service, system impacts, and capacity credit; and 3) Application and Implementation, which relates to the development of grid rules and operational strategies based on the actual performance of wind plants to increase wind energy deployment.

Technology Characterization and Data Collection

A team of experts from NREL, Oak Ridge National Laboratory, the Utility Wind Integration Group (UWIG), and consultants are working with industry members on Technology Characterization and Data Collection activities. In 2005, they supported the Public Service of New Mexico by helping them analyze a 204-MW wind power plant and showed them how to simplify the dynamic modeling required for stability studies. To address the natural variability of wind resources, the team collects cooperative high-rate data at 10 wind projects across the country. These data have formed the basis for power system impact studies conducted in the United States during the last five years.

Tools and Methods Development

Under Tools and Methods Development, the team worked with UWIG and the National Wind Coordinating Committee to review a number of higher penetration studies conducted by leading wind utilities and with the California Energy Commission and independent system operators to examine the impacts of the new 20% renewables goal. In addition, the team provided wind planning scenarios for the Rocky Mountain Area Study and the Western Governor's Clean and Diversified Energy Task force.

UWIG and NREL also worked together to produce a special issue of the IEEE Power and Engineering journal on wind-grid integration. This issue featured five articles by U.S. and European experts on the topic of wind-grid integration. That, together with the establishment of a permanent committee on Wind Energy by the IEEE Power Engineering Society, suggests that wind energy is becoming mainstream and is on its way to becoming accepted as a generation option.

Application and Implementation

Application and Implementation activities include facilitating adoption of equitable grid access and operation rules and development of the information needed to ensure equitable treatment for wind in all major regional wind markets. Grid rules remain an important element of the program. DOE's Office of Energy Efficiency and Renewable Energy and the Office of Electric Delivery and Energy Reliability jointly provide comments on Federal Energy Regulatory Commission's (FERC) proposal to eliminate punitive imbalance charges for wind generators.

The Systems Integration activity continues to be challenged by the sheer number of organizations that need objective information on wind power. In addition to FERC, 51 state regulatory commissions, the National Electric Reliability Council (NERC), 10 or more NERC or regional transmission operators, more than 100 power control or balancing authorities, and hundreds of electric utilities and stakeholders all need information.

WIND POWERING AMERICA

Carpe Ventum – seize the wind – that's what Montana, Idaho, and New Jersey received awards for from Wind Powering America in 2005. They seized the wind by developing their first utility-scale wind farms. Montana is seizing the wind with 90 1.5-MW turbines at the Judith Gap Wind Center near Harlowton that will provide enough power for more than 30,000 homes. Idaho's new 10.5-MW wind farm near Hagerman will generate enough power for almost 7,000 homes, and the Jersey-Atlantic Wind farm near Atlantic City will help power a wastewater facility and more than 2,500 homes.

Montana, Idaho, and many other states are examples of the successful outreach efforts of the Wind Powering America (WPA) activity. The goal of WPA is that by 2010, at least 30 states will have 100 MW of installed wind capacity. WPA also supports the wind industry's goal of 100 GW installed by 2020. To increase the number of states with 100 MW of wind capacity, WPA focuses its outreach and support efforts on state-based activities, rural economic development, public power partnerships, Native American activities, and small wind systems.

State–Based Activities

To promote wind energy at the state level, WPA supports the formation of state wind working groups to provide stakeholders with timely information on the current state of wind technology, economics, state wind resources, economic development impacts, policy options/issues, and barriers to wind development. Group members include landowners and agricultural sector representatives; utilities and regulators; colleges and universities; advocacy groups, and state and local officials.

In 2005, WPA provided technical and outreach support on wind technology for public power, multi-state, and agricultural events. By the end of 2005, 28 states had formed wind working groups, 32 states had more than 20 MW of installed wind capacity and16 states had at least 100 MW of installed capacity.

In addition to assisting state wind working groups, WPA helps wind project stakeholders understand their wind resources through cooperative mapping and anemometry programs. WPA supports a public/private sector mix of wind resource analysts and meteorological consultants to update state wind resource maps. Identifying the level of available wind resource in an area is the first step toward installing large and small wind systems.

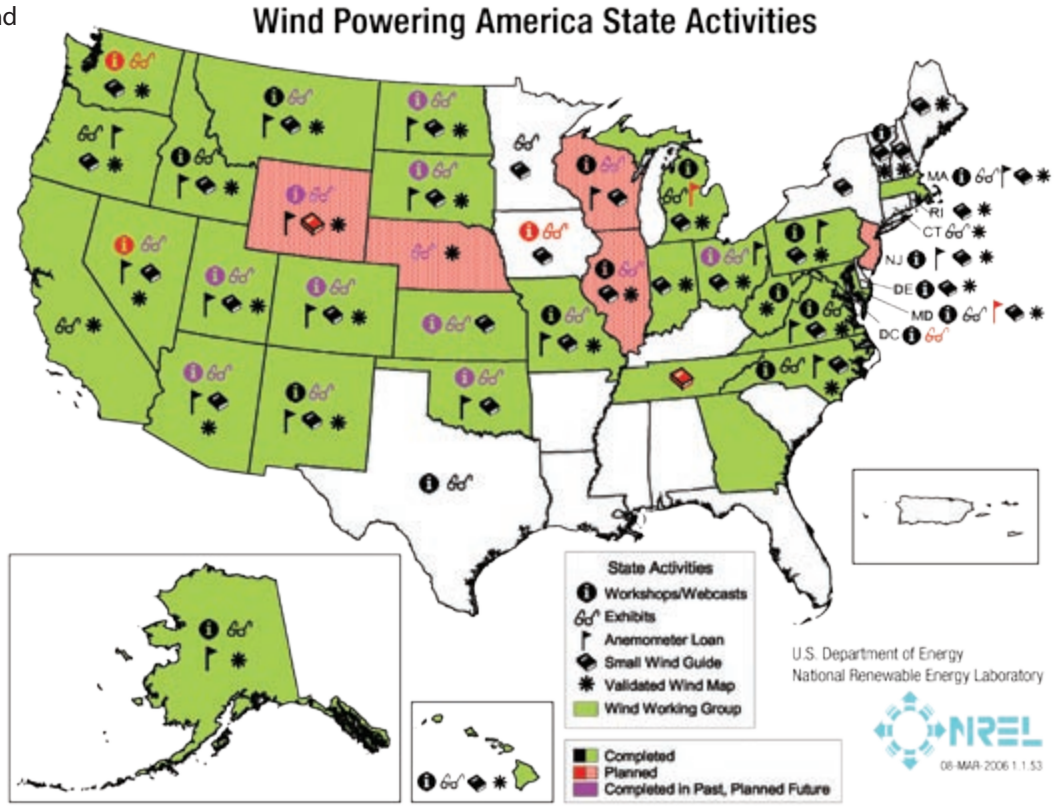
Rural Economic Development

Rural America faces many challenges, including rising fuel and electricity prices, low commodity prices, and the need for sustainable econimic growth.

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 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.

Distributed Wind Support

To compat rising fuel prices, rural landowners and small businesses are also considering the use of distributed and small wind systems to supply all or a part of their electricity needs. These wind systems can boost local energy supplies and stimulate rural economies. The small wind industry estimates that 60% of the United States has enough wind resources for small turbine use, and 24% of the population lives in rural areas where zoning and construction codes permit installation. However, cost, zoning regulations, permitting requirements, and grid connection issues create barriers that impede the growth of the small wind industry.



Gaining acceptance for and encouraging the use of small wind systems is an integral element of WPA's technology assistance and outreach efforts. In 2001, WPA published *Small Wind Electric Systems: A U.S. Consumer's Guide* to help consumers determine whether using small wind energy systems would be economically feasible for them. WPA team members then collaborated with state energy officials to customize the guides to include state-specific wind information. To date, WPA has published guides for 36 states, a Spanish version of the guide for New Mexico, and guides for the American Corn Growers Foundation and the Tennessee Valley Authority. More than 12,000 U.S. and state-specific guides were distributed in 2005.

WPA also sponsors small wind technical workshops, including Farm Bill Section 9006 financing workshops, and provides targeted technical assistance. In 2005, WPA team members conducted workshops at the National Western Stock Show in Denver Colorado and participated in workshops in 11states. WPA also provided staff for exhibit booths at the Midwest Renewable Energy Fair in Wisconsin and the Southwest Sustainability Expo in Flagstaff, Arizona.

In 2006, WPA will continue to identify and support opportunities for small wind turbine outreach. WPA staff will also continue to work with state energy offices, the AWEA Small Wind Turbine Committee, the Interstate Renewable Energy Council, and the state wind working groups to overcome barriers to increased use of small wind turbines.

Power Partnerships

Acceptance by the utility sector is essential to the future growth of the wind energy. Regional transmission constraints, operational policies, and a lack of understanding about the impacts, costs and benefits of wind energy to utilities have long been barriers impeding industry growth. To accelerate industry growth, WPA works in partnership with utilities and utility groups like the American Public Power Association (APPA), the National Rural Electric Cooperative Association (NRECA), power marketing administrations such as Bonneville Power Administration (BPA) and Western Area Power Administration (WAPA), the National Wind Coordinating Committee, and the Utility Wind Interest Group (UWIG). Power partnership activities include development of wind energy grid-impact models; development and distribution of technical and market-specific information; and technical assistance on wind energy technologies, economics, and wind project development process.

Native Americans

The United States is home to more than 700 Native American tribes located on 96 million acres, much of which have excellent wind resources that could be commercially developed to provide electricity and revenue to the reservations. But, before these resources can be full realized, many issues need to be resolved. These include the lack of wind resource data, perceived developer risk, limited loads, investment capital, technical expertise, and transmission to markets.

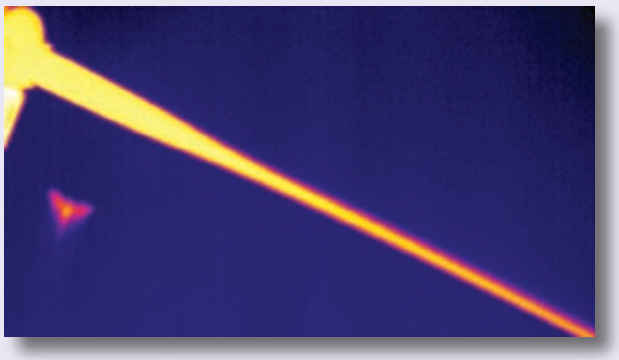
To support the development of Native American wind resources, WPA provides a wide range of technical assistance and outreach activities to more than 20 tribes from 13 states. WPA administers a Native American anemometer loan program enhanced with focused technical assistance to help tribes understand their wind resource and potential development options. In addition, WPA provides training on wind energy for Native Americans through the DOE-supported Wind Energy Applications and Training Symposium (WEATS). WPA was also instrumental in the formation of the Native American Wind Interest Group (NAWIG) to encourage experts to engage interested tribal representatives on all aspects of wind energy.

WPA also collaborates with DOE's Tribal Energy Program by providing technical assistance to those receiving competitive awards for wind evaluation.

For more information on WPA activities visit www.windpoweringamerica.gov

Resolving Environmental Issues

The Wind Program works to resolve environmental issues that may hinder technology acceptance for wind energy technologies through activities that address the potential effects of wind development on the environment and identify corresponding mitigation strategies. To address wildlife research needs, the program supports two collaborative efforts. The Grassland Shrub Steppe Species Collaborative that began in 2006 launched a 4-year effort to study wind turbines in prairie chicken habitat. The Bat and Wind Energy Collaborative investigates bat and wind turbine interaction. Both collaborations include representatives from wind industry, environmental organizations, and the Wind Program. The program also supports the work of the National Wind Coordinating Committee Wildlife Working Group that is focused on collaborative methodologies for mitigation, risk assessment, and nocturnal study techniques. In addition, the program provides technical support and presentations to industry, fellow federal agencies, and environmental groups.

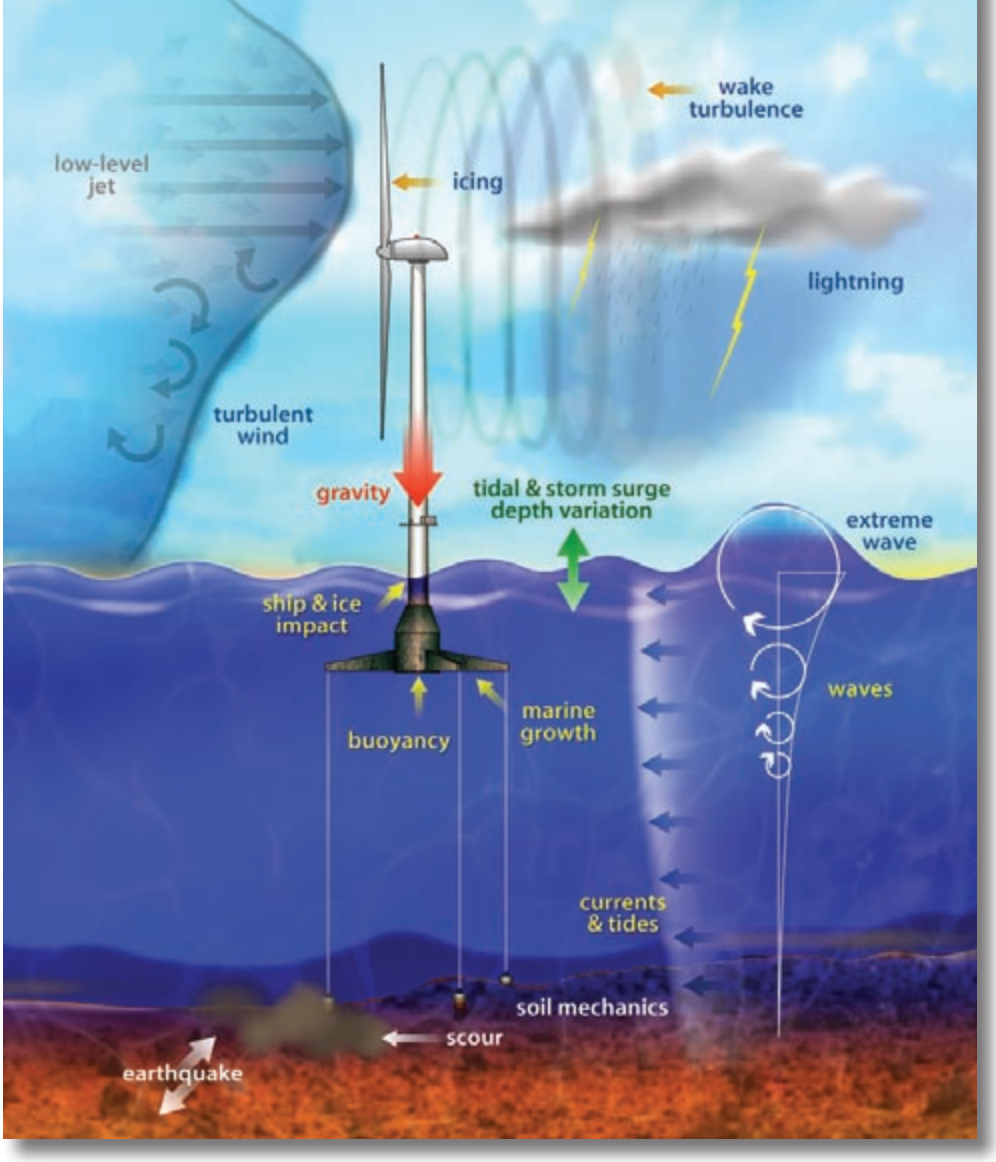


The Bat and Wind Energy Collaborative investigates bat and wind turbine interaction.

TACKLING OFFSHORE WIND TECHNOLOGY CHALLENGES

Many of the largest urban centers and hence, the largest demands for electricity, are located along the nation's coastlines. As the wind industry grows, transmission constraints will make it increasingly difficult to transport the wind energy generated by centrally located wind farms to coastal cities where needs are highest.

Preliminary studies conducted by NREL indicate that there are excellent wind resources a short distance from our shores. Areas between 5 and 50 nautical miles off the coasts could provide 900 GW of wind energy capacity and much of that capacity is located within a reasonable distance of the major coastal load centers with high energy costs.



The Wind Program is developing computer models to analyze the dynamics between offshore wind turbine designs and the harsh marine environment to design technologies capable of adapting.

Current Development

There are only 18 operating offshore wind projects in the world with an installed capacity of 804 MW. All of the current offshore installations are located in the shallow coastal waters (less than 18 m depth) of Europe. More than 11 GW of new offshore wind projects are planned before 2010. Most of that development will take place in Europe, but at least 600 MW of offshore wind is currently in the permitting process in the United States.

R&D Agenda

Although offshore wind technologies will operate in stronger, less turbulent wind that allows them to produce more energy, higher costs associated with offshore installation, operation, and maintenance make them more expensive than onshore installations.

To develop offshore technologies that can operate cost effectively in harsh marine environments, the Wind Program plans to capitalize on U.S. experience in both wind turbine technologies and offshore oil and gas engineering. Because the offshore environment does not have the same transportation constraints as onshore technologies, offshore wind energy technologies are expected to increase in size to take advantage of the lower support structure, maintenance, and infrastructure costs that favor big turbines. Some wind engineers predict turbines could grow to 10 MW and larger.

To help define the R&D activities, the program launched a new initiative in 2006 called SeaCon (sea-based concept studies), which is the first step in a multiyear offshore technology development and research effort. The SeaCon studies will define the requirements for offshore wind infrastructure and technology development, and identify technology improvement opportunities for offshore wind technologies.

One area researchers are trying to gain a better understanding of is the dynamic interaction between wave and wind and fixed and floating platforms. The objective of one of the offshore concept studies conducted by NREL and AWS Truewind, LLC in 2005 was to characterize the offshore wind and wave environments of the Atlantic and Lower Great Lakes regions in which these turbines will operate. The results of the study will help the offshore wind industry more precisely quantify the design load conditions at specific sites, which will enable projects to be engineered and operated more cost effectively. Two additional 2005 studies evaluated floating platform concepts. Massachusetts Institute of Technology began evaluating two floating platform concepts for offshore wind turbines deployed in water depths between 50 and 200 meters, a moored spar floating system and a tension leg platform. Concept Marine Associates, Inc., conducted a study to evaluate a tension-leg platform and a deployable anchor foundation system using concrete materials that can support a 5-MW wind turbine.

The Wind Program also leads a collaborative research effort with the International Energy Agency (IEA) under IEA Annex XXIII – Offshore Wind Energy Technology and Deployment. The objective of this annex is to provide international participants with an overview of the technical and environmental assessment challenges encountered in offshore applications and help them understand the areas of further

R&D needed. DOE leads a research effort in wind turbine technologies for applications in water deeper than 30 m. The goal of this research effort is to develop better computer models for analyzing and evaluating offshore wind turbines on various types of foundations.

In addition to the technical challenges, the offshore industry also faces environmental and regulatory issues. According to extensive analyses conducted by the European community, the effects of wind energy on the marine environment are relatively benign, but regulatory and environmental uncertainties have hindered the approvals for the first offshore wind projects in the United States. The Energy Policy Act enacted in August 2005 granted the Department of Interior's Minerals Management Service (MMS) regulatory responsibility over renewable energy and alternate uses of offshore public lands. For the last 40 years, MMS has regulated the offshore oil and gas industry and other mineral extraction activities in Federal waters known as the Outer Continental Shelf (OCS). While the MMS has a wealth of experience in siting and managing activities on the OCS, their understanding about wind resources or the wind energy industry is limited. Therefore, DOE plans to enter into a memorandum of understanding with MMS to facilitate cooperation between the two agencies and the exchange of information relating to offshore wind energy R&D activities.

The Wind Program is also facilitating an Offshore Wind Energy Collaborative (OWC) with the Massachusetts Technology Collaborative and General Electric. The OWC is a public/private partnership to expedite appropriate development of offshore wind energy in the United States.

ENSURING INDUSTRY GROWTH

To ensure the wind energy industry a long-term role in providing our nation with a clean, domestic power source, Wind Program researchers are exploring innovative applications such as the use of wind energy to produce hydrogen, to clean and move water and work in synergy with hydropower to provide a stable electricity supply.

Using wind to produce hydrogen may offer wind technologies an opportunity to provide low-cost, clean energy for the transportation sector. In addition, co-producing electricity and hydrogen for the power and transportation markets may significantly reduce the total wind-hydrogen system cost. Wind-generated hydrogen may also offer a solution to grid stability problems that may occur in some regions because of the nature of wind, as hydrogen may provide energy when electricity demand is high but wind production is low. In 2006, researchers at NREL will work with Xcel Energy on the Wind2H2 Project to identify the most appropriate ways to link wind turbines and electrolyzers and identify technical and market barriers that need to be better understood for wind-hydrogen applications to progress.

The Wind Program is also conducting research on the use of wind to provide energy needed to relieve some of the stress placed on finite water supplies. In November 2005, DOE hosted a Wind Water Nexus Workshop at NREL that examined possibilities for using wind energy as a power source for municipal water supply, coal bed methane production, desalination, and irrigation. As a result of participant recommendations, the Wind Program decided to focus its 2006 research on analysis of the technical and policy issues and opportunities for wind in the natural gas driven irrigation market and municipal water supplies.

Irrigation, which is the second largest water user after thermoelectric power in the United States, has traditionally used systems powered by diesel, gasoline, grid electricity, propane, or natural gas. Because nine of the top 10 irrigation states are in regions with good to excellent wind resources, there may be an opportunity for wind energy to provide a clean renewable source of energy for irrigation.

Municipal water and wastewater operations are also energy-intensive industries. Energy used by water systems accounts for more than 3% of total electric demand in the United States. Eight of the 10 states with the largest public water supply withdrawals and nine of the 10 states with the highest per capita water consumption have good to excellent wind resources. The use of wind energy to help provide power for municipal water supplies in these regions will also help reduce the amount of water needed for hydroelectric supplies. For more information on the research conducted by NREL on wind/municipal water supply applications see Wind Energy Applications for Municipal Water Services: Opportunities, Situation Analyses, and Case Studies; http://www.nrel.gov/docs/fy06osti/39178.pdf.

To analyze the grid integration issues and costs related to combining wind and hydropower resources to provide a more stable supply of electricity to the grid, the Wind Program is developing three wind/hydropower technology case studies: (1) the Missouri River Case Study, (2) the Lower Colorado River Case Study, and (3) the Grant County Public Utility District Case Study. Preliminary results from the Grant County Case Study, showed that at wind energy penetration levels of 3.5% (12 MW), 18.5% (63.7 MW), and 44% (150 MW), wind energy has very little impact on regulation.

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

Key Contacts

Stan Calvert
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

Paul Veers, Manager
Sandia National Laboratories
Wind Energy Technology Department
P.O. Box 5800, Albuquerque, NM 87185-0708

For more information contact:

EERE Information Center
1-877-EERE-Inf (1-877-337-3463)
www.eere.energy.gov

Wind Energy Web Sites

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

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

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

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

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

UTILITY WIND INTEGRATION GROUP
http://www.uwig.org

WIND POWERING AMERICA
http://www.eere.energy.gov/windandhydro/windpoweringamerica/

Available electronically at www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: reports@adonis.osti.gov

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: www.ntis.gov/ordering.htm

PHOTO CREDITS: Cover photos: GE Wind Energy/PIX12424. NREL/PIX14709. NREL/PIX14643. NREL/PIX14689. NREL/PIX14650. GE Wind Energy/PIX13160. Copleman, Paul, Community Energy, Inc./PIX14345. NREL/PIX14706. Page 2: Stuart Van Greuningen, Idaho Energy Division/PIX14336. Page 3: NREL/PIX14688. NREL/PIX12586. NREL/PIX14010. NREL/PIX11237. NREL/PIX14708. Page 5: NREL/PIX14691. Sandia National Laboratories/PIX14711. Sandia National Laboratories/PIX14710. Page 6: NREL/PIX14649. NREL/PIX14685. NREL/PIX14643. Page 7: NREL/PIX10928. Page 8: Copleman, Paul, Community Energy, Inc./PIX14345. Doug Welch – Courtesy of Hull Municipal Lighting Plant/PIX11261. NREL/PIX09621. Herziger, Lloyd – General Electric Company/PIX11952. ©2003 GE Wind Energy All Rights Reserved/PIX12929. Grace, Robert/PIX14325. Stuart Van Greuningen, Idaho Energy Division/PIX14335. Berry, Donna – Utah State University/PIX13969. Page 9: Piikuni Utilities Corporation/PIX13792. Boston University – Horn, Jason/PIX13891. Page 11: GE Wind Energy/PIX12424.

Produced for the

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

1000 Independence Avenue, SW, Washington, DC 20585

By the National Renewable Energy Laboratory,
a DOE National laboratory

DOE/GO-102006-2319

May 2006

Printed with renewable-source ink on paper containing at least 50% wastepaper, including 10% postconsumer waste.