Wind and Hydropower Technologies Program

Wind Energy Multiyear Program Plan For 2007–2012

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

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Acronyms

AEI	Advanced Energy Initiative
AEO	2005 Annual Energy Outlook
AOP	Annual Operating Plan
APPA	American Public Power Association
ATTU	Annual Turbine Technology Update
AWEA	American Wind Energy Association
AWT	advanced wind turbine
BACI	before-and-after construction impact
BPA	Bonneville Power Administration
BLM	Bureau of Land Management
CFD	computational fluid dynamics
COE	cost of energy
CPS	corporate planning system
CRADA	Cooperative Research and Development Agreement
CREB	Clean Renewable Energy Bonds
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
DWT	distributed wind technologies
ECPA	Energy Conservation and Product Act
EERE	Office of Energy Efficiency and Renewable Energy
EPA	Environmental Protection Agency
EPACT	Energy Policy Act
EPCA	Energy Policy and Conservation Act
ES&H	environmental safety and health
FEM	Finite Element Model
FEMP	Federal Energy Management Program
FERC	Federal Energy Regulatory Commission
FSL	Forecast Systems Laboratory

FTE	full-time employee
FWS	Fish and Wildlife Service
GE	General Electric
GFO	Golden Field Office
GIS	geographic information system
GPRA	Government Performance and Results Act
GW	gigawatts
HFCITP	Hydrogen, Fuel Cells, and Infrastructure Technologies Program
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IDW	I-Manage Data Warehouse
ISO	independent system operator
kW	kilowatts
kWh	kilowatt-hour
LWT	large wind technology
MARKAL	Market Allocation Model
MISO	Midwest Independent Transmission System Operator
MMS	Minerals Management Service
mph	miles per hour
m/s	meters per second
MTC	Massachusetts Technology Collaborative
MW	megawatts
MYPP	Multi-Year Program Plan
NCAR	National Center for Atmospheric Research
NECPA	National Energy Conservation Policy Act
NEMS	National Energy Modeling System
NEP	National Energy Policy
NEPA	National Environmental Policy Act
NES	National Energy Strategy
NGTD	next generation turbine development

NOAA	National Oceanic and Atmospheric Administration
NRECA	National Rural Electric Cooperative Association
NREL	National Renewable Energy Laboratory
NWCC	National Wind Coordinating Committee
NWTC	National Wind Technology Center
OCO	Office of Communication and Outreach
OE	DOE office of Office of Electricity Delivery and Energy Reliability
O&M	operation and maintenance
OMB	Office of Management and Budget
OWC	Offshore Wind Collaborative
OWT	offshore wind technologies
PMC	Project Management Center
PPAF	Program Performance and Accountability Framework
ProMIS	Project Management Information System
PTC	Production Tax Credit
RCAS	Rotor Craft Analysis Systems
R&D	research and development
RD&D	research, development, and deployment
RPS	renewable portfolio standard
RTO	regional transmission organization
SE&A	supporting engineering and analysis
SI	systems integration
SNL	Sandia National Laboratories
SR&T	supporting research and testing
STARS	Standard Accounting and Reporting System
SWRT	small wind research turbine
TA	technology application
TA&C	technology acceptance and coordination
TIOs	technology improvement opportunities
TR&D	technology research and development

TV	Technology Viability
TWh	terawatt-hours
UAE	Unsteady Aerodynamics Experiment
USDA	United States Department of Agriculture
UWIG	Utility Wind Integration Group
Western	Western Area Power Administration
WECC	Western Electric Coordinating Council
WGI	wind grid integration
WinDS	Wind Energy Deployment System Model
WPA	Wind Powering America

Executive Summary

For more than 25 years, the Wind Energy Program, one element of the U.S. Department of Energy (DOE) Wind and Hydropower Technology Program (WHTP) under the Office of Energy Efficiency and Renewable Energy (EERE), has been a central component of the Nation's efforts to advance wind energy technology for large utility-scale and smaller distributed wind technologies. The Wind Program has worked in close partnership with industry and the national laboratories to expand the wind energy technology base and foster innovation, culminating in some of industry's leading products today. The program has also created a family of internationally recognized wind turbine design tools that have led industry, utility, and government agencies in cooperative efforts to promote integration and acceptance of wind energy as a substantial contributor to meeting the Nation's energy needs. These accomplishments have lead to a major improvements, resulting in a drop in the cost of wind energy from 80 cents/kWh in 1980 to as low as 5 cents/kWh today. These technology gains combined with Federal incentives have led to the development of more than 11,600 MW of wind energy capacity by the end of 2006, enough energy to supply over 2.6 million homes. This expanded use of wind technologies is well distributed across the Nation, which is demonstrated by the growth in the number of states with over 100 MW of installed wind technology—from 4 in 1999 to 19 today. The Federal expenditure of just over $1B for developing the U.S. wind market since the early 1970s has showed great dividends. The commercial investments for new U.S. wind capacity totaled more than $4B in 2006 alone. Similar investments are expected through 2008.

Wind also holds many promises for the future. Studies commissioned by DOE in response to the Government Performance and Results Act show that with the successful implementation of the Wind Energy Program, this clean, renewable resource could produce almost 1,000 billion kWh per year by 2050, representing approximately 50% of all new electric generation resulting from the different generation technologies in the EERE portfolio. This would result in 75 million metric tons carbon equivalent savings annually, or 15% of the expected carbon reductions for all EERE programs.

Programmatic Drivers

Programmatic drivers for the Wind Energy Program include the 2001 National Energy Plan, the Energy Policy Act (EPAct) of 2005, and the President's 2006 Advanced Energy Initiative (AEI). These national documents lay the foundation of a national strategy to change the way we power our homes, offices, and vehicles, partially by expanding the generation of clean energy from wind through activities to:

> *"Improve the efficiency and lower the costs of conventional wind turbine technologies; it will also help develop new small-scale wind technologies for use in low-speed wind environments."* – AEI

And

"conduct a program of research, development, demonstration, and commercial application for wind energy, including-- low speed wind energy; offshore wind energy; testing and verification (including construction and operation of a research and testing facility capable of testing wind turbines); and distributed wind energy generation." - EPAct05

The AEI also recognizes wind energy's potential contribution to the Nation's energy solution by stating that, *"Areas with good wind resources have the potential to supply up to 20% of the electricity consumption of the United States."*

The Wind Energy Program uses these three documents, combined with direction from EERE senior management and wide industry input to help determine near- and long-term program priorities and implementation plans.

Near-Term Program Direction
To align the program's FY 2007–2012 plan with the direction of the President, Congress and DOE senior management, a number of shifts in priorities and activities have been undertaken that include:

1. Increasing the program's efforts to overcome near-term deployment barriers in the areas of grid integration and environmental issues.
2. Initiating a dedicated effort to enhance the Nation's energy infrastructure to allow expanded use of wind technologies through increasing access to transmission.
3. Expanding work in the area of turbine performance and reliability to mitigate risk in response to investor, developer, and operator concerns.
4. Broadening program activities in the distributed wind technology market sector (residential, farm, small business) by continuing work on small turbine technology development and supporting community wind projects and turbine applications connected to the distribution side of the grid.
5. Reducing the use of cost-shared private-public partnerships for the development of large wind systems while expanding the use of cost-neutral Cooperative Research and Development Agreements (CRADA) to match the maturing needs of a sustainable industry and better leverage program investments.
6. Reducing the scope of the program's efforts to develop offshore wind technology to allow for assessment of the potential market and the technical challenges to its development.

Long-Term Vision for Wind Energy
Following the guidance of the AEI, and building on the domestic energy focus of EPAct 2005, the Wind Energy Program has developed a new direction for the development and deployment of wind technologies. In conjunction with the American Wind Energy Association and the National Renewable Energy Laboratory, the program launched an effort to assess the potential for and impact of providing 20% of the Nation's electrical energy from wind technology. Following rigorous analysis and investigation of all major

facets of the U.S. energy system, from power transmission to consumer acceptance, this collaborative of over 75 participating organizations has developed a credible assessment of the costs, benefits, and actions required for wind energy to provide 20% of U.S. electricity needs by 2030, securing America's leadership in reliable, clean energy technology. The collaborative report, to be released in the summer of 2007, describes how, as an inexhaustible and affordable domestic resource, wind strengthens our energy security by producing about 1,200 terawatt-hours (TWh) each year from local resources; improves the quality of the air we breathe and slows climate change by eliminating 1,925 million metric tons of carbon equivalent through 2050. Wind energy development also revitalizes rural communities by producing approximately 332 billion dollars in economic investment and more than 2,750,000 full-time equivalent job years, largely in rural areas and manufacturing centers across the Nation.

Challenges to the Near- and Long-Term Vision

These projections seem too good to be true, especially when you consider that wind technology currently accounts for less that 1% of the Nation's total annual energy production, thus demonstrating the great number of challenges that face the wind industry. Although multifaceted, the primary challenges include:

- Perception of risk - Although wind can be installed at a good site for prices lower than conventional technology, generally, new technology must be available at a cost significantly lower for the market to openly accept it because of the perceived higher risk of new technology.
- Higher cost of wind energy - Although the cost of energy from wind is comparable to new conventional technologies, the rising costs associated with wind energy development require further reductions of between 10% and 20% of total system cost to allow wind to develop to its full potential.
- Burdensome grid interconnection requirements - Transmission constraints, unfavorable operational policies, and a lack of understanding of the impacts of wind energy on utility grids are major barriers to wind energy development.
- Utilization of accessible low wind speed sites - As sites with excellent wind resources close to load centers or existing transmission infrastructure are developed, improvements must be made to allow cost-effective access to sites with lower wind speeds.
- Limited transmission infrastructure - Transmission infrastructure limitations hinder the use of high-quality wind resources located far from demand centers.
- Challenging regulatory and policy environment - Unclear regulatory approval processes at the Federal, state, and local levels complicate and raise the costs for the development of wind projects.
- Increased environmental scrutiny - The impacts of wind turbines on avian and bat populations at some sites have caused concern.
- Public acceptance - Some communities object to the real and perceived local impacts of both land-based and offshore wind farms.

Program Activities to Address these Challenges

The Wind and Hydropower Technologies Program conducts activities to support the development and deployment of wind technologies through a coordinated partnership between the DOE Golden Field Office, other DOE offices such as the Office of Electricity Delivery and Energy Reliability, the National Renewable Energy Laboratory, Sandia National Laboratories, other national laboratories, universities, a network of independent organizations such as the National Wind Coordinating Committee, and private organizations.

Program work is undertaken with two main focuses: increasing the Technology Viability of wind systems through technology R&D, and increasing wind energy deployment in the marketplace through Technology Acceptance activities. Under Technology Viability, the program sponsors R&D on large-scale and smaller distributed wind technologies. Under Technology Application, the program sponsors research on transmission and systems integration and conducts general technology acceptance outreach activities. The program also conducts supporting research, development, and application testing to align program efforts with the key activities and the goals that they support.

To ensure that the program is conducting activities that are relevant to today's market, it uses a robust process that combines industry input, technical assessment, and market analysis as central pillars of its portfolio decision-making process. The program also uses a formal peer-review process to benefit from the guidance of industry and the research community and to provide an outside view of the program.

In addition to the peer-review meeting, the program conducts a formal strategic planning meeting as part of the planning process for out-year funding. This meeting includes representatives from industry, research staff, and the peer-review panel. Discussions are held on program direction and strategic planning to ensure that industry partners are able to provide timely and critical insight into market trends that the program should consider when developing the next year's research plan.

Conclusion

Wind energy has a clear role in securing our Nation's energy economy. Although wind energy will not play a major role in this new economy in the near term, the increases in installed capacity over the past few years indicate that its role will increase over time. Every energy paradigm change requires government understanding of the long-term implications of the change so that critical policy support can be provided during a long transition period. It is appropriate for the Federal Government to facilitate this development with sound technical assistance and R&D to remove barriers that may unnecessarily hinder this technology or the emerging industry.

Although facing challenges, wind energy is becoming a favored renewable energy technology for utility-scale power generation and a popular alternative in smaller distributed applications. Each of the potential technology pathways for wider wind development will require the program to address specific technical and acceptance barriers, while coordinating information and outreach between the ever expanding elements of this wide industry, the general public and other energy stakeholders.

Energy is clearly one of the central pillars of our Nation and its economy. Through the Wind Energy Program's mission to "*lead the Nation's efforts to improve wind energy technology"* and *"coordinate with stakeholders on activities that address barriers to the use of wind energy*" it hopes to continue improving wind energy technology, leading to a day when a large portion of our Nation's energy comes from this environmentally safe, inexhaustible, economically viable and indigenous energy option.

1.0 Program Overview

The Wind Energy Program is one element of the U.S. Department of Energy (DOE) Wind and Hydropower Technology Program (WHTP) under the Office of Energy Efficiency and Renewable Energy (EERE). EERE leads the Federal government's research, development, and deployment efforts in energy efficiency and renewable energy.

In May 2001, the President's National Energy Policy Development Group released a National Energy Policy (NEP)[1] containing a set of recommendations that have become the cornerstone of U.S. energy policy under the George W. Bush Administration.

In support of NEP, EERE published a Strategic Plan in October 2002 that describes nine strategic priorities.[2] These include reducing dependence on foreign oil, reducing the burden of energy prices on the disadvantaged, increasing the efficiency of buildings and appliances, reducing the energy intensity of industry, and creating a domestic renewable energy industry. The most important strategic goal for the Wind Energy Program is to: "Increase the viability and deployment of renewable energy technologies."

The program works to support this specific goal by:

- Increasing the viability of wind energy by developing new cost-effective technology and increasing the reliability of all large wind technology; developing cost-effective distributed, small-scale wind technology; and performing research that supports these technology viability activities.

[1] National Energy Policy, National Energy Policy Development Group, Government Printing Office, Washington, D.C. ISBN 0-16-050814-2, May 2001. http://www.ne.doe.gov/pdf/National-Energy-Policy.pdf

[2] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy mission, http://www1.eere.energy.gov/office_eere/mission.html

- Increasing the application of wind energy by helping facilitate the installation of wind systems through supporting research and outreach in power grid integration, transmission, technology acceptance, systems engineering, and analytical support.

Through a partnership with the DOE Office of Electricity Delivery and Energy Reliability, the program is also actively working to address EERE's fourth strategic priority to, "increase the reliability and efficiency of electricity generation, delivery, and use."

The NEP was further strengthened by the release of the President's Advanced Energy Initiative[3], which was unveiled during the 2006 State of the Union Address. This document lays the foundation of a national strategy to change the way we power our homes, offices, and vehicles, and to eliminate our unhealthy addiction to oil. The document calls specifically for expanding the generation of clean energy from wind through activities to:

> *"Improve the efficiency and lower the costs of conventional wind turbine technologies; it will also help develop new small-scale wind technologies for use in low-speed wind environments."*

The Initiative also recognized wind energy's potential contribution to the nation's energy solution by stating that:

> *"Areas with good wind resources have the potential to supply up to 20% of the electricity consumption of the United States."*

DOE's efforts to achieve the mission, as defined above, are further focused by Section 931 of the Energy Policy Act (EPAct) of 2005 [4], which directs that:

> *"The Secretary shall conduct a program of research, development, demonstration, and commercial application for wind energy, including-- low speed wind energy; offshore wind energy; testing and verification (including construction and operation of a research and testing facility capable of testing wind turbines); and distributed wind energy generation."*

The Wind and Hydropower Technologies Program has interpreted the Presidential directive to "change the way we power our homes and businesses" and the implementation focus of EPAct 2005 as a mission to provide leadership to the wind industry and assign higher priority to removing barriers to the use of advanced wind technology, which is intended to speed deployment into all wind regimes.

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[3]Advanced Energy Initiative http://www.whitehouse.gov/stateoftheunion/2006/energy/energy_booklet.pdf
[4] Energy Policy Act of 2005. http://www.energy.gov/about/EPAct.htm

The program's FY 2007-2012 plan contains a number of shifts in priorities and activities to reflect this increased leadership and new direction. These shifts include:

1. Increasing the program's efforts to overcome near-term deployment barriers in the areas of grid integration and environmental issues.
2. Initiating a dedicated effort to enhance the Nation's energy infrastructure to allow expanded use of wind technologies through increasing access to transmission.
3. Expanding work in the area of turbine performance and reliability to mitigate risk in response to investor, developer, and operator concerns.
4. Broadening program activities in the distributed wind technology market sector (residential, farm, small business) by continuing work on small turbine technology development and supporting community wind projects and turbine applications connected to the distribution side of the grid. This will take advantage of significant grass-roots support for wind energy, and help provide the average American with a method to control their energy costs, support local economic development, and help secure the Nation's energy future.
5. Reducing the use of cost-shared private-public partnerships for the development of large wind systems based on the current strength of the wind market. Although partnering with industry is important, the program will shift to an industry partnering strategy based on cost-neutral Cooperative Research and Development Agreements (CRADA) to match the maturing needs of a sustainable industry and better leverage program investments.
6. Reducing the scope of the program's efforts to develop offshore wind technology to allow for assessment of the potential market and the technical challenges to its development.

The program is developing an industry vision report in conjunction with the American Wind Energy Association (AWEA) and the National Renewable Energy Laboratory (NREL) that will help to further refine and redirect the Wind Energy Program's future plans.

1.1 Program History

The Federal Government has sponsored wind energy research since 1972. The early program, at the National Science Foundation, was driven by the needs of electric utilities and by the potential of wind as a "fuel saver" during the oil crisis. This utility focus led the program to conduct R&D activities on the development of large-scale wind turbines. All federal wind activities were centralized within the Department of Energy in 1977 following its creation.

In the early 1970s, analysts believed that large turbines had a strong potential for economies of scale, meaning that energy production would be increased by tapping better resources using taller towers and that utilities would primarily be interested in larger units. When the program began, the feasibility of using large wind turbines (defined as turbines rated at 100 kilowatts [kW] or larger) for grid-tied generation had not been established. The Mod-0 turbine, installed in 1975, and its variant, the Mod-0A, a 100-kW turbine that operated at four sites, proved the feasibility of large-turbine technology. These early turbines provided a test bed for further innovation and paved the way for the development of the first multi-megawatt turbines. The 3.2-megawatt (MW) Mod-5B (Figure 1) was the largest and last turbine in the Mod series.

Figure1. The 3.2-MW Mod-5B, was the largest turbine in the Mod series.

Power systems engineering has been integral to the Wind Energy Program since the early 1970s. Every experimental wind turbine developed since the 100-kW Mod-0A has had a system integration study performed prior to its installation to address concerns over the variable output of wind energy. Utility operators were concerned that a wind turbine array would impose additional generation costs for which conventional units would be required to compensate. Another concern was that a cascading failure would occur if the array shut down during a storm with winds above the maximum safe operating range of the turbines.

Between 1981 and 1985, California became a pioneer in wind power development as a result of favorable development incentives and regulatory reforms (Figure 2 provides a chronology of developments in the post-1980 era). The turbines used in these early commercial installations were much smaller than the systems developed by DOE's large turbine research. Industry developed these small systems to reduce risk in the absence of modeling and design tools.

The incremental approach taken by the small turbine manufacturers allowed extrapolation of lessons learned to machines of increasing size and sophistication, while taking advantage of available policy support. When new installations began declining in 1986 because of a reduction in tax credits and California market incentives, many U.S. manufacturers were forced to declare bankruptcy. As a result of this decline and budget reductions, power systems analyses and wind technology application became low-priority R&D areas for the program during the late 1980s and early 1990s.

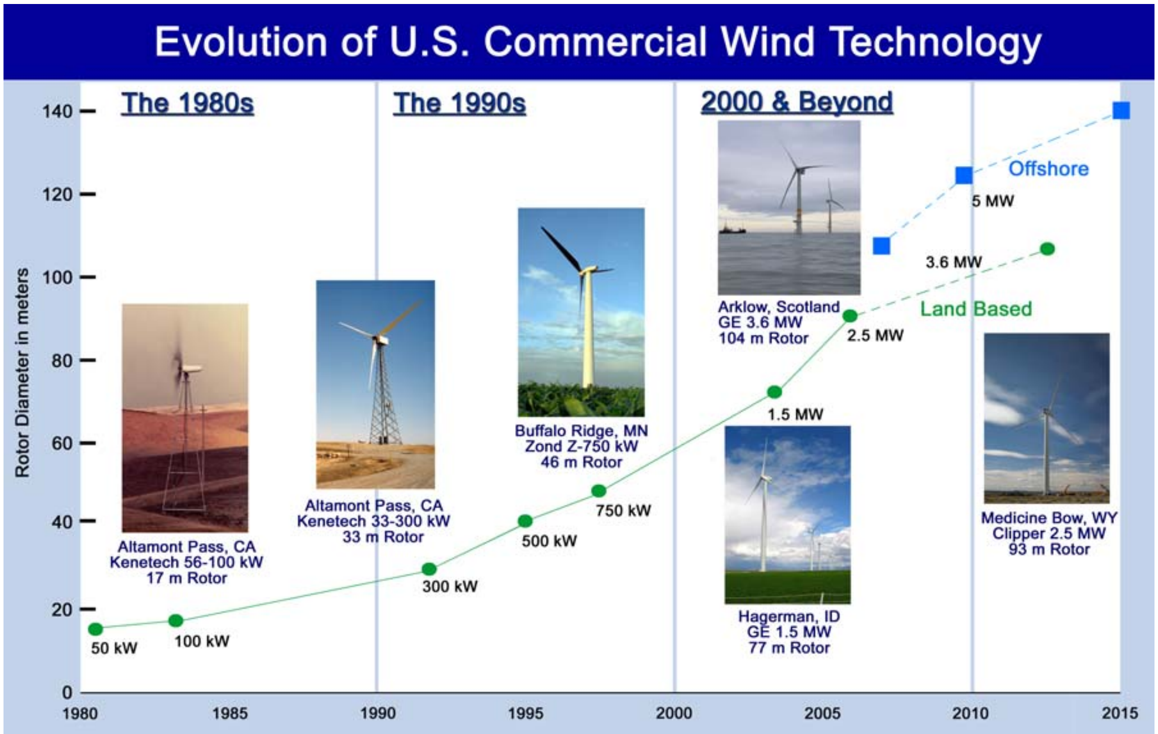

Figure 2. Wind technology developments beginning in 1980.

In 1990, the program developed a new strategy that focused on collaborative activities with utilities and industry. This new emphasis was based on experience gained from earlier R&D activities and guidance from the National Energy Strategy (NES) that was developed in 1989 and 1990. An important element of that strategy was to expand the use of wind energy beyond California. To that end, four objectives were adopted: (1) maintain the existing generation of turbines, (2) increase industry competitiveness, (3) upgrade the research base, and (4) develop advanced wind turbines.

The Advanced Wind Turbine (AWT) Program was initiated by DOE in 1990 to assist the U.S. industry in incorporating advanced technology into its wind turbine designs. The first phase of the AWT Program, Conceptual Design Studies, was completed in 1992[5,6,7,8,9,10]. This activity identified and evaluated improvements intended to make

[5] Hock, S. M.; Thresher, R. W.; Goldman, P. R. (1991). Federal Advanced Wind Turbine Program. 5 pp.; NREL Report No. TP-257-4625. (Available on request)
[6] Butterfield, C. P.; Smith, B.; Laxson, A.; Thresher, R.; Goldman, P. (1993). DOE/NREL Advanced Wind Turbine Development Program. 5 pp.; NREL Report No. TP-442-5415. (Available on request)
[7] Swift, A.; Hock, S. M.; Thresher, R. (1993). Advanced Wind Turbine Performance and Cost Projections: A Configuration Study. Windpower '92: Proceedings of the American Wind Energy Association Conference, 19-23 October 1992, Seattle, Washington. Washington, DC: American Wind Energy Association; pp. 431-447. (Available on request)
[8] Hughes, P.; Sherwin, R. (1994). Advanced Wind Turbine Design Studies: Advanced Conceptual Study, Final Report. 266 pp.; NREL Report No. TP-442-4740. (Available on request)
[9] Advanced Wind Turbine Conceptual Study: Final Report, August, 1990 - March 1992. (1995). 518 pp.; NREL Report No. TP-441-6924(Available on request)
[10] Advanced Wind Turbine Near-Term Product Development: Final Technical Report. (1996). 135 pp.; NREL Report No. TP-441-7229. (Available on request)

existing wind turbines more competitive. It also explored advanced configurations that would be competitive for bulk-electricity generation at sites with moderate wind speeds. Studies indicated that these advanced configurations were capable of achieving substantial improvements in performance, reliability, and cost of energy.

The second phase of the AWT Program, Near Term Product Development, lasted for nearly 4 years. This effort involved the fabrication and testing of prototype turbines designed to produce electricity for $0.05/kilowatt-hour (kWh) or less in Class 4 sites (sites with winds of 5.8 meters per second (m/s) [13 mph]) in the near term. These products were intended to bridge the gap between earlier technologies and the next generation of utility-grade turbines.

The third phase of the AWT Program, Next Generation Product Development, stimulated U. S. industry to explore new concepts and to apply cutting-edge technology to the development of prototype utility-grade wind turbine systems. The objective was to produce electricity for $0.03/kWh or less at Class 6 sites (sites with winds of 6.7 m/s [15 mph]). Of the two turbines developed under this activity, the Enron Wind 1.5 MW unit (now owned and produced by General Electric) proved to be a very successful commercial product.

As a companion to the large turbine development projects, beginning in the 1990s the program also supported the development of more cost-effective small-scale turbines (less than or equal to 100 kWs) for the distributed-generation market. Two principal products were developed under this effort. The Atlantic Orient Corporation produced a 50-kW, three-bladed downwind machine, and Northern Power Systems developed a 100-kW direct-drive turbine for cold weather environments.

Interest in power engineering and systems integration was revived in the mid-1990s, when NREL assumed the technical lead. Since then, research has centered on: estimating a wind plant’s contribution to system reliability, often called capacity credit; studying the challenges of ancillary services; and collecting high-rate real power, reactive power, and voltage data to establish the short-term output variations of a wind plant. One study on high-rate real power performed at the Lake Benton II project shows that the wind output varies little in the short-term and has minimal impact on system costs. Another study performed in the Northern States Power System network looked at ancillary costs and found that an additional system cost of 0.18 cents per kWh was imposed by wind variability on 300 MW or 4% of the wind penetration in that area. A 2004 study indicated additional operating costs of about 0.46 cents/kWh for a 15% penetration level in the Xcel Energy power system network. The program continues to play a key oversight and supportive role in the development of regional wind impact studies while working with organizations such as the Utility Wind Integration Group (UWIG) to obtain a more expansive understanding of wind/grid integration issues.

In 2001, the National Wind Coordinating Committee (NWCC) began holding regional transmission issue forums to allow grid stakeholder dialog and wind sector input to transmission planning groups. These efforts have resulted in many gigawatts (GWs) of wind being considered in conventional regional grid expansion efforts. In 2002, the Wind Energy Program initiated a systems integration project to address technical issues that may limit wind in the marketplace and provide a clearinghouse for research-based information for utilities, cooperatives, and other industry stakeholders on the integration of wind technology into the nation's power system.

Prior to the establishment of the Wind Powering America (WPA) Project in 1999, there were only limited Federal efforts to support the use of wind energy. Most efforts were centered in California and Minnesota, both of which had state policies that made wind energy an attractive option. Development was limited to these two states despite better wind resources in other states, particularly the rural plains states. The founding of the NWCC created a national forum for discussion of national-level issues affecting the U.S. wind industry, including wind/avian interactions and siting lessons for wind project developers.

Since that time the U.S. wind industry has grown form approximately 2500 MW of installed wind capacity with limited annual growth to current installation of more than 11,000 MW by the end of 2006, and has experienced an average annual rate of growth of more than 20%. Additionally, the number of states with over 100 MW of installed wind has grown from 4 in 1999 to 19 today.

Based on the Advanced Energy Initiative, the Energy Policy Act of 2005, direction of new EERE executive leadership, and guidance from industry partners, the program initiated a shift in focus to more equally weight the programs activities between technology development and acceptance activities, beginning in 2006. As has been described in the last section, this shift reduces emphasis on research activities in the area of offshore wind and on larger private/public partnerships for the development of new large wind systems. In place of these activities, the program is greatly expanding work in wind integration and transmission, enhancing work in technology acceptance and siting, and expanding work in small wind systems to include all distributed wind technologies, such as community wind.

1.2 Market Overview and Federal Role of the Program

Although facing challenges, wind energy is becoming a favored renewable energy technology for utility-scale power generation and a popular alternative in smaller distributed applications. With total installations at the end of 2006 of more than 11,000 MW, almost 5,000 MW of which were installed in 2005 and 2006, the wind energy market is expanding rapidly. As a result of the extension of the Renewable Production Tax Credit (PTC) included in EPAct 2005, similar growth rates are expected through 2008.

Wind has the potential to provide a significant portion of the new generation needed to respond to growing domestic demand for electricity, which is projected to increase at an annual rate of 1.4% through 2025. Although wind energy accounted for less than 1% of total national generation at the end of 2006, it provides carbon free, environmentally safe, and domestically secure energy at a cost at or below 4 to 9 cents per kWh in varying wind speed classes. Distributed wind systems also allow communities, businesses, and average Americans to take an active role in determining the Nation's energy future. Wind energy has also shown itself to be a strong contributor to building local economies through fees paid to landowners, creation of local businesses and new jobs, and an increased local tax base for rural counties and communities. The wind energy market has grown at an average of 26% annually for the past 6 years, attracting increasing attention from energy market participants, including the financial community, utilities, policy makers, media, and electricity consumers.

As the market environment for wind turbines has changed, so have the challenges of competing in the marketplace. Although wind historically has competed predominantly against natural gas production, as a nondispatchable electricity supply option wind now must frequently compete with the marginal operating costs of the local utility. This means that the variable operating costs of existing baseload power (often coal and nuclear) are often the basis of competition. Despite rising natural gas fuel costs, wind energy will continue to have to overcome a high capital investment intensity and relatively low capacity factor. However, the higher cost of natural gas generation resulting from the projected increase in demand for imported natural gas over the next 20 years may increase reliance on and cost competitiveness of wind-generated electricity.

As the wind power market continues to expand, the industry faces challenges that include the perception that the technology is risky, cost of energy, burdensome grid interconnection requirements, a challenging regulatory and policy environment, utilization of accessible high wind speed sites, limited transmission infrastructure, increased environmental scrutiny, resistance to visual impacts, and possible interference with radar installations (Table 1). Among these challenges, perceived risk, interconnection requirements, and the challenging regulatory and policy environment stand out, as they will determine whether wind will be afforded the opportunity to compete with other energy options under equitable rules, or whether wind will be put at a disadvantage to other technologies.

The increasing maturity of the U.S. market is being driven by several factors that include reductions in the cost of wind energy, public and policy support for alternative energy sources, and recognition of the price hedge that wind energy can provide against rising natural gas prices. Over the past 20 years, a strong DOE-funded R&D effort combined with private partnerships has lowered the base cost of wind energy from around 80 cents/kWh to as low as 4 cents/kWh. When combined with the PTC, which provides an incentive of 1.9 cents/kWh for the first 10 years of a project, and other tax considerations, the cost of wind energy becomes very competitive, and is sometimes lower than conventional generation sources.

Table 1. Wind Energy Market Barriers	
Perception of risk	Although at good site wind can supply electricity at prices lower than conventional technology, generally, new technology must be available at a cost significantly lower for the market to openly accept it due to the perceived higher risk of the new technology.
Higher cost of wind energy	Although the cost of energy from wind is comparable to new conventional technologies, the rising costs associated with the development of wind energy require further reductions of between 10% and 20% of total system cost to allow wind to develop to its full potential.
Burdensome grid interconnection requirements	Transmission constraints, unfavorable operational policies, and a lack of understanding of the impacts of wind energy on utility grids are major barriers to wind energy development.
Utilization of accessible high wind speed sites	As sites with excellent wind resources close to load centers or existing transmission infrastructure are developed, improvements must be made to allow cost-effective access to sites with lower wind speeds.
Limited transmission infrastructure	Transmission infrastructure limitations hinder the use of high-quality wind resources located far from demand centers.
Challenging regulatory and policy environment	Unclear regulatory approval processes at the Federal, state, and local levels complicate and raise the costs for the development of wind projects.
Increased environmental scrutiny	The impacts of wind turbines on avian and bat populations at some sites have caused concern.
Public acceptance	Some communities object to the real and perceived local impacts of both land-based and offshore wind farms.

Public and policy support for renewable generation in the face of rapidly fluctuating energy prices and environmental concerns develops primarily at the state level. Wind related financial policies include state-sponsored Renewable Portfolio Standards (RPS), generation payments and grants combined with the Federal PTC, U.S. Department of Agriculture (USDA) grants and loans, and new Clean Renewable Energy Bonds (CREB).

By the end of 2006, 22 states and the District of Columbia had RPS requirements that mandate the use of renewable power for a certain portion of the state's needs. Texas leads the way with its requirement of 5880 MW of renewable energy by January 1, 2015. Because wind energy is the least expensive renewable energy technology, it is widely used to supply the burgeoning green credit market and fulfill state-based RPS requirements.

In addition to development of large bulk-power generation, state-based RPS policies have been a major driver for the uptake of distributed wind technologies. As with large wind technologies, research on distributed wind systems has been a part of the program since its inception. Although current research on small wind turbines (less than 100 kW) is expected to be completed in FY 2007, opportunities for wind technology in distributed applications, either connected at distribution voltages or completely off-grid, appear to be substantial.[11] Initial studies conducted by the program indicated that distributed wind technologies, including community, rural business applications, and residential wind should represent more than 5,000 MW by 2020.

Enacted in 1992, the PTC currently provides a 1.9 cent/kWh tax credit for electricity produced by commercial wind generation plants to help them compete with other generation technologies. The PTC has supported the rapid growth in wind power over the past 10 years. It is the principal Federal financial policy responsible for the installation of nearly 12 GW of wind in the United States. As a significant and direct financial incentive, the PTC has dramatically influenced wind energy investment decisions. Although the PTC has stimulated a large amount of wind development, Congress has allowed the PTC to lapse on several occasions, creating a series of biennial boom-and-bust cycles (Figure 3) that have not provided a stable business environment in which companies can thrive. The result has been annual cycles of significant swings in manufacturing demand and turbine installations. Theses swings in demand have discouraged companies from investing in new U.S.-based manufacturing capacity, pushing up costs and subjecting the U.S. market to foreign exchange-related cost fluctuations for equipment imported from Europe. The PTC is currently authorized through calendar year 2008.

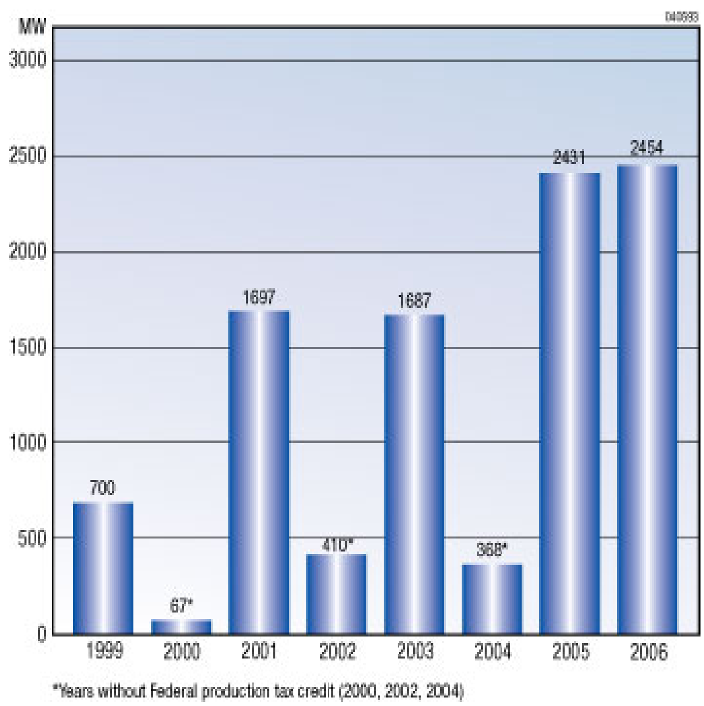

Figure 3. Wind capacity growth slowed drastically during the years when the PTC was allowed to lapse.

[11] U.S. Small Wind Turbine Industry Roadmap. (2002). 36 pp.; NREL Report No. BK-500-31958; DOE/GO-102002-1598 http://www.nrel.gov/docs/gen/fy02/31958.pdf

While the use of wind energy in the U.S. electric sector has increased, wind's use overseas has burgeoned. The European market, especially in Germany, Denmark, Spain, Italy, and the Netherlands has been driven by national policy mandates that provide attractive cost structures for wind-generated electricity. Wind is also a major energy supplier in India and China. The total installed capacity of wind technology worldwide was 71,146 MW at the end of 2006 (Figure 4) based on WindPower Monthly, which shows a slightly different total U.S. installed capacity than estimates completed by DOE and the American Wind Energy Association.

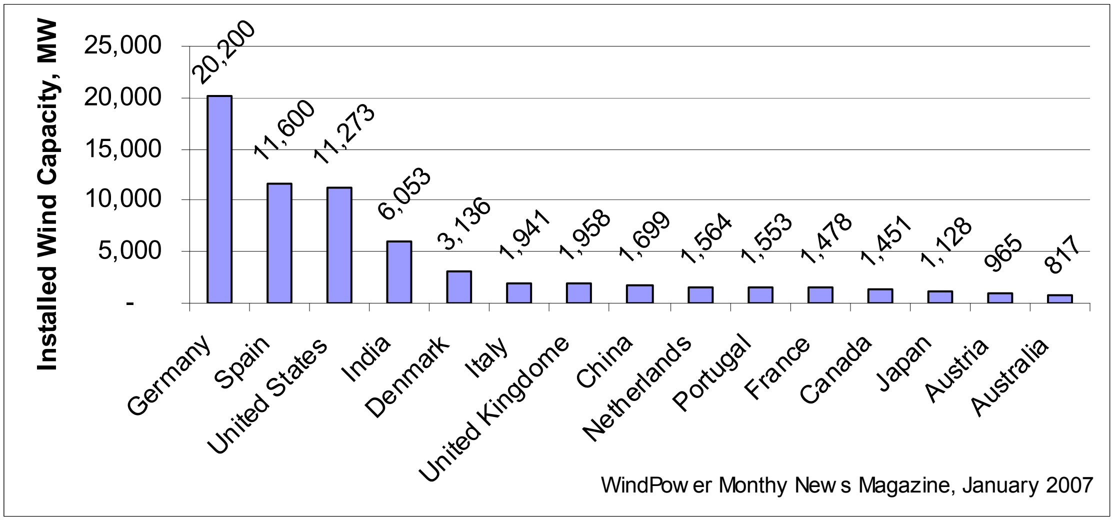

Figure 4. Top 15 countries based on total wind installations

The United States faces many challenges as it prepares to meet its energy needs in the twenty-first century. Electricity supply crises, such as those in California; fluctuating commodity, natural gas, and gasoline prices; heightened concerns about the security of the domestic energy infrastructure and foreign supply sources; and uncertainties about the outcome of electric industry restructuring all present challenges to energy policymakers.

As one of the most viable renewable energy sources on the market today, wind energy can play a strong role in meeting our nation's energy needs, addressing many of the issues currently facing energy policymakers. Studies commissioned by EERE in response to the Government Performance and Results Act (GPRA)[12] show that with the successful implementation of the Wind Energy Program, this clean renewable resource could represent approximately 50% of all new electric generation resulting from the different generation technologies in the EERE portfolio—almost 1000 billion kWh per year by 2050,. This comparison may not be appropriate for some programs focused on conservation or conversion to alternative technologies such as hydrogen; therefore, a comparison on annual CO_2 savings may be more indicative of wind's potentially enormous contribution. Based on the results of the analysis conducted for the FY 2008

[12] Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs FY 2008 Budget Request (2007) NREL Report No. TP -640-41347 http://www1.eere.energy.gov/ba/pdfs/41347.pdf)

budget development, the improvements made through the Wind Energy Program represent 15% of the annual 500 million metric tons carbon equivalent savings expected from all EERE programs. This represents the highest carbon impact within the electric generation portfolio. These results suggest that continuing or expanded investment in wind energy will deliver an increasing return.

Wind energy has a clear role that can help to secure our Nation's energy economy, as has been demonstrated in Europe. In the near term, wind energy will not play a major role in this new economy, but the increases in installed capacity over the past few years indicate that the role will grow over time. Every energy paradigm change requires government understanding of the long-term implications of the change so that critical policy support can be provided during a long transition period. It is appropriate for the Federal Government to facilitate this development with sound technical assistance and R&D to remove barriers that may unnecessarily hinder this technology or the emerging industry.

Historically, Federal and state officials have used research, development, and deployment (RD&D) activities combined with financial or other policies to enhance market acceptance of new technologies. In the wind industry, RD&D has been primarily directed at reductions in the cost of the technology for both central station and distributed technologies and removing barriers to its deployment. Policy has focused on financial incentives such as the PTC to help level the playing field from a cost perspective, or state-based RPS that encourage use of the technology. These activities increase installed capacity and promote public acceptance.

As a technology becomes commercial, the greatest economic efficiency is found in an approach which balances RD&D and policies that push the technology to become competitive while encouraging adoption. For this reason, both R&D and policy support are required until wind technology can be considered mature and the need for this external support disappears.

Some have argued that the strength of the wind market, in which almost 2500 MW have been installed in the last two years, indicates that the wind industry no longer needs RD&D or policies that level the playing field. The following points illuminate the need for a continued Federal role in wind technology RD&D.

- U.S. wind energy capacity at the end of 2006 was 11,604 MW, which is less than 1% of total installed generating capacity. Given this small installed capacity, wind obviously is not a mature technology. The premise that wind is mature is likely due to comparison with other renewable energy technologies, among which wind is more mature than the others. However, compared to conventional energy technologies, wind power receives minimal support. The Federal Government expects to spend over $10 billion on clean coal technology through 2020. The clean coal industry makes up slightly more than 50% of the nation's installed capacity. The nuclear industry represents almost 20% of installed capacity, and continues to receive extensive Federal support. Arguments that wind technology should no longer receive Federal support should be assessed in relation to all generating technologies, and not simply other renewable technologies.

- Testing wind turbines and their components for land-based, offshore, and small, distributed wind applications is required to reduce commercial risk and satisfy international and national standards. Testing centers are needed to conduct controlled research on turbine operation and use. For example, wind turbine blades are designed to withstand 20 years of high operating loads, far beyond the service life of other large structures subjected to high strains. The implementation, operation, and maintenance of test facilities require an investment in infrastructure, testing equipment, and personnel that no single industry member could sustain. Federally led, public-private partnerships (for example, the FutureGen coal technology research facility) are typically required to implement the large capital projects that enable the technology and market to develop.
- The characteristics and availability of national resources must be known for renewable-based technologies to become widely used. More information is needed about wind conditions over the United States. This information is crucial given the size of modern wind turbines and the potential market for small turbines. Atmospheric conditions such as low-level jets, low-speed turbulence, and nighttime air disturbances are not well enough understood to allow industry to define technology and siting needs. Research into these conditions has national level implications; it applies to the whole market, and can be compared to the U.S. Geologic Service's assessment of the Nation's oil and gas reserves.
- One reason for the rapid decrease in the cost of wind technology is the development of advanced wind turbine design software that has been made available to the wind industry through government laboratories. These tools have allowed industry to accurately assess the loads on wind turbines and model computer-based conceptual designs. The tools must be improved to allow accurate modeling and assessment of industry technology trends, and to allow government researchers to model different technology options, assess their potential for performance improvements, and direct Federal research. Model development and validation cannot be completed by the private sector because of obvious intellectual privacy concerns.
- Promising future technologies such as offshore wind power, conversion of wind power to hydrogen, and expansion of vehicle-to-grid and wind-to-vehicle technology all require high-risk, long-term research to enable commercial success. The Federal Government, and specifically DOE, plays a role in supporting high-risk basic energy research that may not have near-term impacts but has promising long-term potential.
- Federal organizations play an important role as an impartial independent technical advisor to facilitate discussion and help protect and educate the public. Corporate organizations and trade associations are often considered to be biased, and neutral parties are essential in providing balance in often contentious discussion on costs and benefits.
- Wind technologies raise a number of technical and social issues that must be addressed by other governmental institutions. State officials, other Federal agencies, Native American organizations, regulators, and the regional power administrators must have technical assistance to evaluate wind technology. DOE has a responsibility

to provide energy-related support to these and other governmental organizations, for wind and other technologies.

- Many of the implementation issues and barriers that hinder wind technology development cross state boundaries, and therefore, require Federal facilitation and support. The state-by-state approach to development has national implications, and a lack of Federal assistance and supervision would hamper technology acceptance.
- The domestic small-wind market does not have the capital support currently found in the large-wind market; therefore, support in the development of more reliable, more efficient and lower cost distributed wind technologies requires further assistance until the key issues are sufficiently documented to attract private equity. This becomes more critical due to the current dominant role that U.S. suppliers have in the international small-wind market, a dominance that is being eroded by expanded technology development support from other governments.

Wind energy can play an important role in reducing the nation's dependence on imported fuels, preserving the environment, and reducing the potentially devastating impact of global climate change – and it can do all this without adversely impacting consumers' pocketbooks; a true win-win-win scenario. Because of national and international interest in this capability, wind power is becoming a strong player in the world's power markets.

However, the implementation of a new technology paradigm is always difficult. Federal organizations have an important role to play in the transition to new generating technology. Through continued properly targeted and managed Federal support, the United States can lead and take advantage of this paradigm change. The 2005 Annual Energy Outlook (AEO)[13] shows that by 2015, wind energy will be less expensive than nuclear, and practically the same price as energy from natural gas and coal, even though prices for these fuels are estimated to be less than today's in nominal dollars. Even with these conservative estimates, wind energy is expected to have a large market presence. The AEO and GPRA[14] analyses indicate that without continued Federal support, implementation of wind technologies will be significantly reduced, showing a direct link between continued support and adoption of the technology by the energy sector and the general public.

[13] *2005 Annual Energy Outlook*, Energy Information Administration, http://www.eia.doe.gov/oiaf/aeo/index.html

[14] *Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs, FY 2006 Budget Request*, National Renewable Energy Laboratory, May 2005, NREL/TP-620-37931. http://pix.nrel.gov:8020/BASIS/nich/www/nrel/SDF

1.3 Program Vision

The Presidential Advanced Energy Initiative (AEI)[15] presents a vision for the future development of wind energy by stating:

> *"Areas with good wind resources have the potential to supply up to 20% of the electricity consumption of the United States,"* and increased federal funding *"… will help improve the efficiency and lower the costs of conventional wind turbine technologies; it will also help develop new small-scale wind technologies for use in low-speed wind environments."*

Following the guidance of this document, and building on the domestic energy focus of EPAct 2005, the Wind Energy Program has developed a new direction for the development and deployment of wind technologies. In conjunction with AWEA and NREL, the program launched an effort to assess the potential for and impact of providing 20% of the Nation's electrical energy from wind technology. The Wind Vision Report, the initial document developed by this collaboration, will be released in the summer of 2007. The goal of the collaborative is to rigorously investigate the viability of a vision that includes the production of 20% of the Nation's electrical energy needs from wind technology. Following rigorous analysis and investigation of all major facets of the U.S. energy system, from power transmission to consumer acceptance, this collaborative of over 75 participating organizations has proven that wind energy can provide 20% of U.S. electricity needs by 2030, securing America's leadership in reliable, clean energy technology. The collaborative's report describes how as an inexhaustible and affordable domestic resource, wind strengthens our energy security, improves the quality of the air we breathe, slows climate change, and revitalizes rural communities.

At 20% penetration of the electric sector, wind will produce about 1,200 terawatt-hours (TWh) of the Nation's electrical energy each year, eliminating 1,925 million metric tons of carbon equivalent through 2050 – equivalent to the carbon dioxide produced by the whole transportation sector during 3-1/2 years. This would also lead to approximately 332 billion dollars in economic investment and more than 2,750,000 full-time equivalent job years, largely in rural areas, for construction and plant operation over the 20-year expected operational life of each project. Many states in the Great Lakes and southeast regions could benefit dramatically from turbine component manufacturing, with 20 states gaining 20,000 or more manufacturing jobs. According to current estimates, the cost of producing 20% of the nation's energy from wind in 2030 would add less than one dollar to the monthly electricity bills of a median American household, and could reduce the cost of natural gas used for heating by as much as 20% by reducing natural gas demand. The Wind Energy Program embraces this vision of the future of wind energy.

As the DOE Wind Energy Program plans for wind technology development, it appears that the technology will take three development paths: large land-based technology,

[15] Advanced Energy Initiative, http://www.whitehouse.gov/stateoftheunion/2006/energy/energy_booklet.pdf; page 13, 2006.

distributed wind technology, and emerging applications, as shown in Figure 5. Each of these paths presents unique technology challenges and non-technology barriers.

The land-based electricity path, which is a priority for the program, is expected to result The land-based electricity path, which is a priority for the Program, is expected to result in cost-competitive 2- to 5-MW turbine technology by 2012. Land-based activities have focused on development of technologies that can operate cost effectively at low wind speeds, and on improving the reliability and performance of turbines in higher wind speeds. Two basic drivers contribute to the cost of wind energy: the wind resource and transmission. Figure 6 shows the supply curve for the U.S. wind resource, detailing over 12,000 GW of potential at a cost below $0.14 cents/kWh, excluding the cost of transmission and siting factors that will limit the use of these resources. As the high wind resource locations close to loads or accessible transmission are developed, projects must move into lower resource sites and pay for the development of expanded transmission infrastructure, which increases the price of power. Figure 7 shows the supply curve with transmission costs included.

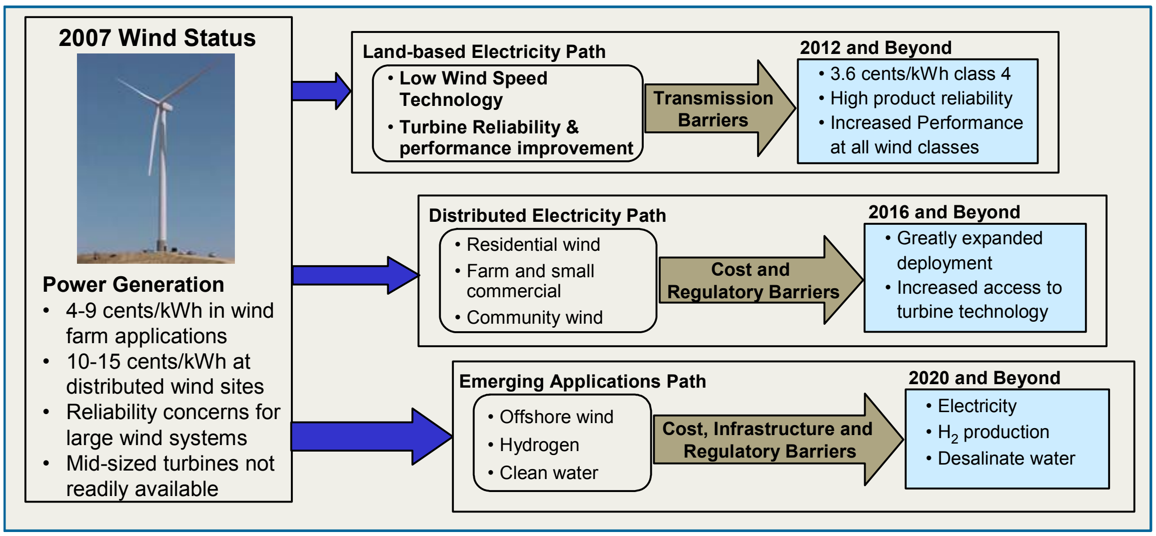

Figure 5. Three evolution pathways for wind technology development.

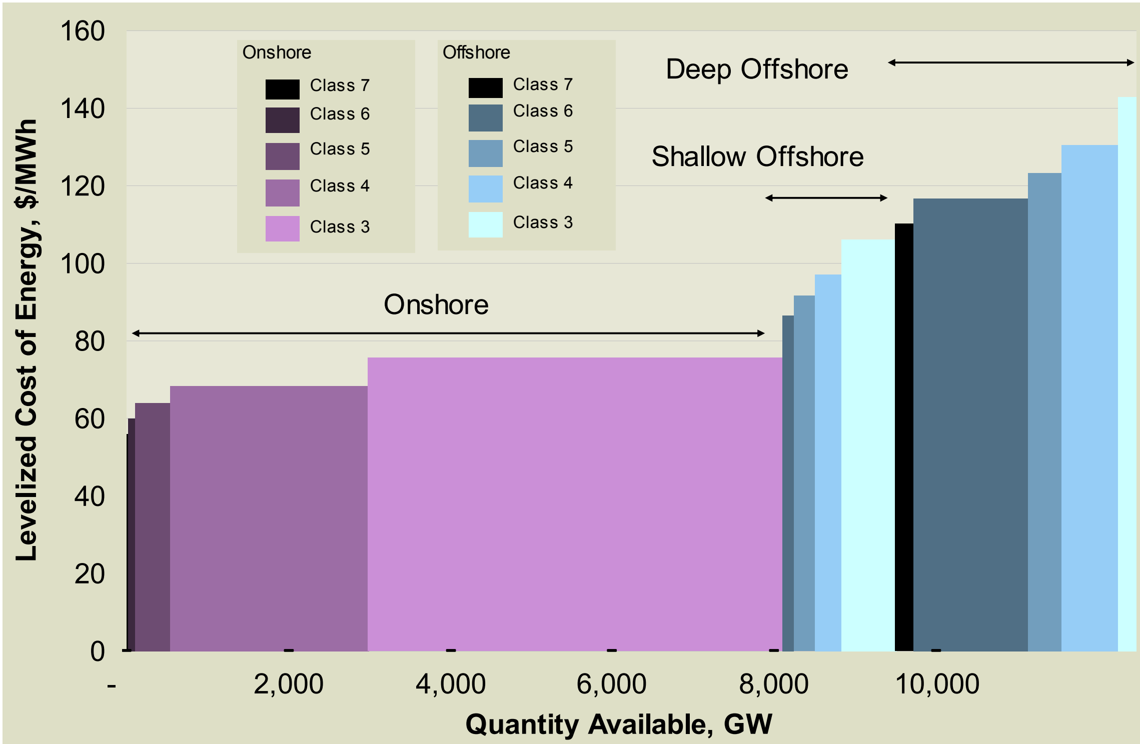

Figure 6: U.S. wind supply curve, no transmission cost (with PTC).

As the total cost increases, work to keep the cost competitive must focus on four areas:

1. Expanding the Nation's transmission infrastructure without placing the full burden of this expansion on wind project developers
2. Reducing the cost of energy from high wind resource sites through reliability and performance enhancement, to allow for higher transmission costs
3. Furthering the development of distributed wind technologies to allow communities, rural businesses, and residents take advantage of local wind resources.
4. Making lower wind resource or offshore sites cost-competitive to circumvent the need for expanded transmission.

The first option focuses on the development of energy infrastructure and is more related to policy development than R&D, especially from the perspective of the Wind Energy Program. The final three avenues follow an R&D-based technical approach, in which the cost of wind energy at all sites is reduced to allow energy to be delivered cost–competitively, first with, and later without, support of incentives such as the PTC.

Figure 6 shows that at high wind resource locations (Class 6 and above) approximately 60.7 GW of potential can be developed at relatively low cost of below 8.0 cents/kWh without the PTC or other incentives. Class 3, 4 and 5 sites allow the development of an additional 307.9 GW. Although these estimates already eliminate resources that are clearly unsuitable for development, such as National Parks, some portion of the remaining resource will not be developed due to other siting, public acceptance, or permitting issues. Additionally, because of the geographic spread of the resources and regulations governing the electric sector, the ultimate barrier to the use of this technology is the integration of wind into the Nation's electric system.

Figure 7 shows that reaching 20% energy penetration from wind, which is estimated to require approximately 330 GW of installed capacity, will require the development of Class 4 and above sites, both land-based and offshore. The economic viability of these lower wind resource sites would open up vast resources to wind development and bring wind-generated electricity closer to major load centers. Figure 8 shows the magnitude of lower wind speed sites, and illustrates the 20-fold greater potential for wind in the United States if these sites can be used cost-effectively. These sites are closer to major load centers than Class 6 sites. The average distance between Class 6 resource areas and the 50 largest load centers is nearly 500 miles, while the average distance for most Class 4 sites is about 100 miles.[16]

Along with wind technology for large bulk-power generation facilities, distributed wind technologies have been a part of the program since its inception. Although current research on small wind turbines (less than 100 kW) is expected to be completed in FY 2007, opportunities for wind technology in distributed applications, either connected at distribution voltages or completely off-grid, appear to be substantial[17].Technology options such as off-grid water pumping for crop irrigation, residential-scale wind turbines, community wind, or hybrid wind-diesel applications show great potential for engaging local populations in addressing America's energy future. The absence of detailed studies makes this market hard to assess, but indicators suggest that broadening distributed technologies R&D from small wind turbines may be advisable because community wind and larger distributed applications may require turbines of 100 kW to 1 MW. These turbines are not currently available from U.S. companies. The program will continue to monitor this market and determine whether developing technologies for this market is appropriate.

[16] Goldman, P., et. al. Advanced Low Wind Speed Technology Research and Development in the U.S. Department of Energy Wind Program, Proceedings of the 2002 Global Windpower Conference, Paris, France, April 2002. (Available on request)
[17] U.S. Small Wind Turbine Industry Roadmap. (2002). 36 pp.; NREL Report No. BK-500-31958; DOE/GO-102002-1598 http://www.nrel.gov/docs/gen/fy02/31958.pdf

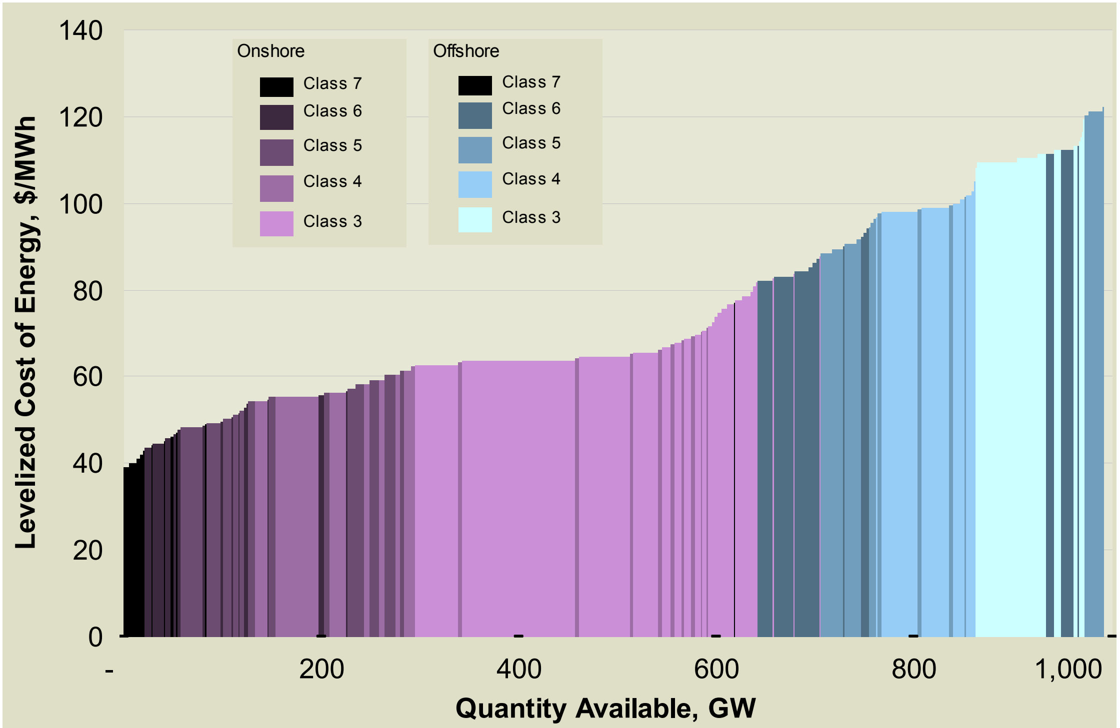

Figure 7: Wind energy supply curve, including transmission costs (2005 costs and performance, with PTC)

Given the program realignment and overall budget priorities, the program is placing less emphasis on offshore generation R&D activities. Through 2009, the program's offshore wind technology priorities are to better understand the challenges and benefits of developing the Nation's offshore resources, and to work with other Federal organizations, such as the Mineral Management Service, to produce a regulatory framework for future development. Although there are a large number of positive aspects of offshore wind energy, such as the proximity to coastal load and access to large-scale transmission, there are also issues, such as increased costs, higher risk, and the general availability of good land based resources, that might deter the market. Because of these issues, a programmatic decision will be made in FY 2009 to determine if there is sufficient market interest and a defined government role to support offshore wind. If government can play a role, the program will launch a series of phased public-private partnerships for offshore wind technologies, similar to those successfully employed for land-based applications.

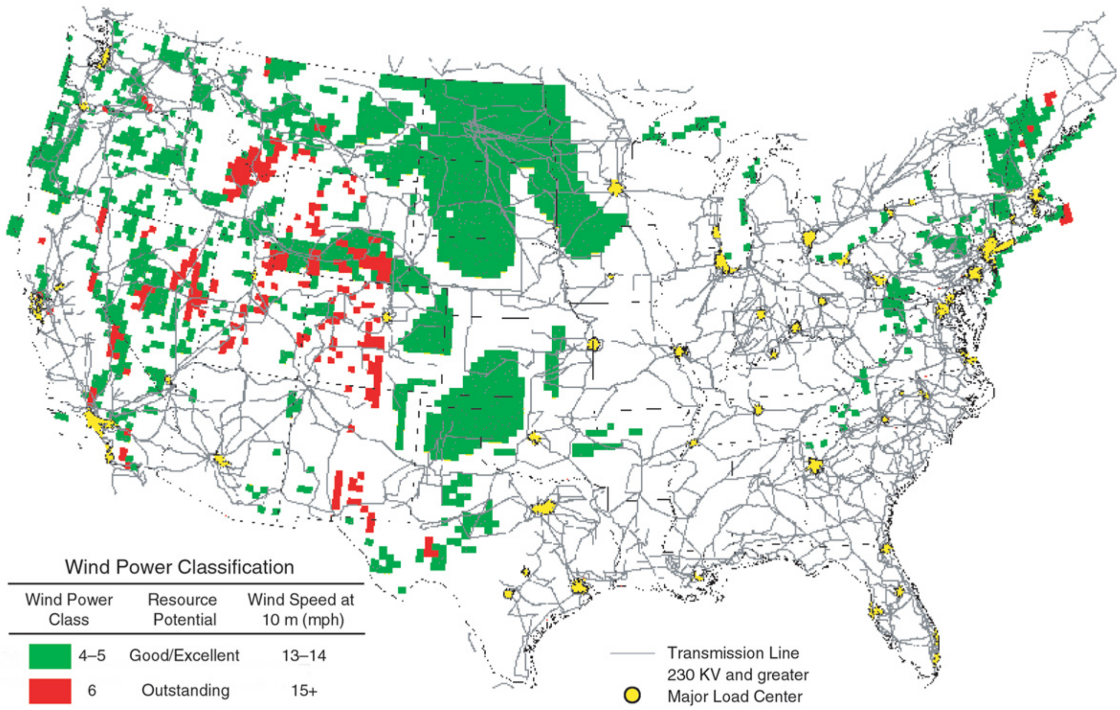

Figure 8. Wind resource, transmission, and load centers

The emerging applications path leads to tailoring of wind energy for emerging applications, such as expanded transitional and deepwater offshore technologies, hydrogen production, production and delivery of clean water, and integration of wind with other energy technologies such as hydropower. The huge transitional and deepwater offshore resource provides an opportunity for the production of power that is close to load centers, out of public sight, and has low environmental impacts, if it can be developed at a competitive cost with acceptable operational risk. Hydrogen production would enable wind to provide low-cost clean energy for the transportation sector. Finally, water is becoming a critical issue in America's west, providing a major opportunity for wind technologies both on and off the grid. Wind energy uses no water, and it can reduce the use of fossil-fueled power generation that consumes between 400 and 600 gallons of water per megawatt-hour. 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 evolutionary pathway will begin to impact the marketplace after 2020.

Each of the technology pathways will require the program to address specific acceptance barriers. The program will continue to coordinate technical and acceptance activities as each of the new pathways is developed and implemented.

1.4 Program Mission

The Wind Energy Program's mission is to:

> "*support the President's National Energy Policy and Departmental priorities for increasing the viability and deployment of renewable energy; lead the Nation's efforts to improve wind energy technology through public-private partnerships that enhance domestic economic benefit from wind power development; and coordinate with stakeholders on activities that address barriers to the use of wind energy*."

To achieve the mission as stated in the NEP, the Wind Energy Program will conduct near- and long-term research to solve technology issues and maintain U.S. industry momentum as a technological innovator. The program will also work with the wider energy industry, governments at the state and Federal levels, and the public to ensure that wind technology is assessed fairly based on its benefits and impacts when compared to other alternative and conventional energy generation technologies. Through research on transmission, system integration, and technology acceptance, the program will work to remove barriers that limit the widespread adoption of wind technology.

The natural variability of the wind resource raises concerns about how wind can be integrated into routine grid operations, particularly with regard to regulation, load following, scheduling, line voltage, and reserves. A lack of information in these areas is inhibiting market acceptance and hindering development. Through close collaboration with industry, utilities, and government organizations at the state and Federal levels, the program is addressing wind turbine interconnection issues and the transmission of wind energy from rural wind resources to regional or national load centers. This process provides tools, clear information, and documented experience to a wide range of stakeholders in the energy community, so that educated decisions can be made regarding the use of wind technologies.

Wind energy acceptance is largely achieved through outreach activities at the state and local level. The program's Wind Powering America project eases market barriers through outreach, policy support, and the development of informational documentation regarding the benefits and impacts of wind technology, and seeks to enable a sustainable U.S. wind market beyond states with significant installed capacity, stimulate rural economic development through project development, enhance tribal energy self-sufficiency, and explore emerging markets and applications. Although closely aligned with the program's system integration activities, the activities conducted through the Wind Powering America project strive to address more general concerns with the use of wind technology.

In addition, the program supports the development of the industry-led Wind Vision Report that considers the possibility and impacts of generating 20% of the nation's electric generation from wind sources by 2030.

1.5 Program Design

The Wind and Hydropower Technologies Program was created as a result of a reorganization of EERE, which combined the wind and hydropower program areas. The two formerly separate programs have an integrated management structure, with similar program structures devoted to the Department's two key priorities of increasing the viability and application of renewable energy. Integrating the programs provides opportunities to use both established renewable energy technologies synergistically. Hydropower resources can be operated to provide an element of dispatchability to wind power, while wind power can support innovative strategies to balance power production with agricultural and environmental interests. Although DOE has concluded most of its activities in the area of hydropower technologies, leaving further development to industry, the program is researching the potential for synergies of wind and hydropower. The program will continue to assess hydropower opportunities, including but not limited to pumped hydro and promising wave, tidal, and ocean current energy technologies.

1.5.1 Program Structure

The Wind Energy Program undertakes two key activities to carry out its mission: increasing the technology viability (TV) of wind systems through technology R&D, and increasing wind energy deployment in the marketplace through technology acceptance (TA) activities. Figure 9 depicts the four primary activities within these two key areas that comprise the Wind Energy Program.

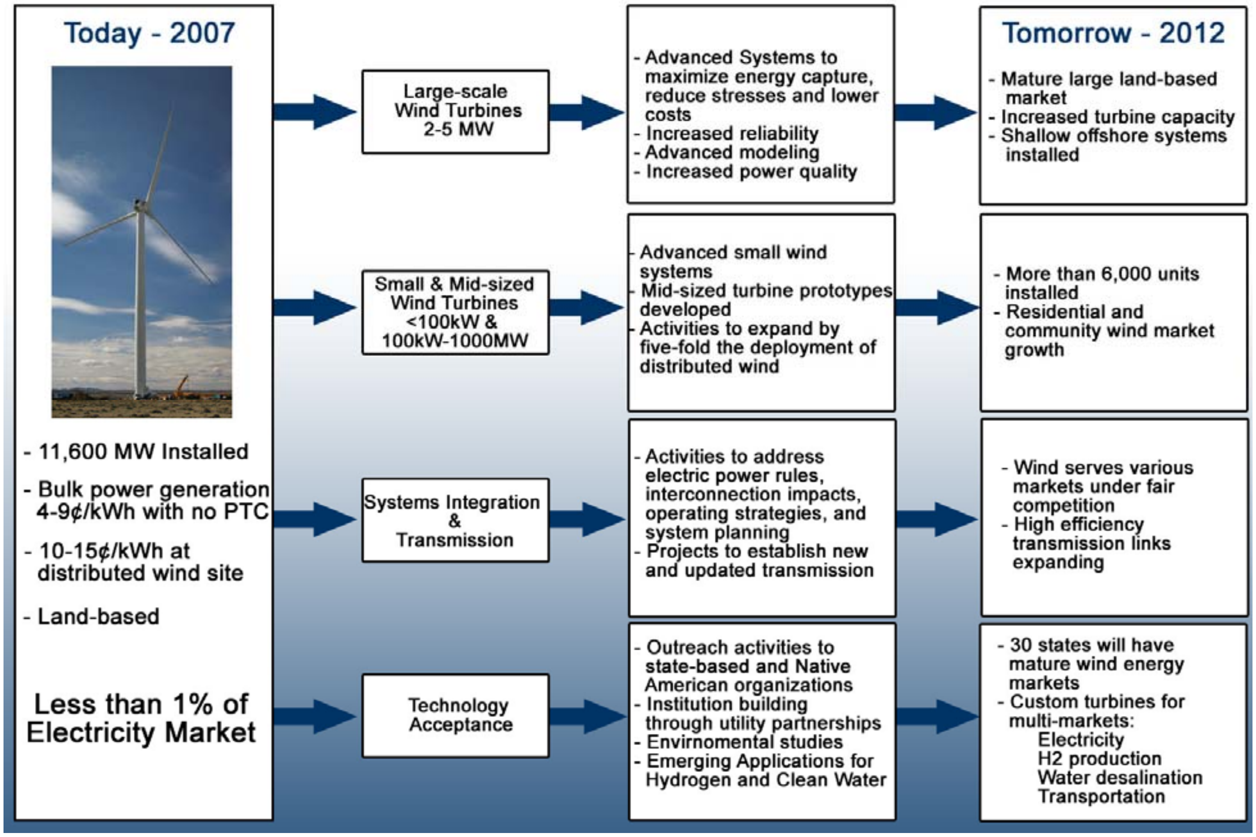

Figure 9. Key program activities.

Under Technology Viability, the program sponsors R&D on large-scale wind technology (LWT) and smaller distributed wind technology (DWT). Under Technology Application, the program sponsors research on transmission and systems integration (SI) and the more general technology acceptance (TA) outreach activities. The program also conducts supporting research, development, and application testing to align program efforts with the key activities and the goals that they support.

1.5.2 Program Logic

The program logic model in Table 2 provides a brief overview of the program's key activities and demonstrates how they are designed to meet overall program goals.

Table 2. Program Logic Model for Wind Program				
Project	**Large Wind Turbine Technology**	**Distributed Wind Technology**	**Transmission & System Integration**	**Technology Acceptance**
Resources	• Appropriations • Industry cost sharing • NWTC facilities • IEA	• Appropriations • Industry cost sharing • NWTC facilities	• Appropriations • State funds • Partners	• Appropriations • State funds (energy offices) • Partners
Activities	• Technology development through public-private partnerships. • Supporting research and testing. • Reliability and performance improvement for existing turbine technologies. • Low wind speed technology development. • Offshore wind and resource assessment.	• Technology development through public-private partnerships. • Supporting research and testing.	• Wind generator modeling. • Wind farm data monitoring. • Resource characterization. • Grid operational impact analysis. • Transmission and generation planning. • Grid rules development. • Institution building through utility partnerships.	• Outreach to state-based organizations. • Small wind. • Institution building through utility partnerships. • Support for Native American interest in wind power. • Environmental and siting mitigation. • Emerging applications. • Resource Assessment.
Outputs	• New components, concepts and wind systems for land-based applications in Class 4 wind regimes. • Basic research tools to assist industry. • COE 3.6 cents/kWh in Class 4 wind by 2012. • Better understanding of offshore wind energy market and technical challenges. • COE 5 cents/kWh in Class 6 wind in shallow water by 2014.	• By 2015 expand by five-fold the number of distributed wind turbines deployed in the U.S. market from a 2007 baseline. • New components, concepts and wind systems for applications of less than 100 kW. • Development of wind turbines to support mid-sized market applications.	• Ability of wind systems to compete without disadvantage in key areas of market rules, interconnection impacts, operating strategies, and system planning. • Development of new transmission to facilitate wind development.	• 30 states with mature markets that support wind industry growth. • Technical and outreach support widely available. • Fewer barriers to large and small wind integration.
Short-term Outcomes 2007–2010	• The use of wind energy in high and low resource areas accelerates due to their improved cost effectiveness.	• Wind turbines for residential (1-2 kW) use and commercial/ community applications (100 kW and above) enter the marketplace.	• Wind becomes a participant in defining the national needs of emerging grid operation and rulemaking processes. • Announcement of 3 new transmission lines to bring low-cost wind to urban load centers.	• 30 states achieve a level of public awareness and policy environment that fosters a vibrant market for wind energy development.
Intermediate Outcomes 2010–2020	• The use of wind energy as a low-cost electricity source, without financial incentives, becomes widespread as technology matures. • Commercial development of shallow water technologies. • Commercial wind turbine technology for transitional water depths is developed and demonstrated in offshore sites.	• Distributed uses of wind energy at all sizes emerge as a significant opportunity for technology deployment and end-users embrace wind for a growing number of uses.	• Utilities and developers gain clear understanding of barriers to integration and know how to address them. • Increased transmission implemented allowing the expanded use of wind technologies.	• Public acceptance of wind technologies in rural areas, supporting local economic development. • 6-8 regional wind collaborative organizations emerge and function to plan and integrate appropriately large amounts of wind energy into regional operating systems.
Long-Term Outcomes and Problem Solutions 2020 and beyond	• The percentage of energy generated from wind exceeds 10%, confirming wind as a major National energy source. • Wind turbine technology for use in deepwater offshore applications is proven economic and becomes a major new electricity source for states bordering coastal zones.	• Wind turbines for emerging applications become available and gain acceptance for specialized uses such as hydrogen production and water supply.	• Wind achieves high grid penetration level and is a nationally accepted part of our energy portfolio. • National transmission infrastructure allows high levels of wind penetration.	• Awareness and acceptance levels are achieved nationally, making further coordination efforts unnecessary.

1.5.3 Relationship to Other Federal Programs

In seeking to lower barriers to the deployment of wind energy, the Wind Energy Program has developed key working relationships with other EERE, DOE, and Federal programs. Each of these organizations has a unique role to play in making wind a part of the National energy supply portfolio.

Because the Federal government is the largest user of energy in the world, its use of wind power can play an important role in expanding wind markets. Federal facilities are beginning to look to wind as a source of clean power. In general, Federal facilities are not owners of wind plants, but agree to purchase power from those plants. The Wind Energy Program works with the Federal Energy Management Program (FEMP) to foster use of wind power by Federal agencies.

The program has also forged numerous partnerships with other Federal agencies as it pursues the grid integration needs of the wind community. For example, the Wind Energy Program worked with the Office of Electricity Delivery and Energy Reliability to prepare a joint report to Congress[18] on the location of wind resources in the upper Midwest. The report is being extended to include the expansion of the National transmission infrastructure to bring large amounts of low-cost wind energy from rural areas to national load centers.

In addition, the SI staff work with other Federal entities, such as the Bonneville Power Administration (BPA) and the Western Area Power Administration (Western), to understand both general regional wind integration issues and wind-hydropower integration issues. Program and laboratory staff members have worked with staff members from the Federal Energy Regulatory Commission (FERC) to help them better understand wind energy characteristics (FERC provides oversight to the national grid system and establishes rules for the future grid treatment of wind).

The program has become increasingly involved in environmental issues associated with siting for both land-based and offshore projects. A key example of this is the program's collaboration with the Federal Aviation Administration, Department of Homeland Security, and the Department of Defense (DoD) to address issues with wind turbine/radar interactions. This has lead to the development of an interagency collaboration on wind turbine siting. Program members are also working with the Department of Interior's (DOI's) Minerals Management Service (MMS) to coordinate interagency efforts to open Federal lands to responsible renewable energy development and develop a regulatory framework directly applicable to offshore wind energy projects in Federal waters. Similarly, the program is partnering with the DOI Bureau of Land Management (BLM) to develop resource assessments and to design and implement policies and procedures to open BLM-managed lands to responsible wind energy development, primarily in the western United States.

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[18] *Analysis of Wind Resource Locations and Transmission Requirement in the Upper Midwest.* June 2004, http://www.nrel.gov/wind/uppermidwestanalysis.html

An important success related to public lands was achieved in 2003 when the BLM adopted procedures that include wind in BLM's long-term land plans and allow programmatic environmental impact statements to streamline siting processes. These changes, advocated by the Wind Energy Program and officially supported via technical assistance and funding, should facilitate the use of wind power on Federal lands. This effort will also serve as a model for other Federal agencies, such as the U.S. Forest Service and USDA, and for state public lands administrators.

The program cooperates with the DOI Fish and Wildlife Service (FWS) to examine and develop responsible development practices for species under its stewardship. It participates in an FWS, industry, and environmental stakeholder partnership to study wind-bat interactions in the mid-Atlantic region.

To reduce market barriers, the program has been cooperating with the USDA's Rural Business-Cooperative Service to provide outreach and technical assistance in support of Section 9006 of the Farm Bill, which provides grants to rural small businesses to stimulate investment in renewable energy and energy efficiency systems.

In emerging applications, the program is participating in the Sustainable Water Resources Roundtable, which is composed of government (DOE, USDA, Army Corps of Engineers, DOE, Environmental Protection Agency [EPA], National Oceanic and Atmospheric Administration [NOAA], and states), industry, environmental, public interest groups, and academic representatives. Program members have also had discussions with the U.S. Bureau of Reclamation about partnering on wind-powered desalination.

Program members coordinate with the DOE Hydrogen Program to ensure that wind-generated hydrogen is included in that program's planning. NREL's National Wind Technology Center (NWTC) staff is working with the Hydrogen, Fuel Cells, and Infrastructure Technologies Program (HFCITP) to test electrolyzers operating with variable power input, which could be a future wind application. The Wind Energy Program also coordinates the response to informational requests regarding wind and hydrogen as a result of EPAct 2005.

Working relationships with Federal programs and agencies outside of DOE are required to overcome specific technical barriers, because these organizations have critical technical skills. For example, NOAA, which operates the Forecast Systems Laboratory (FSL) in Boulder, Colorado, works with Wind Energy Program researchers to develop advanced forecasting techniques and products using the FSL's state-of-the-art numerical weather prediction model. At the USDA's Agricultural Research Center in Bushland, Texas, the program sponsors wind technology development for agricultural applications, such as irrigation and farm power, and for hybrid systems (e.g., wind-diesel) for distributed and remote applications.

As part of its TA effort, the program also works with NWCC and UWIG to form partnerships with public power organizations, such as the American Public Power

Association (APPA) and the National Rural Electric Cooperative Association (NRECA), to build momentum for utility acceptance and support for wind-grid integration.

1.6 Wind Energy Program Goals and Multiyear Targets

The DOE Strategic Plan, published in 2003,[19] describes four strategic goals that support the Department's mission. These goals are in the areas of defense, energy, science, and the environment. The energy strategic goal is directly relevant to the Wind Energy Program. All of the Wind Energy Program's efforts support that goal, as shown in Figure 10.

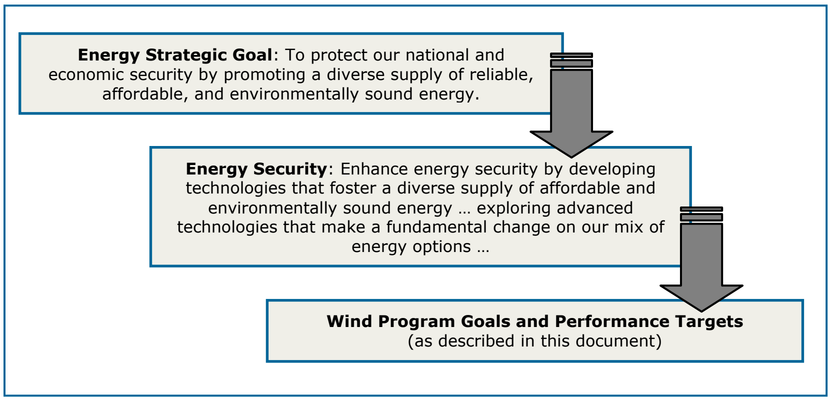

Figure 10. Relationship of Wind Program goals to DOE strategic goals.

EERE leads the Federal Government's RD&D efforts in energy efficiency and renewable energy. EERE's Strategic Plan, published in 2002,[20] describes nine strategic goals. These include reducing dependence on foreign oil, reducing the burden of energy prices on the disadvantaged, increasing the efficiency of buildings and appliances, reducing the energy intensity of industry, and creating a domestic renewable energy industry. Most relevant to the Wind Energy Program is the priority to:

> *Increase the viability and deployment of renewable energy technologies, by improving performance and reducing costs, and by facilitating market adoption of renewable technologies.*

1.6.1 Program Strategic Goals

"By 2016, complete program technology R&D, technical support, collaborative efforts, and outreach needed to overcome barriers (energy cost, energy market rules and infrastructure, and energy sector acceptance) to allow wind energy to compete with conventional fuels without disadvantage in serving and meeting the Nation's energy needs."

[19] The Department of Energy Strategic Plan, August 6, 2003, http://www.nti.org/e_research/official_docs/doe/doe080603.pdf
[20] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy Strategic Plan 2002, http://www.eere.energy.gov/office_eere/strategic_plan.html

1.6.2 Program Performance Goals

The program has defined performance goals shown in Table 3 for its TV and TA activities that will position wind as an attractive advanced technology option for the twenty-first century.

	Table 3. Performance Goals
2007	• Reduce the cost of electricity from distributed wind systems to 10-15 cents/kWh in Class 3 wind resources.
2010	• Facilitate the installation of at least 100 MW of wind energy in 30 states.
2012	• Reduce the cost of electricity from large wind systems in Class 4 winds to 3.6 cents/kWh for onshore systems.
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.
2014	• Reduce the cost of electricity from large wind systems in Class 6 winds to 7 cents/kWh for shallow water (depths up to 30 meters) offshore systems (from a baseline of 9.5 cents/kWh in 2005).
2015	• Expand the number of distributed wind turbines deployed in the U.S. market fivefold from a 2007 baseline.

Life cycle cost of energy (COE) has been adopted by the Wind Energy Program as the primary means of measuring the program's progress toward achieving its goals. This methodology is consistent with that used in other bulk power generating technologies, such as coal or nuclear. The specific methodology used for calculating COE for onshore and offshore installations is described in the draft version of the *Primer: The Wind Energy Program's Approach to Calculating Cost of Energy*. In this methodology, all costs are presented in fixed-year dollars to aid in comparison between different technologies and to remove price fluctuations over time due to inflation and commodity price changes. It should be noted that the COE reported here does not represent a market cost, but rather a cost-based technology metric used to track long-term progress toward the program's technology-based goals. The COE targets differ from actual market conditions, as baseline technology assumptions do not include such factors as the on and off nature of the PTC that leads to turbine demand spikes; changing financial variables such as interest rates; fluctuating commodity prices and currency exchange rates; and changes in expected equipment life. The real cost of power from wind energy varies between 4 and 12 cents/kWh, depending on the resource and the specific financing structure of the specific project.

1.6.3 Program Multiyear Targets

Program Outputs
The outputs for the Wind Energy Program are the Joule milestones designated annually for each program area. (Joule is a system used by DOE to track the progress of technology programs.) Successful achievement of the milestones provides new components and systems that position the wind industry to compete without subsidies in the full range of U.S. electricity markets. Past milestones led to the development of General Electric's (GE's) highly successful 1.5-MW S-Series turbine that supplied more than half of the capacity added to the grid in 2003. Achievement of 2004 milestones accelerated the development of a 2.5-MW Liberty turbine for Clipper Windpower, which began manufacturing in 2005 and full-scale production in 2006.

For TA, the expected outputs will be in the form of information and technical support needed to address integration barriers such as market rules, interconnection impacts, operating strategies, and system planning, as shown in Table 5. In addition to reducing integration barriers, the program is addressing more general legal, institutional, and zoning barriers, allowing informed decision-making in processes that evaluate wind for land-based, offshore, and distributed applications.

Table 4. Technology Viability Outputs 2007 - 2012

- Expanded turbine performance and reliability improvements implemented in turbine technology for all wind regimes.
- Complete field-testing performance documentation of the sub-scale wind turbine research-blade series
- Continue collaboration with wind plant operators to determine operations and maintenance experience and target reliability enhancements
- Complete tradeoff studies for offshore wind turbine systems while developing information required for the program to make an accurate assessment of further DOE involvement in the 2009 timeframe.
- Fund a second round of small wind turbine concept, component, and system prototype projects that focus on improving product reliability, performance, and cost.
- Issue a solicitation for prototypes aimed at improving cost and performance for larger turbines to support the wider distributed wind market.
- Initiate laboratory and field-testing activity to verify distributed wind technology's ability to meet the requirements of state and other renewable incentive programs.

Table 5. Technology Application Outputs 2007 - 2012

- Conduct large-scale wind plant operational studies in conjunction with regional transmission system, utility, and wind plant operators.
- Develop mitigation strategies and guidelines for adverse impacts for use by regional transmission organization staff and wind plant operators.
- Evaluate simulation tools developed to represent several geographically diverse wind plants connected to the same power system to provide an analytical basis for integration of larger amounts of wind energy.
- Launch a new regional wind support effort with expanded support for state wind working groups, tribal wind energy development projects, partnerships with agricultural sector organizations, and community and rural school wind projects.
- Increase efforts to assess and mitigate environmental impacts of wind turbines by funding collaborative research activities such the Grassland and Shrub-Steppe Species Collaborative; working with Department of Interior to develop siting guidelines; and producing technical and outreach materials on environmentally sensitive ways to develop wind.

Program Outcomes

The Wind Energy Program will contribute to our national security and economy, while benefiting the environment. The Great Plains region, which has been dubbed "the Saudi Arabia of wind" because of its tremendous untapped wind energy potential, offers domestic energy that can increase our national energy security and strengthen our energy infrastructure by diversifying our energy supplies. Reliance on 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 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 NEMS-GPRA 06 model[21], with the realization of the Wind Program's goals, wind energy will displace 2.29 quadrillion Btu (equivalent to 298 GWh) of non-renewable generation per year by 2020.

The successful achievement of the Wind Energy Program's goals will lead to several positive environmental outcomes, one of which is the displacement of carbon emissions. According to the GPRA report, wind energy could displace 52.4 million metric tons of carbon equivalent per year by 2020. Table 6 shows the projected incremental benefits of DOE-supported program activities for the FY 2008 budget request.

Specific short-, medium-, and long-term outcomes can be found in Table 2.

Table 6. GPRA Projections for the FY 2008 Wind Energy Program Budget Request (incremental benefits of DOE-supported program activities)

Metric	2010	2020	2030	2040	2050*
Additional GW installed	0.7	46	52	130	177
Avoided carbon emissions, annual (MMTC)	1	30	36	113	139
Consumer savings, annual (bil. 2004$)	--	9	8	12	-4[a]
Electric power industry savings, annual (bil. 2004$)	-0.1	4	3	9	3
Energy intensity reduced (% change in E/GDP)	0.0%	0.7%	0.7%	2%	2%

[a]The drop in the price of electricity causes a small shift towards less expensive and less efficient end-use equipment. This results in increased consumer savings in investment costs throughout the timeframe (especially 2030 on). However, by the end of the modeling period (i.e. 2040 to 2050), the average electricity price begins to increase, which results in negative consumer savings. The increase in electricity price is caused by increasing investment costs in the electric sector for both wind turbines and backup combustion turbines.

[21] *Project Benefits of Federal Energy Efficiency and Renewable Energy Programs FY 2006 Budget Request*, National Renewable Energy Laboratory, Golden, CO. NREL/TP-620-37931, May 2005.

2.0 Technology Research, Development, and/or Deployment Plan

As explained in section 1.5.1, the Wind Energy Program technology research, development and deployment activities are grouped under two program elements: Technology Viability (TV) and Technology Application (TA).

TV activities improve the cost effectiveness of large and small (distributed) wind energy systems through competitively selected public/private partnerships, and by conducting supporting research and testing. TV R&D falls into two categories – large wind technology (LWT) and distributed wind technology (DWT) – which address a set of identified opportunities for technology improvement that result in reductions in the cost of energy (COE), and thus contribute directly to achievement of the program's COE goals. Achieving these goals will support the Energy Efficiency and Renewable Energy (EERE) Strategic Plan goals of reducing dependence on foreign oil, reducing the burden of energy prices on the disadvantaged, and creating a domestic renewable energy industry.

All Technology Viability research and testing efforts bring specialized technical expertise, comprehensive design and analysis tools, and unique testing facilities to bear on problems that industry encounters in bringing new wind technology to the marketplace. Supporting research and testing (SR&T) activities support the research and development goals of the LWT and DWT activities through advancement of technologies that have the potential to reduce the COE of large utility-scale and small distributed wind systems in low wind speed regimes.

TA encompasses the program's systems integration (SI) and technology acceptance activities. Systems integration activities enhance wind's compatibility with the nation's long-term energy needs through wind plant power profile data gathering and development of grid impact analysis tools, and by facilitating adoption of equitable grid access and operational rules for wind. Other activities ensure that wind characteristics and needs are considered in regional transmission expansion planning. This effort targets all major regional wind markets. Outreach activities through program and professional publications are enhanced by informational forums such as the Utility Wind Integration Group (UWIG) and the National Wind Coordinating Committee (NWCC).

Most technology acceptance activities are directed by the Wind Powering America (WPA) project initiated in 1999. WPA supports state-based activities, rural economic development, public power partnerships, Native American activities, and small wind systems. At the state level, WPA supports state wind working groups that provide stakeholders with timely information on the state of wind technology, the economics and economic impacts of wind development, state wind resources, policy options and issues, and barriers to development. Group members include landowners and agricultural sector representatives; utilities and regulators; colleges and universities; advocacy groups; and state and local officials. WPA's efforts in removing nontechnical barriers will be essential to the long-term success of both large and distributed wind technologies, as well as emerging wind applications.

2.1 Large Wind Technologies

2.1.1 LWT Strategic Goals

The strategic goals of the LWT activity are to reduce the cost of large wind turbines until they are competitive with conventional energy generation without tax incentives and increase the commercial viability and deployment of wind energy by improving the reliability and performance of existing technology, while setting the stage for future wind technologies through applied research and market assessment. As discussed in Section 1.3 Program Vision, this activity performs research on both land-based and offshore large wind turbine technologies.

The activity has three primary areas: reliability and performance, low wind speed technology, and offshore technology. Reliability activities seek to improve current wind technology, generally installed in Class 5 and 6 sites. The goal of low wind speed technology activities is to improve the cost and performance of wind turbines in Class 4 resources. Offshore wind technology for U.S. coastal waters shows promise for longer-term growth, and will act as a hedge against transmission bottlenecks that may limit development in eastern regions.

To increase the viability and deployment of large wind energy technologies, the program must address two key issues: lowering costs and increasing wind energy access to transmission. Equipment cost and system performance are the most critical factors impacting the cost of wind energy, but many other factors such as technology risk, development costs, and environmental impacts play a role in determining the price of wind energy. The program addresses these issues through work on risk mitigation, reliability improvement, and innovative technology development and support.

Reducing costs while improving performance will require advances in several research disciplines. While it will be possible to achieve some near-term COE reductions based on current technologies, additional reductions will require investment in fundamental long-term research. Most LWT program work is conducted at the Department of Energy (DOE) National Laboratories, particularly the National Renewable Energy Laboratory (NREL) and Sandia National Laboratories (SNL).

Reducing the cost of wind power will have a limited impact if it is not possible to get the energy to customers. The program is using two strategies to address this issue: bringing the technology closer to the load, and expanding the transmission infrastructure to allow energy transfer from remote locations. The program addresses transmission expansion through its technology applications activities. Low wind speed turbines and offshore wind are technology-based approaches to allow wind technology to be installed closer to load centers, thus circumventing transmission bottlenecks. Low wind speed sites provide 20 times more land for development and can be found much closer to the load centers, reducing the transmission distance by as much as a factor of five. Offshore wind technology provides easy access to the nation's coastal load centers and takes advantage of the huge offshore wind resource. Although the marginal costs of these options are higher than at the best land-based sites, development of these technologies will allow our nation to fully utilize its vast wind resources.

2.1.2 LWT Performance Goals

The wind program's performance goals prioritize low wind speed and offshore wind technology. These two core activities will enable development of the LWT market, and will direct research into areas that will ensure the long-term viability of the wind industry. Work conducted under each of the programs key R&D areas will have a direct impact on the current turbine fleet, and in many cases will lead to stepwise improvements in current turbine designs. One example of how the program's R&D efforts can impact the LWT market and current turbine fleet is the Clipper Windpower Liberty C series turbine developed under a program/industry partnership, primarily for the low wind speed market. Clipper completed its prototype in 2005 after only 3 years of R&D. The company now offers several versions of the turbine covering all ranges of resource areas. Clipper's broad range of turbine options allows developers to select the most appropriate turbines for their projects, enabling technology for lower wind resources to be used when appropriate. 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.

The performance goals must be understood in the context of the DOE and Office of Management and Budget (OMB) reporting structure. For example, COE values are tracked against a fixed technology baseline that reflects a set of standard financial and technology assumptions for each technology (land-based and offshore). COE targets differ from actual market conditions, as baseline technology assumptions do not include such factors as the on and off nature of the Production Tax Credit (PTC) that leads to turbine demand spikes; changing financial variables; and fluctuating commodity prices and currency exchange rates. Performance goals are not designed to track the market cost or price of these technologies, but to measure improvements toward a goal that may be reached ten or more years in the future.

The performance goal of the land-based programmatic activity is to reduce the cost of electricity from large land-based wind systems in Class 4 winds to 3.6 cents/kilowatt-hour (kWh) by 2012. When the LWT effort was initiated, program researchers projected that improvements in COE might occur as shown in the LWT target trajectory in Figure 11. This trajectory has been used to help set the program's annual targets for land-based technology improvements.

Based on industry feedback from the program's Strategic Planning Meeting, comments from the program's peer review panel, resource constraints, and directional changes by DOE senior management, the program has reconsidered its approach to offshore wind technologies. Through FY09, the program is minimizing expenditures for offshore wind

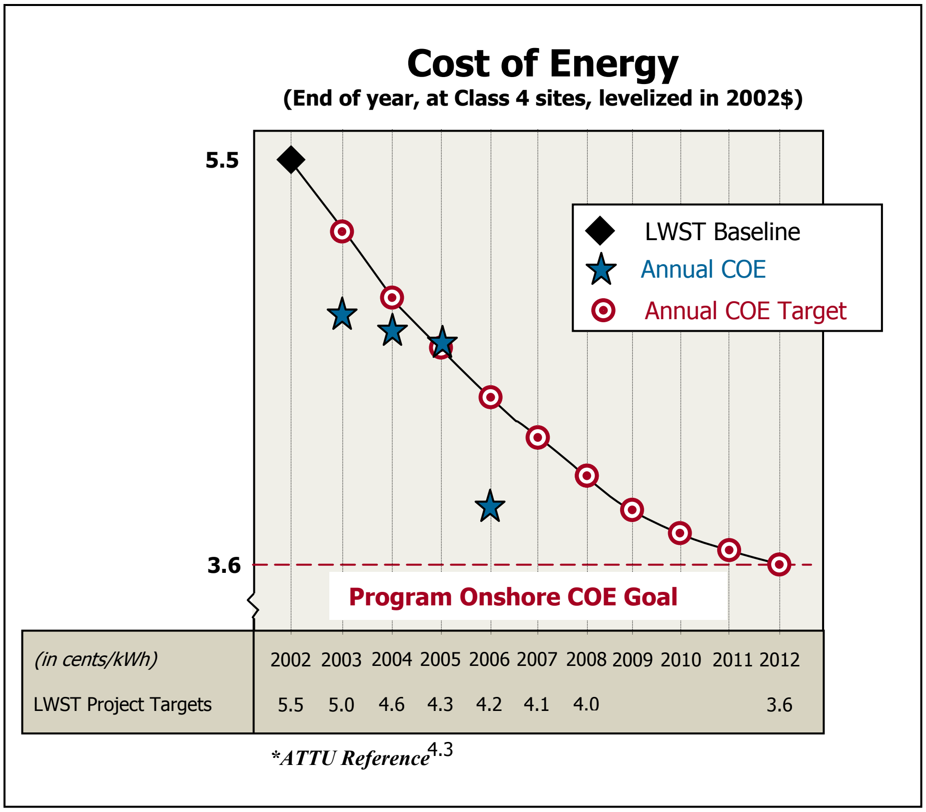

Figure 11. Wind Turbine Technology COE Tracking Process

technology partnerships and focusing on developing a better understanding of the offshore market, potential, conditions, and development barriers. In FY09, the program plans to hold a formal stage-gate assessment to determine the role and scope of continued governmental support for the development of offshore wind technologies. Although the program will rely on the results of the FY09 programmatic decision, based on the level of offshore wind development in Europe and the interest among U.S. industry, the program, and thus this document, expects there will be a federal role in the further expansion of the U.S. offshore wind industry.

As a result of this change in approach, the program has revised its goals associated with offshore development based on FY06 and out-year funding levels. The current program goal is to reduce the cost of electricity from large wind systems in Class 6 winds to 7 cents/kWh (from a baseline of 9.5 cents/kilowatt-hour in 2005) for shallow water offshore systems (depths up to 30 meters) by 2014. If the programmatic decision determines that there is no role for DOE to play in the development of offshore wind energy, this official goal will be dropped.

Annual Assessment of Progress

To understand how progress is being made against target trajectories, program researchers use performance-based management techniques to consider potential technological responses to the barriers and challenges presented by operation of turbines, land-based and offshore. As the first step in the development process, the program has identified technology improvement opportunities (TIOs) that it uses to set program priorities and track progress. The program conducts an annual progress assessment known as the Annual Turbine Technology Update (ATTU).[22]

The ATTU assessment process is based on three key principles:

1. Full COE improvement is realized when a product is commercialized at the level of 100 megawatts (MW) of installed capacity (100 MW is considered to be the level of manufacturing production or output that indicates market maturity).
2. COE improvement is measured by tracking the progress of industry subcontracts to develop new technologies.
3. Different types of industry subcontracts mature the technology to different levels.

The program uses these principles to project COE improvements for each industry subcontract. COE improvements are identified for each TIO and broken down into the major factors that impact COE: turbine capital cost; balance of station cost; "levelized" replacement cost; operations and maintenance cost; and annual energy production. Although TIOs may be similar across subcontracts, they are developed independently.

Each subcontract is evaluated based on the intended technology maturity. A conceptual study is given a low value because it only results in a design concept. A component development effort is valued more highly because it creates hardware that may be retrofitted to a commercial machine or incorporated into a new advanced system design. A prototype development is valued most highly because it demonstrates a full system. The highest valuation is reserved for prototypes or components that achieve commercialization of 100 MW or more.

Progress on partnerships and other program activities is measured by achievement of clearly defined milestones within each project, such as detailed design reviews, test initiation, or test completion; these define the completion percentage. By combining the predicted improvement, project valuation, and completion percentage of the partnership, the COE improvement at a given time can be assessed.

Table 7 provides details of the ATTU assessment for the FY 2006 LWT program activity. The COE achievements that result from these assessments are shown in Figure 11 as "Annual COE Achieved" points.

All program activities are reviewed in the annual ATTU assessment, and if it is determined that a research effort is not yielding the expected results and is unlikely to contribute significantly to future COE reductions, the Wind Energy Program will review the activity for adjustment or termination. The program's peer reviewers are consulted when such determinations are being made.

[22] Schreck S., Laxson, A., *Low Wind Speed Technologies Annual Turbine Technology Update (ATTU) Process for Land Based, Utility Class Technologies*, NREL Technical report, NREL/TP-500-37505, 2005. Available at: http://www.nrel.gov/docs/fy05osti/37505.pdf

The TIO predicted improvement percentages depicted in Table 7 are the maximum possible improvements for that TIO. Although a TIO may be impacted by a number of technologies, not all technologies that can be used to impact a TIO can work together. To determine the maximum possible improvement for each TIO, the technologies have been evaluated and their potential cumulative impact has been treated statistically to avoid overstating the possible gain. Likewise, not all technologies within one TIO can be used with all technologies within another TIO.

The total impact of all TIOs on the projected improvement has also been treated statistically using a Monte Carlo approach in a process referred to as Pathways Analysis as shown in Figure 12. It is not possible to simply add the TIO improvement percentages to determine the total COE improvement that will result if all technologies are developed.

Table 7. Results of Annual Turbine Technology Updates

The goal of the LWST R&D is to reduce the COE to 3.6 cents/kWh in Class 4 winds by 2012. The process to achieve this goal is described elsewhere in the MYPP. As part of this process, a set of TIOs was identified to track the advances that were expected to lead to the LWST goal. Through its ATTU process, the program can evaluate its yearly progress toward achieving the LWST goal.

2006 ATTU Projection

Much of the FY06 COE reductions derived from three prototype development subcontracts. Leading the first was Clipper Windpower, which completed an extremely successful field test of their prototype turbine in late FY06. Also pursuing prototyping efforts during FY06 were General Electric and Northern Power Systems. However, FY06 funding constraints measurably slowed progress on these two subcontracts.

Substantial FY06 COE reductions also were contributed by several component development subcontracts, These included a passive load mitigating sweep-twist blasé from Knight and Carver, enhanced efficiency/reliability power electronics form Northern Power Systems, and high power density convoloid fearing from Genesis Partners. Two complementary windPACT generator/drivertrain combinations developed prior to FY06 underwent testing on the NWTC dynamometer, substantially completing these efforts and accruing further COE reductions for the ATTU.

Technical Improvement Opportunity	Predicted Improvement (Percent)	Cumulative Improvement To Date	Current Year Improvement	Improvement from Prior Year (Percent)	COE Improvements (U.S. Dollars)
Advanced (Enlarged) Rotors	21.23%	6.96%	1.14%	5.82%	$0.0033
Manufacturing	2.07%	0.00%	-0.14%	0.14%	$0.0000
Reduced Losses and Increased Availability	5.75%	1.76%	1.56%	0.21%	$0.0008
Advanced Towers	4.37%	5.06%	4.85%	0.21%	$0.0024
Site-Specific Design/Reduced Design	28.54%	0.78%	0.78%	0.00%	$0.0004
New Drivetrain Concepts	3.69%	2.90%	2.16%	0.74%	$0.0014
Advanced Power Electronics	6.02%	2.02%	1.61%	0.41%	$0.0010
Learning Curve Effects	5.82%	0.00%	0.00%	0.00%	$0.0000
				Total Reduction	$0.0094
				Reference COE	$0.0480
				New COE	$0.0386

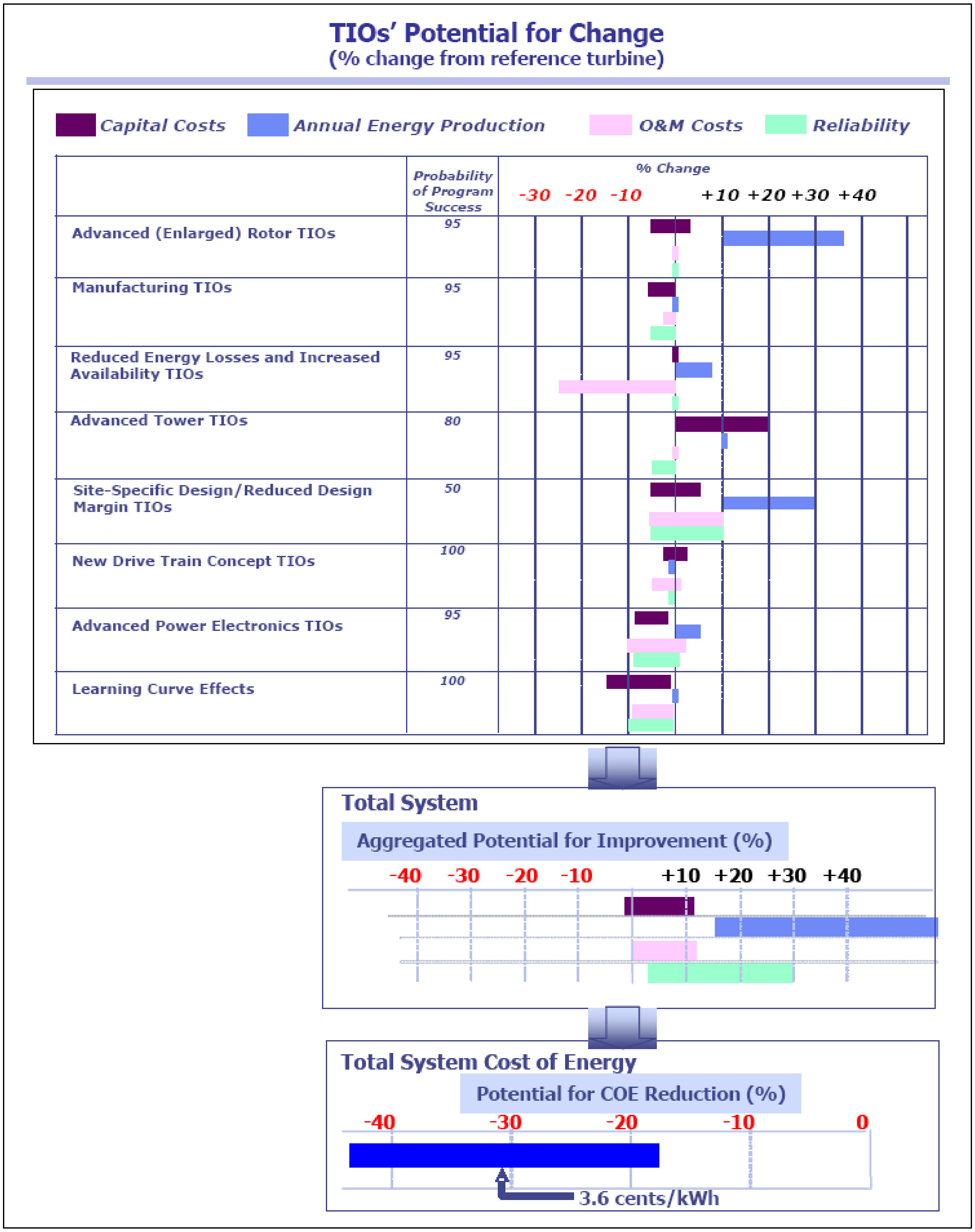

Figure 12. Wind Technologies Pathways Model.

As a beginning point for a pathways analysis and a reference point for technical assessment, program researchers, technical consultants, and peer reviewers defined a 2002 reference turbine configuration against which R&D progress is measured. The technical assessment process includes three steps (Figure 13):

1. Characterization of TIOs – In this step, the program identifies TIOs that may reduce the cost or enhance the performance of the reference turbine configuration. Examples of TIOs include rotor efficiency enhancements, taller towers, and reduced design margins. These improvements are assessed to quantify their potential contribution to improving cost effectiveness. COE is used for this analysis because it captures the capital investment cost and performance tradeoffs facing turbine designers.
2. Research Activity Prioritization and Performance Goals – In this step, program planners identify the research activities necessary to achieve the TIOs. Each activity's potential contribution to technology improvement is identified. Research activities that contribute little to achieving technical targets (such as RA4 in the example figure) are not funded. Those contributing the most are given the highest funding and management priorities.
3. Detailed Portfolio Planning – After developing a prioritized list of research activities, program planners formulate the program's research plan over the planning horizon.

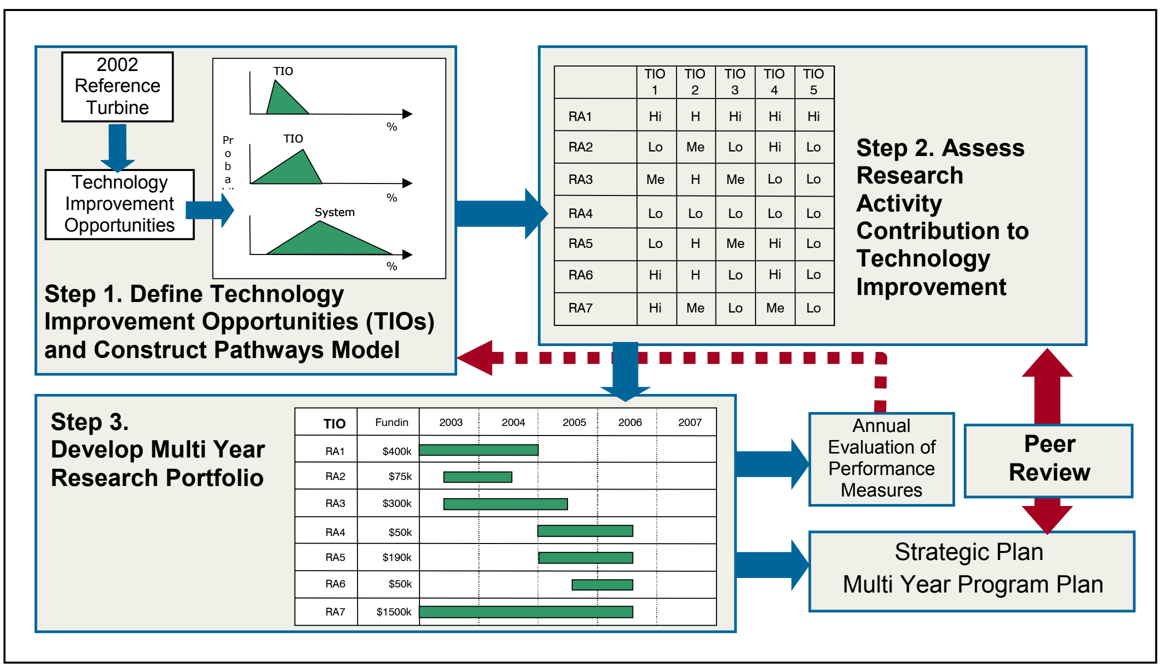

Figure 13. Technical Assessment Process

2.1.3 LWT Market Challenges and Barriers

Competitive COE levels for wind have been achieved for LWT by focusing development on Class 6 sites and by taking advantage of the 1.9-cent/kWh Federal Production Tax Credit (PTC). With favorable financial terms, some wind farms at Class 6 sites have been able to market electricity at prices as low as 4 cents/kWh without the subsidy. However, most Class 6 sites are located in remote areas that do not have easy access to transmission lines. As more sites are being developed, Class 6 sites that are easily accessible are becoming scarce. Development of all accessible high resource sites may cause wind energy growth to plateau in the near future unless additional transmission can be made available. Further reducing the cost of wind energy will allow for the higher transmission charges that result from expansion. Increasing turbine performance and reliability will help enable wind energy development on sites with available transmission (generally in lower resource areas or offshore) more cost effective.

Assuring turbine reliability and performance is critical for leveraging the financial resources needed to implement large-scale wind projects. As with any capital intensive project, the financing structure of a wind plant has huge impacts on the final cost of energy. Although financial markets are warming to wind as a sound energy investment, problems with turbine reliability or poor performance could cause withdrawal of capital needed for further market expansion.

The program's efforts to develop land-based technologies that can operate cost effectively at lower wind speed sites have increased the performance of wind systems in all wind resource classes, opening up vast resources to wind development and bringing wind-generated electricity closer to major load centers. If low wind speed sites could be used cost-effectively, it would increase the potential for wind in the United States 20-fold, greatly expanding the land available for wind projects. These sites are also significantly closer to major load centers than Class 6 sites, reducing the current average distance between economic resource areas and the 50 largest load centers from nearly 500 miles to about 100 miles. Reducing that distance will significantly lower transmission costs, reduce the need for additional transmission infrastructure, and lower the risk of transmission bottlenecks hampering future wind development. The expansion of land area with profitable resources would also smooth development challenges by reducing the intensity of development at the small number of high resource locations. Technology developments initiated in the low wind speed project have already been implemented in many commercial turbines, reducing the cost of wind energy through cost reductions and efficiency improvements.

Offshore wind technology will operate in winds that are stronger and less turbulent than most adjacent land-based sites. Stronger winds will allow offshore machines to operate at higher capacity factors, and projects are expected to benefit from reduced transmission costs due to proximity to load centers, but these benefits are offset by higher capital costs associated with offshore installations. Design concepts from sheltered shallow-water sites in Europe show that the costs associated with shallow-water offshore technology run 1.3 to 1.5 times higher than onshore projects due to premiums charged for marine protection, and operation, maintenance, and higher installation costs because of the difficulty of working at sea. Because almost all offshore technologies will be initially tested in land-based applications, solutions to these offshore issues will reduce costs for all LWT designs.

The variable nature of the wind resource, the relatively low capacity factor of wind plants, the remote locations of most good wind sites, and the fact that utilities cannot turn the wind on when needed, are major differences from conventional generation sources that create market challenges and barriers to wind deployment. Challenges and barriers for offshore technology include those for land-based applications plus a lack of information about the offshore design regime, ocean-based environmental concerns, and a different policy and regulatory environment. One of the key activities of offshore research is to obtain a better understanding of the barriers facing offshore wind development and determine how and whether they can be overcome.

Although the lack of transmission is a market barrier, increased transmission accessibility is applicable to more than just wind systems. DOE is working to develop new transmission corridors to bring energy from remote areas to national load centers. Consequently, most transmission-related work is conducted under the program's systems integration activities discussed in Section 2.3.

Table 8 lists market barriers for LWT related to low wind speed and offshore wind technology.

Table 8. Summary of Market Challenges and Barriers Addressed by LWT Activities

Barrier Number	Barrier Description
M1	COE at low wind speed and offshore sites is not competitive.
M2	Novel designs may not be accepted by operators due to lack of a track record.
M3	Turbulence sensitivity of turbines results in premature failures and high replacement costs for turbines installed in highly turbulent locations.
M4	Manufacturing fluctuations due to repeated expirations of PTC adversely impact COE reductions.
M5	Increasing utility power quality requirements may increase machine costs.
M6	Lower capacity factors at low wind speed sites may reduce power value for the grid.
M7	Reliability of wind systems.
M8	Environmental and visual impacts.
M9	Understanding of the offshore design regime.
M10	Policy and regulatory environment.
M11	Risk of offshore turbine applications as compared to land-based applications.

COE at low wind speed and offshore sites is not competitive – Current wind technology cannot be used cost competitively at low resource or offshore sites without subsidies. New designs capable of competing without tax subsidies are needed to allow continued development as transmission bottlenecks increase.

Novel designs may not be accepted by operators due to lack of a track record – New designs required to achieve lower COE will not have a track record to convince operators of the design's reliability because the innovations have not been tested over long periods.

Turbulence sensitivity of turbines results in premature failures and high replacement costs for turbines installed in highly turbulent locations – Sites on the Great Plains may be subject to low level jets with high turbulence, although the average wind resource is relatively low. This could reduce the life and reliability of the turbines.

Manufacturing fluctuations due to repeated expirations of the PTC adversely impact COE reductions – A major factor in COE reduction is capital cost reduction due to efficiencies in manufacturing. The instability of the PTC over the last 5 years has decreased investment in U.S. manufacturing, reducing efficiencies and increasing costs.

Increasing utility power quality requirements may increase machine costs – Utilities have reviewed wind's value to the grid and are demanding new capabilities such as fault ride through and power factor correction. Only wind turbines with advanced power electronics can provide such capabilities, while older turbine designs increase balance of system costs.

Lower capacity factors at low wind speed sites may reduce power value for the grid – The intermittent nature of the wind lowers wind energy's capacity factor, which is undesirable for utilities. Designs must be improved to increase capacity factors and development opportunities.

Reliability of wind systems – The fleet of modern wind turbines is young, and turbine manufacturers and operators are concerned that some components will not live up to their design specifications. For example, anecdotal information indicates that wind turbine gearboxes fail significantly before the end of their design life. Although gearbox failure causes little damage to other components, it can cause significant down time, and replacement is costly. Uncertainty regarding turbine reliability forces manufactures and operators to hedge against premature component failure, increasing turbine costs.

Environmental and visual impacts – Although wind turbines do not appear to have major adverse effects on the environment, the paucity of peer-reviewed studies to support this claim is an impediment to industry and limits the Federal government's credibility. Beyond environmental issues, potential visual impacts for both land-based and offshore developments raise public concerns about aesthetics and potential impacts on tourism.

Understanding of the offshore design regime – Offshore installations will operate in a different environment than current technologies. Land-based design specifications do not provide a complete description of offshore design conditions. Lack of certification and standards for offshore wind turbines increases market risk for offshore installations, which leads to higher costs.

Policy and regulatory environment – National policies that encourage responsible siting, installation, and operation of wind facilities are essential for industry success. Although a lot more is known about the environmental impact of land-based technologies, many different issues still impact project development. The Bureau of Land Management (BLM) has developed a programmatic Environmental Impact Assessment for projects on BLM land, and other organizations within the Department of Interior (DOI) are considering similar approaches. Permitting of offshore wind energy projects is clearly in its infancy. At this point only one National Environmental Policy Act (NEPA) document has been drafted to analyze the environmental impacts of offshore wind installations in the United States and the only site-specific construction impact studies conducted to date have been in Europe. The Minerals Management Service (MMS) of DOI has been given the responsibility of determining the regulatory framework and programmatic environmental impact statement, but until these documents are completed and the regulatory process has been tested by the completion of successful projects, this will be an impediment to offshore development. Other regulatory impacts, such as wind and radar interaction must also undergo continued assessment and clarification.

Risk of offshore turbine applications as compared to land-based applications – Although shallow offshore wind farms have been operating in European coastal water for over 10 years, the risk of implementing turbines off the coast of the United States may be too high for project developers, financers, and insurance companies as compared to increased land-based installations, even if the theoretical cost of offshore technology is lower. The program must help mitigate the increased risks associated with offshore development.

2.1.4 LWT Technical (Non-Market) Challenges and Barriers

Land-based wind turbines are currently capable of producing electricity at between 5 and 9 cents/kWh in Class 4 wind regimes and 4 to 7 cents/kWh in Class 6 resources without the PTC (the range is due to many factors including the project's financial structure). While Class 4 wind resources are well characterized, existing turbine designs not optimized for low wind regimes have only limited potential to achieve lower costs of energy. Estimates for offshore sites show that Class 6 or above resources could produce power for approximately 7 to 9 cents/kWh, based on limited shallow water experience in Europe. Many opportunities to reduce these costs exist, but without program technical support research will be applied only to European technology and conditions, providing limited improvements for U.S. projects.

Researchers must overcome many technical obstacles to optimize existing technologies for cost-effective operation in all regions. Cost and performance tradeoffs are becoming the focus of industry turbine designers. Turbines at higher hub heights, and with larger rotors, are subject to unpredictable and frequently turbulent conditions that make the turbine designer's work difficult. With a trend toward taller towers to take advantage of stronger winds aloft, turbine manufactures need to be able to understand and control turbine dynamics in these environments, and match the weight of turbines to crane lifting capabilities.

Because U.S. wind turbine designers and manufacturers have had little need to look beyond designing for Class 6 sites, they have proceeded incrementally toward larger rotor diameters and lower costs. Incremental design changes have lessened design risk, but studies conducted under the WindPACT Project indicate that more complex design improvements are required to enable the decreases in COE needed to achieve the land-based LWT goals. Table 9 lists technical barriers being addressed by LWT activities for both land-based and offshore technologies.

Table 9. Summary of Technical Challenges and Barriers Addressed by LWT Activities

Barrier Number	Barrier Description
T1	Technical limits to rotor size limit capacity factors
T2	Poorly defined site characteristics , *uncertainties in aerodynamic loads and inadequate modeling tools* necessitate increased design margins
T3	Poor grid power quality and power factor control *added to increased utility requirements* increase the operational cost of energy
T4	Increased turbine size increases transportation and weight impacts
T5	High tower costs reduce the ability to access strong wind resources aloft
T6	Poor power train conversion efficiency reduces benefits of rotor improvements
T7	Operation and Maintenance (O&M) costs limit the ability to reduce COE
T8	Transitional depth foundation designs, including anchor systems for offshore systems are not well understood and are untested
T9	Design tools for wind and wave loading dynamics for offshore machines are not available
T10	The cost of adapting land-based technologies for shallow offshore projects is high
T11	Turbine reliability is insufficient for harsh, remote offshore environments
T12	Offshore design conditions are not well understood or documented
T13	All environmental impacts not well understood

Technical limits to rotor size limit capacity factors – The capacity factor is the amount of energy a turbine actually generates divided by the amount it would generate if it ran at full capacity. Larger rotors capture more of the energy in the wind, especially in lower wind resource areas. One way to improve capacity factor is to increase swept area by lengthening blades. However, as blades get longer, they challenge the ability of designs and materials to support their own weight, withstand wind loads, and remain transportable.

Poorly defined site characteristics, uncertainties in aerodynamic loads and inadequate modeling tools necessitate increased design margins – Design safety factors or margins are required so that wind turbines can survive unexpected adverse conditions. When site conditions are well known and design tools are available to assess the impacts of these conditions, design margins can be reduced to save costs. Many installation sites do not undergo adequate data acquisition campaigns, or data analysis is inadequate, or atmospheric physics are not well enough understood to allow adjustments to design margins. These uncertainties, and their impact on aerodynamic loads and rotor performance will continue to be cost and risk factors until improved predictive codes, both structural design codes and aerodynamics codes, are developed and can be implemented.

Poor grid power quality and power factor control added to increased utility requirements increase the operational cost of energy – Demands by utilities and grid operators for turbines that can provide increased power factor control on weak grids, while also requiring wind turbines to meet utility ride-through requirements (the ability to continue operating during a grid fault), can increase the overall cost of new turbine designs by requiring added power converter capabilities and place existing turbine designs at a disadvantage.

Increased turbine size increases transportation and weight impacts – Wind turbine economics are being achieved by enlarging turbine size and taking advantage of economies of scale. However, a potential drawback to this trend is the increasing size of components that have to be transported over the road, by rail, or by barge and then lifted into place. As machines get larger, transportation becomes more costly, and may limit deployment of some machines.

High tower costs reduce the ability to access strong wind resources aloft – Taller wind turbine towers can access higher velocity winds because of wind shear (an increase in wind velocity as height above the ground increases). However taller towers are more expensive and more difficult to transport and erect. To support taller towers, turbine bases must normally grow in diameter. Bases that are more than approximately 4 meters in diameter cause transport costs to skyrocket because of limitations in road capacity, bridge heights, and utility line heights.

Poor power train conversion efficiency reduces the benefits of rotor improvements – Though the wind turbine rotor extracts the power from the wind, converting that power to electricity requires a power drivetrain that normally consists of a gearbox, generator, and power converter. Early wind turbine designs were based on off-the-shelf components that were not well suited for the wind turbine operating environment, resulting in an overall loss of power conversion efficiency. Drivetrain components must be optimized to perform at higher efficiencies in normal operating conditions.

Operation and maintenance (O&M) costs limit the ability to reduce COE – In early machine designs, the capital cost of components was the primary driver of COE. As machines have matured, capital cost has decreased while efficiency increased, so that O&M costs have become a larger percentage of COE. O&M must be considered during the design process for future turbines to keep it from becoming the dominant cost factor.

Transitional depth foundation designs, including anchor systems for offshore systems, are not well understood and are untested – Almost all offshore wind installations have used a monopole or concrete gravity base foundation in water less than 20 meters deep. Foundations for large offshore wind structures installed in deeper water, whether fixed to the sea floor or floating, are one of the key issues that will impact the feasibility of wind development at transitional depths.

Design tools for wind and wave loading dynamics for offshore machines are not available – The design codes developed and validated by the program to support LWT and previous land-based projects are not capable of simultaneously addressing wind and wave loading on turbine structures. Additionally, because extreme wind events will coincide with increased wave activity, the two inputs are coupled. The situation becomes even more complex when floating foundation systems are considered. Offshore turbines will have to be designed with detailed understanding of the characteristics of offshore winds (higher energy, lower turbulence) and the effects of wave, current, and possible ice loadings at the base.

The cost of adapting land-based technologies for shallow offshore projects is too high – Severe marine environments can be destructive even in shallow water. The first offshore projects in Europe that used standard or slightly modified turbines designed for onshore applications achieved poor results. Although initial U.S. offshore development may use the same approach, critical assessment of all wind turbine systems will be required to allow cost-effective operation in marine environments.

Turbine reliability is insufficient for harsh, remote, offshore environments – For offshore wind to be cost effective, turbines installed offshore will require higher unit availability than is common in land-based installations. The remoteness and potential access difficulty will require maintenance practices to be reassessed.

Offshore design conditions are not well understood or documented – Land-based approaches to design specification are not capable of providing a complete description of offshore design conditions. Lack of certification and standards for offshore wind turbines increases the market risk for offshore installations, which leads to higher costs. Once the design conditions are understood, new standards and certifications must be adopted that will allow the offshore market to develop freely.

All environmental impacts are not well understood– Research methods, analysis techniques, and data on environmental impacts and subsequent permitting of wind projects is in some cases lacking, especially in offshore environments.

2.1.5 LWT Strategies for Overcoming Challenges and Barriers

To address the market and technical barriers for the large wind technologies discussed above, the program is pursuing four technical strategies: mitigating risks and increasing turbine reliability; improving wind system performance; assessing the longer-term potential for U.S. based offshore wind technology; and providing supporting research and testing.

In the development of wind energy technologies, the program relies on partnerships with industry for the development of new wind turbine designs. This development is supported by applied research conducted at national laboratories and universities and by detailed testing of equipment in both controlled and field environments. The coordinated partnership approach has proven to be the most effective method of achieving the goal of increasing the deployment of wind systems. Working in close partnership with private entities allows the new technology and enabling research developed through the program to be quickly commercialized and deployed in new wind turbine designs. This approach bridges the gap between technology R&D and commercialization that has plagued many R&D efforts. New multimegawatt-scale turbine prototype development projects can cost between $20 and $40 million, a large investment for U.S. wind companies, even with a strong balance sheet. To reduce these development risks, many companies are concentrating on stepwise improvements to existing technology, drastically slowing technology development. Additionally, many smaller companies have innovative ideas, but because of their size and the limited size of the market, they are not able to develop technology that can compete. Through leveraged partnerships and cost neutral collaboration, federal support reduces the capital risk and allows the introduction of groundbreaking technologies.

The expertise and facilities provided by the DOE program have proven invaluable in the development of the current fleet of U.S. turbines. For example, testing facilities for blades and drivetrains were initially sponsored by DOE, but the facilities (including recent necessary expansions) are now being supported through partnerships with industry.

Due to the increasing strength of the large wind sector in the United States, the concept of public/private partnerships is being reviewed. The historical practice of capital-based leveraged cost sharing may no longer be needed for the development of large land-based wind systems. Other partnership models, such as Collaborative Research and Development Agreements (CRADAs) and loan-based financial assistance, are being promoted and investigated. The program still believes that the primary method to ensure that advances in wind technology (whether produced by DOE laboratories or by private corporations) enter the commercial market is through partnership with industry.

Although the new partnership structure is still under development, the partnerships will continue to combine the world-class applied engineering, research, and testing capabilities available at the national laboratories with projects supported by the private sector to develop, test, and implement new wind turbine technologies that advance the program's overall strategic goals. The program is not abandoning the successful cost-shared partnership approach, but it is reassessing the application of the approach given the market for land-based wind systems and the need for fiscal restraint due to limited program resources. For example, if the program seeks to develop offshore wind technologies, the program may feel it is appropriate to provide different types of cooperative assistance given the considerable technical challenges, higher risk, and expected deployment costs.

Through the SR&T effort, NREL's National Wind Technology Center (NWTC) and SNL perform wind technology research to help industry improve the performance of components and integrated turbine systems suited for U.S. applications. Program researchers work closely with industry to define and prioritize research activities that address both long- and short-term requirements. Given the complexity of the technological changes and the size of the equipment that must be designed and tested, it is unlikely that industry would undertake this research without the assistance of the Federal programs.

For clarity, the SR&T activity has been broken down into its five key technical areas: advanced rotor development; site-specific design; generator, drivetrain, and power electronics; design review and analysis; and testing support. SR&T supports the advancement of technology that has the potential to reduce the COE of large utility-scale wind systems.

As discussed previously, the program uses industry partnerships, LWT R&D, and SR&T to improve reliability, improve efficiency and performance of the near-term fleet, and conduct initial investigations into offshore wind technologies and longer-term market options.

Table 10 provides an overview of LWT development efforts and how they target market and technical barriers.

Table 10. Barriers Addressed by LWT Activities	
Program Activity	Related Barriers
LWT Component/System Development	M 1, 2, 3, 6 T 1, 3, 4, 5, 6, 7, 8
Supporting Research & Testing	
• Advanced rotor development	M 1, 3, 6 T 1, 4, 7, 9, 10, 11
• Site-specific design	M 1, 2, 3, 6, 8, 9 T 2, 5, 10
• Generator, drivetrain and power electronics	M 1, 2, 5, 7 T 3, 4, 6, 7, 8, 11
• Enabling research for offshore systems	M 7, 8, 9, 11, 11, 13 T 7, 8, 9, 10, 11, 12
• Design review and analysis	M 2, 7 T 7, 8, 9
• Testing support	M 2, 3 T 6, 7, 9, 10, 11
• Environmental support	M 8, 10 T 13

Risk Mitigation and Turbine Reliability

One of the primary objectives of the program's LWT activity is to increase investor confidence in wind energy by mitigating technology risk and improving product reliability. Increasing amounts of capital have been entering the wind market, but machine failures, underperformance, and low reliability can quickly dry up funding. To strengthen investor confidence in wind energy, LWT supports technical tasks conducted in concert or partnership with industry to make wind a more attractive and valuable investment option. Although this activity addresses wind technology already installed in Class 5 and 6 regimes, the results are applicable to all wind turbine technologies, including low wind speed, offshore, and (to some extent) small distributed systems.

Factors affecting turbine reliability include environmental conditions, accuracy of load assessment, designed-in reliability (redundancy or modularity), condition monitoring, designed in maintainability (access, handling), and testing. Operational reliability can be improved through better understanding of the underlying physics of component loads and/or maintenance systems combined with O&M and reliability analyses and health monitoring. Turbine reliability activities fall into three categories: O&M data collection and fault analysis, component reliability testing, and condition monitoring/remote sensing.

O&M data collection and fault analysis – This program element, initiated in 2006 collects and assesses turbine O&M data to help quantify problems and assess future support activities. This activity is conducted through collaboration with turbine operators, developers, and manufacturers who are the main custodians of turbine performance data. Several meetings were held to solicit contributions, and participants expressed strong interest in continued collaboration. Nondisclosure agreements with industry representatives are required due to the sensitivity and proprietary nature of most operation and performance data. The program is also using other methods to collect O&M data, and has developed an O&M database to record and provide access to turbine operational data. Once sufficient data has been obtained, the program will analyze the data to identify R&D opportunities to improve overall fleet reliability.

Component Reliability Testing; Gearboxes – Gearbox failures remain the weak link in wind turbine reliability and one of the primary O&M cost drivers. The world's best gearbox designs have yet to reach their 20 year design life; many fail in less than ten years. This project takes both short- and long-term approaches to resolving component-related reliability issues, with the highest priority on turbine drivetrains and gearboxes. By understanding the failures reported from field data, testing failure hypotheses in the laboratory, and developing advanced modeling tools to develop new designs and technologies, failure rates among identified components could be significantly reduced.

As a first step in addressing gearbox reliability, a major industry collaborative project will be launched to study the dominant gearbox failure modes. The project will begin with controlled laboratory tests taking advantage of state-of-the-art design practices, standards, and load prediction tools applied to a representative drivetrain at the NWTC 2.5-MW dynamometer test facility, followed by field tests conducted on a fully instrumented full-scale turbine drivetrain. The drivetrain will also be a platform for verifying the effectiveness of new condition monitoring technology. Aeroelastic load prediction codes will be integrated with advanced gearbox design tools to enable better wind turbine design. Gearbox design tools are used to predict internal stresses and loads on gears and bearings, but they are currently decoupled from full turbine dynamics models that can capture elastic deflections of the main shaft, main frame, and gearbox housing. This comprehensive program will reduce the cost of energy by addressing near-term O&M problems and long-term design problems.

The O&M data collection and analysis task will identify specific system components that pose high failure risk and allow the program to identify the causes of these failures. Once these issues are understood, condition monitoring may reduce these failures and limit their impacts.

Condition monitoring/remote sensing – The goal of this activity is to help industry develop remote sensing and condition monitoring capabilities. Advances in these areas will improve turbine reliability and economics. As wind plants become larger (several 1000 MW plants are currently under discussion) and more remote, the ability to monitor operation and manipulate turbines remotely will greatly improve performance by reducing loads and increasing energy capture. Monitoring operation will also allow operators to plan for equipment maintenance, thus reducing O&M costs. Early damage detection combined with advanced turbine controls could prevent long downtimes by allowing optimized curtailed system operation, for example by reducing thrust loads if drivetrain bearings are showing signs of deterioration. These improvements will require reliable sensor technology. Real-time structural monitoring should be performed to evaluate the state of health throughout the life of components.

Turbine reliability activities will follow the protocol of early collaboration with industry followed by laboratory-based research and testing. As progress is made, field tests will be conducted, and finally the new methods will be introduced to existing and new wind turbine fleets.

Improving Wind System Performance

This activity focuses on improving performance and efficiency, increasing the cost effectiveness of all large wind technologies through TIOs identified through collaboration with industry, and expanding the economic resource. Table 11 lists the targeted TIOs. This work is conducted through partnerships supported by laboratory-based research and testing. Strong industry partnerships ensure that the program stays focused on pressing industry needs and accelerate commercial implementation of advances. Although the program is redefining its partnership methodology, work with private sector companies will remain a critical part of the program's efforts. A new WindPACT assessment will be started in FY2007 to help prioritize research activities.

Initial WindPACT studies indicate that the combined TIOs identified for LWST represent a 30% to 40% decrease in overall COE. Some of these TIOs have already been implemented in turbines available on the market. These TIOs are discussed in greater detail in NREL's *Consolidated Report on TIO and Pathways Analysis Update*[23].

Table 11. Large Wind Technology Improvement Opportunities
• Advanced (enlarged) rotors • Manufacturing • Reduced energy losses and increased availability • Advanced towers • Site-specific design/reduced design margins • New drivetrain concepts • Advanced power electronics • Learning curve effects

Most of the program's activities are directed at the utility-scale turbine sector, and although the activities are categorized by projects such as low wind speed technology R&D, results may impact all parts of the utility-scale market. For example, the Clipper Liberty C series turbine was developed under a program/industry partnership primarily for the low wind speed market, but the company now offers versions ranging from an 89-m rotor diameter class Ia turbine for high-resource sites, to a 96-m diameter class IIb turbine for lower wind speed sites. Clipper is also planning a 99- or 100-m diameter rotor to be used in low wind resource locations. This range of turbine options allows developers to select the most appropriate turbines for their projects and demonstrates how low wind speed technology activities affect the whole market.

Taking turbine designs to the limit of cost and performance will require advances in several research disciplines, some will be based on current technologies while others will require investment in fundamental long-term research. An important adjunct to the SR&T activities is interactions with the International Energy Agency (IEA) and the International Electrotechnical Commission (IEC). These interactions ensure that codes and standards are appropriately supported and received by the technical community.

[23] *Consolidated Report on TIO and Pathways Analysis Update*: including "Update of Assessment of Technology Improvement Opportunities" and "Progress Report on Pathways Analysis Model Updates," Princeton Energy Resources International, LLC, NREL, July 2005.

Offshore Wind Technologies
Through FY09 the program will apply limited resources to offshore wind technology research to analyze the potential of offshore wind energy development. Near-term activities will seek to obtain and evaluate the information needed to allow a programmatic go/no-go decision in FY09/FY10 regarding future offshore wind technology development. In addition, the Wind Energy Program will engage in activities that are critical to the initial deployment of offshore wind turbines in the United States, including assessing environmental conditions and working with the MMS to develop offshore regulatory policy under the direction of the Energy Policy Act of 2005 (EPAct05) Section 321, *Alternate Energy-Related Uses on the Outer Continental Shelf.* These activities will allow the program to determine whether there is a significant market and governmental role for offshore wind technologies. If a government role can be defined, phased solicitations to facilitate development of offshore technology are proposed to build on the success of the program's partnering strategy.

Through FY09, offshore activities will be conducted in three functional areas to provide information required for the go/no-go decision; technology assessment, deployment and outreach, and international collaboration and standards.

Technology assessment – This activity assesses offshore wind technology to establish baseline costs and identify technology options and feasibility, market drivers, and potential deployment barriers. Existing marine technology will be evaluated for use in offshore wind applications, and analysis tools are being developed to evaluate technology pathway options. This research provides most of the data and analysis tools to be used in making the programmatic FY09 go/no-go decision for offshore wind energy development activities.

Deployment and outreach – The primary objective of deployment and outreach is to strengthen market readiness for potential projects. Participation in a variety of deployment activities will help transform the market and allow DOE to remain engaged with regulatory and state organizations that are handling near-term offshore deployment and market barrier mitigation. DOE will maintain a close working relationship with MMS, which is leading regulatory policy development under EPAct 2005.

International collaboration and standards – The objective of this activity is to maintain technical information exchanges with dominant European offshore markets. The program will sustain existing partnerships with European wind organizations, the IEA Offshore Annex 23, and the IEC. U.S. interests will benefit from access to technology development experience obtained from the EU, and monitoring actual offshore projects will help establish the feasibility of offshore wind in the United States. Similarly, international standards development will affect future requirements for offshore wind turbine certification and structural safety in the United States.

In FY2006, the program began a series of Sea-Based Concept (SeaCon) Studies to determine cost reduction opportunities for offshore wind energy through life cycle cost analysis, quantification of project risks, and adaptation of European and offshore oil and gas experience to U.S. wind applications. These activities will determine the baseline costs of offshore wind and the potential for long-term cost reductions. Table 12 shows the topics that were included in the initial phase of the SeaCon Studies. Although the program had expected to follow its initial in-house scoping studies with more detailed assessments, many follow-up studies are not expected to be initiated until after the go/no-go assessment in FY2009 because of the decision to postpone large-scale investment in offshore turbine development.

Table 12. Topics of Sea-Based Concept Studies
• Offshore cost and economic modeling • U.S. offshore infrastructure: assessment of capability and needs • Offshore reliability models • Anchoring and mooring studies • Turbine design optimization • Operation and maintenance and accessibility options • Offshore grid system infrastructure and transmission options • Fixed bottom support structures • Floating platforms • System scaling studies • Environmental assessments of offshore wind turbine impacts in the United States • External conditions definition

The second phase studies will be conducted by organizations experienced in wind energy and offshore and marine applications and by researchers at the national laboratories and universities.

Supporting Research and Testing

As described previously, program research is carried out through a combination of partnerships with industry and supporting research and testing. The following description of SR&T activities provides additional information on specific program activities.

For clarity, the SR&T activity has been broken down into five technical areas as shown in Table 13. SR&T supports the advancement of technology that has been shown to have the potential to reduce the COE of large utility-scale wind systems.

Table 13. SR&T Research Portfolio for Land-Based Wind Technology
Advanced Rotor Development • Blade development • Aerodynamic code development and validation • Systems and controls • Aeroacoustics research and testing Site-Specific Design • Inflow characterization • Design load specification Generator, Drivetrain and Power Electronics Design Review and Analysis • Partnership design reviews • Technical analysis support Testing Support • Structural testing • Dynamometer testing • Field-testing

Advanced rotor development – A wind turbine rotor is a unique component. The rotor's blades control the energy capture and almost all the loads, and are therefore a primary target of research efforts. The challenge is to create the scientific knowledge base and engineering tools to enable designers to achieve optimum performance at the lowest possible cost by using new materials, advanced control techniques, improved manufacturing processes, and enhanced design tools. This work will assist the industry in meeting the LWT goals by increasing rotors' swept areas to enable use in previously uneconomic wind regimes.

Advanced rotor development work can be divided into four subtasks:

1) Blade development: The development of blade structures and materials that are stiffer and stronger to span a greater swept area, but also lighter and adaptive to reduce system loads.
2) Aerodynamic code development and validation: Overcoming the inability of the current generation of aerodynamic loads/performance codes to adequately predict steady or unsteady loads in the near- and post-stall operating regime.
3) Aeroacoustics research and testing: Sponsoring the development of a semi-empirical noise prediction code that can be used by LWT manufacturers to ensure that new rotor designs and full systems have acceptable noise signatures.
4) Systems and controls: Rapidly advancing technological control innovation using the control of conventional turbine components and advanced devices to optimally meet two sometimes conflicting goals – increasing energy capture while reducing structural loading.

Each of these subtasks will play an important role in LWT progress over the planning period.

Site specific design – Future wind energy installations will be in areas of significantly different wind resource potential and terrain roughness. Land-based turbines will be installed in areas with lower wind speeds, using taller towers and longer blades to harvest more energy. To design for loads characteristic of more energetic sites would drive up costs unnecessarily and limit wind's cost-effectiveness. The benefits of designing large installations (100 MW or more) for specific site conditions are substantial. The nature of atmospheric loading at increasing heights will be assessed and documented. Blade designs, including aerodynamic geometry, controls, and structural details, must be tuned to the energy capture requirements and durability suitable for low-energy lightly-loaded sites.

Structural strength requirements throughout the system are based on the expected maximum event and turbulence at the site. This subtask covers the development of systematic methods for specifying site energy, load conditions, and turbine inflow characterization. The program will partner with industry to collect site-specific information in important regions of the country and make field measurements to validate the specification methods.

Generator, drivetrain and power electronics – The generator, gearbox, and power converter represent roughly 25% of the installed capital cost of a modern wind turbine. Generators have historically been based on wound rotors or squirrel cage induction designs, but such generator designs may not be ideal for future turbines. The drivetrain is becoming a driver in machine design because its weight and size affect other wind turbine configuration and erection factors, such as tower size and crane rating. Variable-speed wind turbine designs are dependent on the efficiency and mode of operation of the power converter that changes variable-frequency AC from the generator to fixed-frequency AC conditioned for injection into the electrical grid. Conversion efficiency is a critical factor.

Future designs of generators and power converters must be specialized and tailored for wind turbines because most of the time wind turbines operate at less than rated power. Permanent-magnet generators that allow lighter rotor designs and have lower losses will play a role, as will power converters and generators that allow variable-speed operation and have higher efficiencies below rated power. Reliability will be an issue because the generator and power converter are key points of system failure. This task will use public/private partnerships to explore enabling research areas that will contribute to LWT improvements in converter and generator designs, focusing on generator and converter architecture, controls, and reliability.

Design review and analysis – As the Wind Energy Program develops new technology through industry collaboration, it will also provide oversight and technical support. Design review and analysis provides a means by which NREL and SNL can provide specialized expertise for industry-led activities. It also supports the proposal or CRADA evaluation process. This support and oversight will assist industry, protect the program's investment in these partnerships, and enhance their chance of success. This effort has two major functions: detailed design and testing reviews on partnership subcontracts to ensure the efforts are proceeding in a safe and efficient manner, and technical analysis support as appropriate to assist subcontractors in solving technical problems and completing designated tasks.

Testing support – The NWTC has unique facilities developed to provide the testing capabilities needed to achieve LWT goals. Testing is conducted on full-scale LWT turbine systems installed in the field and on a myriad of turbine components and subsystems. Component testing utilizes the NWTC's specialized blade and dynamometer test facilities. These tests support SR&T, certification, and technology characterization. Field-testing of turbine loads, power performance, power quality, and acoustic emissions are conducted in accordance with standards developed under the IEC and the American Association of Laboratory Accreditation. NWTC activities essential to maintaining strong LWT testing capability include the application of test methodology expertise, maintenance and development of instrumentation systems, and development of testing standards.

As described above, computer modeling and dynamic simulations are an important element of DOE's support of industry turbine development. Validating and improving these models is difficult because the models cannot always simulate true inflow, turbine response, or control performance. To fill this gap, extensive and detailed field and laboratory testing is necessary. The data are used to optimize turbine configurations and COE, e.g. by improving control algorithms and simulation codes from which the turbines were designed.

Three primary types of testing are conducted through the DOE program:

1. Structural Testing: NREL operates the only structural testing facility in the United States capable of testing full-scale wind turbine blades. Blade testing is necessary to prevent failures of large blades on field-deployed turbines and to meet certification requirements. The facility's present capabilities include fatigue testing, ultimate static strength testing, and several nondestructive techniques. The rapid growth in the size of wind turbines challenges the ability of the NWTC structural test facility to meet the needs of the U.S. wind turbine industry. To keep up with the ever-increasing list of new requirements, the test facilities must continuously be upgraded to increase test speed and data quality and to reduce the cost and energy required to perform a given test. A temporary test stand has been constructed outside of the blade test facility to provide limited static and fatigue testing of blades up to 50 m in length. To resolve this problem on a more permanent basis, the program will enter into a competitively-solicited CRADA for an expanded test facility. The design CRADA is expected to be completed in 2007, and construction is expected to start in 2008.
2. Dynamometer Testing: The NWTC's 2.5-MW dynamometer facility is dedicated to testing wind turbine drivetrains, drivetrain components, and power conversion systems. The NWTC staff conducts tests on gearbox fatigue; wind turbine control simulations; transient operation; generator and power system component efficiency, performance, and reliability. This facility is capable of conducting full-system testing of wind turbine drivetrain systems to identify critical integration issues before field deployment. As with the structural blade test facility, the dynamometer facility is facing size limitations. The program plans to take two approaches to expanding the facilities to meet industry needs arising from the increasing size of wind turbines. Facility upgrades and modifications are being evaluated with the objective of extending the existing facility test capacity of 1 to 2 MW to beyond 2.5 MW. In addition, the program is exploring the possibility of building a multimegawatt drivetrain test facility in the United States as part of a collaborative effort with private industry, state or local governments, and academic or other research institutions, similar to the approach used for the new wind turbine blade test facility.
3. Field Testing: Field testing supports a wide range of program technology development activities and makes up the final stage of the testing available to industry. The program partners with industry to conduct tests on full-scale turbines under atmospheric conditions representative of commercial installations, as well as components and subsystem test articles. Field-test data are vital to industry and the program for assessing the viability of new, innovative turbine configurations, because models need tuning with test data to establish necessary confidence levels. The NWTC also provides accredited test data that are essential

inputs to design evaluations and are required for certification and due diligence activities.

2.1.6 LWT Milestones and Decision Points

The milestones for the LWT Activities provide planning guidance and a means for tracking progress. Critical stage gates for project evaluation from 2007 through 2012 include the following:

2007 Milestones

- Complete action plan for WindPACT II for land-based component technology development
- Complete evaluation of prototype flatback airfoil blades
- Complete selection and negotiation of large wind turbine blade test CRADA partner
- Begin laboratory testing on prototype swept blades for LWST Phase II Component Development
- Complete drivetrain testing under the WindPACT program
- Complete commissioning CART3 turbine generator and power electronics
- Achieve COE of 4.1 cents/kWh in land-based Class 4 winds; 9.25 cents/kWh for shallow water offshore systems in Class 6 winds; and 11.93 cents/kWh for transitional offshore systems in Class 6 winds.

2008 Milestones

- Award WindPACT II agreements/subcontracts
- Complete wind-radar mitigation supporting case studies and analyses
- Complete fabrication of full-scale blade demonstrating wide spectrum of advanced technologies.

2009 Milestones

- Go/No-Go decision regarding offshore wind technology development.

2010 Milestones

- Complete WindPACT II phase one studies for land-based component technology development.

2011 – 2013 Milestones

- Develop design guidelines for large turbine instability control
- Develop grid analysis models including storage, transmission and control algorithms
- Achieve COE of 3.6 cents/kWh in onshore Class 4 winds.

2.2 Distributed Wind Technologies

Distributed wind energy systems provide clean, renewable power for on-site use and help relieve pressure on the power grid, while providing jobs and contributing to energy security for homes, farms, schools, factories, private and public facilities, distribution utilities, and remote locations. America pioneered small wind technology in the 1920s, and it is the one renewable energy industry segment that the United States still dominates in technology, manufacturing, and world market share.

With the expected completion of the FY2007 Distributed Wind Technology programmatic goal of producing energy from between 10-15 cents per kWh in a Class 3 wind resource site, the Wind Energy Program has investigated the need and market potential for the continued development of distributed wind turbine technologies. Although reaching the previous program goal is an impressive achievement, in many cases, small wind technologies are still not economically self sustaining.

Utility-scale turbines have increased in size to more than a megawatt while small-scale turbines remain at less than 100 kW. Although a 50-kW turbine can provide enough power for a small family farm, the public has expressed an interest in mid-sized turbines— 100 kW to 1 MW— that can provide enough electricity to power farms, businesses, and industrial facilities, Figure 14. Because of zoning constraints, small wind electric systems are easier to install in rural communities, and they offer a low-cost alternative to photovoltaic power systems that are being increasingly used in urban communities. Small-scale distributed wind turbines also produce electricity at lower wind speeds than utility-scale turbines, greatly expanding the availability of land with a harvestable wind resource. These factors, combined with increasingly high energy prices and demands for on-site power generation, have resulted in strong market pull for the distributed wind industry, which is poised for rapid market growth.

Figure 14 shows the few commercial turbines that are available in the United States. Most of these turbines are older 1980s vintage technology that has not been optimized for use with higher towers and expanded rotors, or with variable-speed generators and advanced power electronics to provide volt ampere reactive support on weak rural distribution lines and direct-drive topologies. Commercial turbines over 100 kW have been in the marketplace for some time, and specific problems involving high reliability issues like gearboxes and bearings, have been identified.

Therefore, the program is expanding its DWT R&D efforts to include wind turbines of any size that are installed remotely or connected to the grid at a distribution-level voltage. Using this definition, distributed wind systems generally provide electricity on the retail side (behind) of the electric meter or are installed close to a specific load, eliminating the need for transmission access.

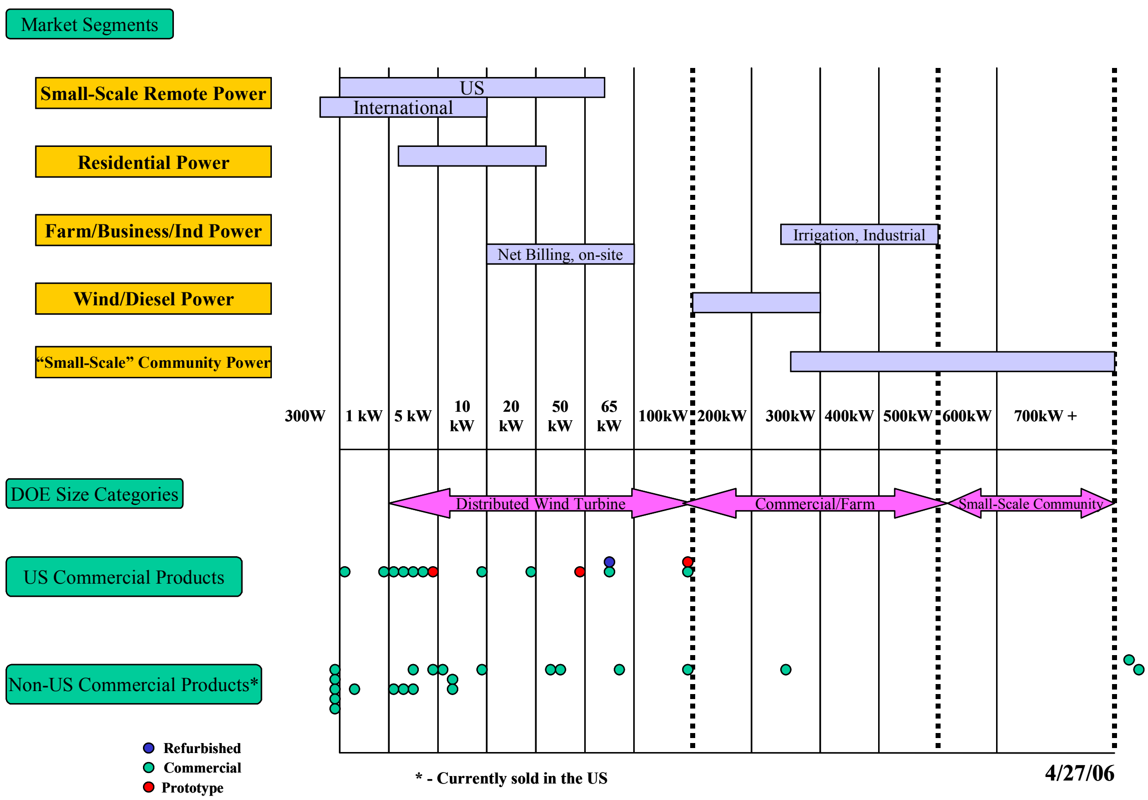

Figure 14: Markets and availability of turbines for the distributed wind applications.

The next round of DWT R&D activities planned by the program includes:

- Concept and component development
- DWT prototype development for small turbines, 100 kW and less
- Small turbine improved product reliability through:
  - Independent testing of turbines 65 kW and less to IEC standards
  - Support of the Small Wind Certification Corporation
  - Support of small wind installer certification through the North American Board of Certified Energy Practitioners (NABCEP)
- DWT prototype development for mid-size (rural) turbines.

The DWT R&D activities are described in more detail in section 2.2.5 DWT Strategies for Overcoming Challenges and Barriers.

2.2.1 DWT Strategic Goals

The strategic goal for DWT is to help establish a core of U.S. manufacturers that can compete in the global marketplace. The program's strategy of forming R&D partnerships with industry has been successful in moving the industry closer to this goal. Past and ongoing efforts have yielded innovative control approaches and turbine components, including enhanced generator designs, higher stall characteristics, and blade designs that have low or no acoustic emissions.

SR&T activities support the research and development goals of the DWT activities by developing technologies with the potential to reduce the COE of distributed wind systems in low wind speed regimes. As applied to both large utility and distributed wind technologies, the SR&T effort brings specialized technical expertise, comprehensive design and analysis tools, and the unique testing facilities of the National laboratories to bear on problems that industry will encounter in bringing new wind technology to the marketplace.

Achieving the program's goals will support the EERE Strategic Plan goals of reducing dependence on foreign oil, reducing the burden of energy prices on the disadvantaged, and creating a domestic renewable energy industry.

2.2.2 DWT Performance Goals

The program's previous goal of reducing the COE from small wind systems to the same cost in Class 3 resources (10-15 cents/kWh) as they were in Class 5 resources in 2002 is expected to be achieved by the end of FY2007. The upper end of the goal range represents grid-connected residential-sized turbines (10 kW and below), while the lower end of the range represents business/industrial turbines (11 kW – 100 kW).

Because the technical range of the new DWT activities is expanding, the program's goals will also be expanded to include market growth. This new goal allows the program to directly address issues associated with the development and deployment of distributed wind systems, in addition to cost reductions.

The new goal for DWT activities is to expand the number of distributed wind turbines deployed in the U.S. market five-fold by 2015, from a 2007 baseline. The Interstate Renewable Energy Council (IREC) will help evaluate the baseline goal and future yearly goals on behalf of the program. The preliminary assumption is that there are 2200 distributed turbines installed in 2007. Based on that estimate, goals for the number of installed units have been established for each year from 2007 through 2015, as shown in Table 14.

Table 14. Small Turbine Unit Goals for 2007 – 2015

Year	Number of units to be installed
2007	2,200
2008	2,706
2009	3,328
2010	4,094
2011	5,035
2012	6,194
2013	7,618
2014	9,369
2015	11,524

A draft baseline report from IREC on the number of distributed turbines installed in the United States is due in FY07. This may result in a reworking of the yearly numeric goals.

2.2.3 DWT Market Challenges and Barriers

The U.S. markets for both residential and mid-size distributed wind turbines (larger than 100 kW) are growing. The extent of these markets is currently being explored[24,25], but the number of consumers looking for independent solutions and considering small turbine purchases is also increasing, partly as a result of public policy incentives. However, there are still many market-based barriers that decrease the potential for this clean, local, and renewable technology alternative. A summary of the challenges is presented in Table 15.

Table 15. Summary of Market Challenges and Barriers to Distributed Wind Technology Development

Barrier Number	Barrier Description
M1	Lack of effective standards
M2	Low public awareness of industry and technology
M3	Misconceptions about the wind resource
M4	Restrictive zoning
M5	Lack of consistent incentives across markets
M6	Excessive interconnection requirements
M7	Lack of commercially available mid-sized turbines
M8	Cost of technology on the market

Lack of effective standards – As the domestic market expands, distributed wind manufacturers need a baseline for establishing turbine performance, noise, reliability, and credibility. Although there are international design standards (IEC 61400-121, power performance measurements of grid-connected wind turbines, IEC 61400-2 design requirements for small wind turbines) and draft national performance standards (the draft AWEA small wind standard) for small turbines that could be used by state or national incentive programs, the testing and documentation required to meet the standards raises manufacturing costs.

Low public awareness of the industry and technology – In comparison to the photovoltaics industry, there are relatively few distributed wind turbine installations. Therefore, distributed wind turbines do not get the same exposure as photovoltaic systems. In addition, unlike the solar industry, there are no Fortune 500 companies in the industry. The distributed wind turbine companies have limited resources and capabilities to promote the technology.

[24] "Overcoming Technical and Market Barriers for Distributed Wind Applications: Reaching the Mainstream"; Rhoads-Weaver, H.; Forsyth, T.; Proceedings of the Solar 2006 Conference, 9-13 July 2006, Denver, Colorado

[25] "Market Assessment and Summary of Barriers for Distributed Wind Applications"; Forsyth T.; Baring-Gould, E.I.; NREL Technical Report - NREL/TP-500-39851, to be published Winter 2007.

Misconceptions about the wind resource – The attention given to wind farm development in high-wind areas has convinced some people that they must have an exceptional wind resource to benefit from wind technology. However, distributed wind turbines are designed to operate cost-effectively in lower wind speed areas where most people live and work. Wind maps have inadvertently exacerbated the problem by classifying wind regimes according to their potential for utility-scale wind turbines used in wind farms.

Restrictive zoning – Most local jurisdictions limit the height of structures in residential and sometimes other zones to 35 feet. This restriction was developed nearly 100 years ago to ensure that the height of structures would not exceed the capability of old fire fighting equipment to pump water. Today, this height limit is a significant obstacle to siting distributed wind turbines. Most residential (e.g. systems up to 15 kW) turbines must be installed on towers that are 80 to 120 feet tall to access better wind resources. The 35-foot height restriction causes unnecessary expense and delays in obtaining building permits and community approval.

Lack of consistent incentives across markets – Most current incentives are being implemented by states. This results in a lack of clear and consistent incentives, which complicates and distorts the national market for small wind systems. More systematic market incentives, such as a national production tax credit for distributed wind applications and state-based rebates for all distributed applications, would simplify adoption of the technology.

Excessive interconnection requirements and unequal billing policies – Even though the Federal Public Utility Regulatory Policies Act (PURPA section 210) gives all U.S. citizens the right to interconnect distributed wind turbines and to receive payment for excess electricity production, the policies of many utilities discourage installation. Additionally, utilities with limited experience with customer-owned generation may use the same process for approving a 10-kW residential wind installation as for a 500-MW gas turbine cogeneration facility. It sometimes takes more hours of labor by the customer and the turbine vendor to gain approval for interconnection than it takes to build and install the turbine itself. Weak or uninterested public utility commissions can allow utilities to effectively thwart the Federal rights provided under PURPA. Interconnection standards that have emerged in the last five years have required distributed wind turbines to deliver power to the utility grid that is of higher quality than the power delivered by the utility to its customers.

Lack of commercially available mid-sized turbines – There is limited commercial availability in the United States of mid-sized turbines ranging from 100 kW to 1 MW for small commercial and community wind applications. Consumers interested in community wind must either accommodate a utility-grade turbine of 1.5 MW or more, or go to foreign suppliers for a mid-sized turbine.

Technology is still not fully competitive - Although distributed wind technologies are cost effective in wind areas and locations with very high power costs, such as remote diesel stations or areas in the Northeast, further cost reductions will be needed to attract more U.S. consumers.

While these market barriers are being whittled away as more consumers seek permission to install their own turbines, there is no easy means to influence county zoning boards and rural utilities. Elimination of these barriers will require education on the technical and political issues. Many of these barriers are addressed through coordinated efforts undertaken by the small wind activity under Technology Acceptance activities described in section 2.4.

2.2.4 DWT Technical (Non-Market) Challenges and Barriers

The technical challenges and barriers to furthering the use of distributed wind technology, some of which were identified in the distributed wind technologies Roadmap developed by the American Wind Energy Association,[26] are shown in Table 16. The first two barriers, high wind turbine systems cost and insufficient product reliability, are identified as near-term opportunities, and the subsequent barriers are identified as mid-term opportunities.

Table 16. Summary of Technical Challenges and Barriers to Distributed Technology Development

Barrier Number	Barrier Description
T1	High wind turbine system costs
T2	Insufficient product reliability and lack of maintenance support
T3	Turbine productivity hampered by power electronics
T4	Need for quiet operation, turbine noise
T5	Technologies not designed for low wind regimes
T6	Tower options are designed for larger wind systems
T7	Lack of performance standards, testing and ratings
T8	Absence of small turbine technology design and assessment tools

High wind turbine systems cost – Although many people want distributed wind turbines, most find that the price is too high and the payback period on the investment is too long. System costs can be reduced by improving the technology and increasing production rates. Because distributed wind turbines are currently produced in limited quantities, there are only limited economies of mass production. Advances in technology such as new blade manufacturing techniques, super-magnet direct-drive generators, and power electronics can make distributed wind turbines less expensive to build, more productive, and more reliable.

Insufficient product reliability and lack of maintenance support – It is a substantial challenge to design, manufacture, and install distributed wind turbines that are low in cost and yet rugged enough to withstand 20 to 30 years of operation in all kinds of weather. The value of a new design is only proven after several years of operation at dozens of

[26] American Wind Energy Association, *Home and Farm Wind Energy Systems: Reaching the Next Level, AWEA Global Small Wind Industry Market Study Confirms Need for Level Playing Field*, June 2005. http://www.awea.org/AWEA_SWT_Market_Study_6-05.pdf

sites. At present, there is no way to duplicate the wear and tear of actual environmental conditions sustained during product development. Strategies to increase product reliability must be developed based on the results of component testing, prototype field-testing, and field-verification tests for commercial units. The installation of distributed wind systems generates additional costs for field support.

Turbine productivity is hampered by power electronics issues – Because most distributed wind turbine designs operate at variable speed, producing variable frequency and variable voltage output, power electronic converters are used to convert the output to standard 60-cycle AC. Existing inverter technology trades low efficiency at low power ratings for high efficiency at near-rated power levels. Because most distributed turbines operate in moderate to average wind speeds, they suffer from the low overall efficiency associated with this design philosophy.

Turbine noise - High-growth domestic markets for small wind turbines will demand quieter rotors for turbines sited in residential neighborhoods. Many residential turbines operate at high rotational speeds and continue to spin even when they are furled (pointed out of the wind), producing relatively high noise levels.

Technologies not designed for low wind regimes - Most mid-sized wind turbines used in the distributed market were designed before recent advances in low wind speed technology. However, a large number of sites where distributed applications will be applied are not in high wind speed regimes and would benefit greatly from low wind speed designs.

Tower options are designed for larger wind systems - Most towers are designed for central station wind farms. To enable more cost-effective installation and maintenance, distributed wind turbine towers and systems such as self-erecting towers or lightweight tall towers must be designed for small turbines in rural distributed applications.

Lack of performance standards, testing and ratings - The lack of industry accepted standards undermines the credibility of performance estimates for wind turbines.

Absence of small turbine technology design and assessment tools – Most computer codes used in turbine design were developed for large wind turbines, which differ significantly from small turbine technologies. For example, many distributed turbines use passive over-speed controls such as furling. In furling, the force of the wind turns the rotor sideways, as water-pumping windmills have done for over 100 years. Because computer codes have not been able to accurately predict the performance or assist in the detailed design of furling mechanisms, such designs must be tested empirically, raising development costs. Better codes would reduce design costs and increase reliability. Work performed under the Small Wind Research Turbine (SWRT) Project has gathered small turbine data to validate computer models. Although this work led to an improved understanding of small turbine furling and thrust, and consequently improved modeling codes, it also exposed code weaknesses that researchers hope to address in 2007.

Technical problems that are more general in nature that could be addressed by the program include improving the survivability of small wind systems through tower grounding against lightning.

2.2.5 DWT Strategies for Overcoming Challenges and Barriers

In FY2007, the program will finish activities that will lead to achievement of the programmatic goal of producing wind energy at between 10 and 15 cents/kWh in a Class 3 resource. However, for significant market penetration to occur, further technology development will be needed to improve the performance, cost, and availability of small wind turbines.

In FY 2008, the DWT activity will build on previous successes to improve the market availability of DWT for consumers, especially those that have relatively high retail costs of electricity. To accomplish this, the DWT activity will continue to focus on improving product reliability, performance, accessibility, and cost. The program has also identified a significant potential market for mid-to-large turbines installed on the distribution side of the meter in low wind speed areas. This encompasses distributed applications such as farming and community wind. Following further assessment of these markets, the program expects to develop technology partnerships and supporting research for this market segment.

The second key part of the distributed wind project will be to increase the accessibility of small wind in all markets, as reflected in the new program goal. Many barriers to small wind development are addressed by the Technology Application portion of the program, particularly the Wind Powering America (WPA) project, which covers utility and distributed wind technologies. WPA will work to reduce barriers, such as permitting and interconnection regulations, through active outreach to interested parties and industry stakeholders. The program will also work with state regulators and the implementing agencies of state incentive programs to ensure that the technology available on the market can be incorporated easily into state-based programs. For example, in the coming year, the program will invest resources to establish an independent testing program for commercially available small wind turbines. The turbines will be tested at NREL's National Wind Technology Center. The objective is to provide independent test results for a number of small turbines and allow them the opportunity to earn a certification granted by an independent certification body, which is being formed by the Small Wind Certification Corporation. This will allow turbines to be accepted for multiple state incentive programs as compared to the current process of independent state by state certification.

Finally, research activities under the Supporting Research and Testing (SR&T) activity target distributed technologies. If budgets allow, the program will expand the scope of the second round of WindPACT studies to cover medium-sized wind turbines. These studies are expected to identify specific research areas requiring further investigation.

Table 17 provides a crosswalk between expected FY07 program activities and the technical barriers described in Section 2.2.4.

Table 17. Barriers Addressed by Distributed Wind Technology Activities	
Program Activity	Related Barriers
Component/System Development	M 7, 8 T 1, 2, 3, 4, 5, 6
Enabling Research	M 1, 3, 6, 7, 8 T1, 2, 4, 5, 7, 8
Design Review & Analysis Support	M 1, 7, 8 T 1, 2, 3, 4, 5
Testing Support	M 1, 4, 6, 7, 8 T 2, 3, 4

Component/System Development

The program will continue to support Round I component and prototype development, which is managed by the GFO with technical support from NREL. The Round I financial assistance agreements include support for component grants with Windward Engineering (over-speed control methodologies to be tested on a 5-kW DWT system), Composite Engineering (blade manufacturing technology), and Abundant Renewable Energy (preliminary design of a low-cost 10-kW DWT system). NREL also has a financial agreement with Northern Power Systems to redesign its Northwind 100, a 100-kW cold weather turbine, for low wind speed applications. NREL will continue to support its subcontract work with Southwest Windpower. These remaining DOE/GO Round 1 grants are scheduled to be completed in FY 2007.

Enabling Research

Taking turbine designs to the limit of cost and performance requires investment in fundamental research and codes development. Enabling research has provided quality data on how small wind turbine design parameters affect turbine operation and acoustics. Future research activities will continue to focus on areas identified in the AWEA Roadmap, including the design of low-cost, very tall towers; development of blade and airfoil technology for low-cost robust rotors; improved system integration through increased component efficiency; cost-shared research on power electronics; development of test protocols and analytical methods to improve reliability; improved manufacturing processes and methodologies; research on ways to lower turbine noise; research on the effects of turbulence and shear environments that affect turbine operations; and enhanced turbine design techniques specifically for rotor aerodynamic and turbine dynamics.

Design Review and Analysis

The program will continue to provide the targeted design review and analysis expertise needed to meet DWT subkey goals. Projects to be supported include public/private partnerships from DWT competitive solicitations awarded by GFO and ongoing multi-year DWT subcontractor projects. This support and oversight will assist industry partners and enhance their chances of success while protecting the Wind Program's investments.

Testing Support

Field-testing supports a wide range of DWT activities. Field testing involves installation of sensors and transducers (e.g. strain gages, accelerometers) used to quantify loads on operating turbine structural components, noise emissions, output of electrical systems, and meteorological inflow conditions. The test devices are connected to special rugged computer-based data acquisition systems. The large quantities of resulting data often require specialized processing and analysis. Field tests measure turbine loads, acoustic emissions, power production, and power quality. Resulting loads data are essential in verifying computer simulation models of wind turbine configurations. Field test data are especially important for assessing the viability of new, innovative turbine configurations, because models need tuning with test data to establish necessary confidence levels. The program will conduct field tests, structural tests, and dynamometer tests to support DWT subkey goals.

2.2.6 Distributed Wind Technology Milestones and Decision Points

Milestones for the DWT activities provide planning guidance and a means by which progress can be tracked.

2007 Milestones

- Begin field-testing of a prototype turbine
- Complete final review of a turbine design project
- Complete CRADA testing of SWWP beta Skystream turbine
- Reduce the cost of electricity from distributed wind systems to 10–15 cents/kWh in Class 3 wind resources.

2008 Milestones

- Conduct independent testing of small turbines.
- Complete assessment of DWT market.

2009 Milestones

- Release RFP for commercial/farm value engineered turbine.
- Complete independent testing of small wind turbines.

2010 Milestones

- Award one subcontract for commercial/farm value engineered turbine.
- Establish regional independent test center for small turbines.

2011 – 2013 Milestones

2.3 Systems Integration

The President's Advanced Energy Initiative (AEI), published in 2006, elevates the role of renewable energy technologies in the Nation's energy future. The location and generation variability characteristics of renewable energy technologies create challenges for electric power system planners and operators in realizing full potential of these resources. The uncontrolled natural variability of wind resources raise questions about their effects on routine system operations and operational costs, as well as capacity and reliability values. Additionally many of the nations best wind resources are located far from urban areas, where new transmission is required for access. Although transmission access for significant amounts of new generation is an issue for all sources, for wind, solar, and emerging renewable power technologies to become mainstream electricity sources, they must have appropriate dynamic models. This will enable non-discriminatory interconnection evaluation, access to the existing utility grid, the ability to operate without disadvantage under market rules, and appropriate representation in regional planning processes. Ultimately, to most effectively realize a substantial portion of our national energy needs with renewable energy, strategic integration of a full range of advanced technologies for energy production, delivery, storage, control, and use will be needed.

The Systems Integration (SI) activity within the Wind Energy Program is working to enhance wind's compatibility with the nation's long-term energy needs by sponsoring activities in wind plant power profile data gathering, system impact analysis tools development, and the adoption of equitable grid access and operational rules for wind. Other activities ensure that wind characteristics and needs are considered in regional planning process. Through the Renewable Systems Interconnection (RSI) Joint Program, a collaboration between several renewable energy technology programs, the program is also looking more critically at the issues related to energy delivery, allowing low-cost wind energy to be transported to urban load centers. All of the SI program efforts target all major regional wind markets. Outreach activities through program and professional publications are enhanced by the informational forums sponsored by the Utility Wind Interest Group (UWIG) and the National Wind Coordinating Committee (NWCC).

2.3.1 SI Strategic Goals

Wind power is a unique source of electricity. The natural variability of the wind resource raises questions about planning and reliability value, as well as concerns about how wind can be integrated into routine grid operations and the effects it will have on regulation, load following, scheduling, line voltage, and reserves. These concerns are inhibiting wind power market acceptance and growth. Several recent SI studies indicate improving economics and state and regional policies for wind power. As a result of these studies, there is greater support for increasing the penetration of wind power to 20% or more of the nation's electricity supply.

The AEI has also focused attention on integrating large amounts of wind power. For wind to become a mainstream electricity technology, it must have appropriate dynamic models for interconnection evaluation, fair access to the existing utility grid, and the ability to operate without disadvantage under market rules. Long lead times for constructing new transmission and cost allocation and recovery issues for new lines are also barriers. According to the American Wind Energy Association (AWEA), transmission is a critical infrastructure element to enable competitive electricity markets to develop and move electricity to market, much as the interstate highway system does for the nation's transportation needs. With this in mind, one of the program's strategic goals is to ensure nondiscriminatory access to the energy delivery network through education, regulation, and policy.

2.3.2 SI Performance Goals

The goal of the SI activity is: "By 2012, complete program activities addressing electric power market rules, interconnection impacts, operating strategies, and system planning support needs for wind energy to compete without disadvantage to serve the Nation's energy needs."

Progress towards this goal will be measured by examining SI accomplishments in each region of the country. When program activities in these four areas are complete, the program's efforts will be judged to have been successful. The completion of program activities is not predicated upon acceptance or implementation of program outputs, because the program can only provide support and make tools available for use; it cannot directly influence whether they are adopted by regional planners, policy makers, and utility operators. However, because the wind industry and public-interest stakeholders will be motivated to encourage the adoption of program results, the probability of acceptance and implementation is high.

It is noteworthy that the program does not have a performance goal associated with improving transmission infrastructure for wind technologies. The programs primary task in this activity area is to provide the tools, data, and assistance necessary for entities responsible for our Nation's transmission infrastructure to accurately represent wind energy in their integrated resource planning activities.

2.3.3 SI Market Challenges and Barriers

The electric industry is in a challenging period characterized by changing, diverse, and non-uniform market rules and regulatory oversight, corporate restructuring, high competition, and technological change. The integration of renewable energy, including wind energy, into the generation supply mix is one of many issues the industry is grappling with in adapting to this more competitive market structure. SI-related market barriers arise because wind technology interacts with the grid in different ways than other technologies. Because of these differences, utilities are concerned about possible impacts on system operations when a large amount of wind power is introduced into the electric power system.

Because utility operators and decision makers, state regulators, and investment bankers are unfamiliar with wind power, they are overly cautious in their view of wind power as a generation asset. Principal concerns include potential system effects due to limitations in wind forecasting and potential electrical system stability and dispatch implications. The rules and processes that are appropriate and equitable for conventional dispatchable technologies are not equitable for wind. These concerns, if not adequately addressed, could limit the development potential of wind power in this country. Many of these market barriers are being addressed by SI research.

The development of new transmission lines introduces different, though sometimes overlapping, market barriers that must also be addressed. These barriers can be broken down into two areas: regulatory and cost allocation.

- *Regulatory* – The Energy Policy Act of 2005 (EPAct 2005) provided DOE with the direction and authority to coordinate the Federal authorizations needed for new transmission. EPAct charges DOE with two responsibilities: designating electric transmission corridors of national interest (using reliability criteria), and designating energy corridors on western Federal land. However, the development of new transmission corridors requires the coordination of many different organizations and groups at the Federal, regional, state, and local levels. Finding consensus and working through the issues associated with the development of new transmission infrastructure is a barrier to development.
- *Cost and Financial Allocation* –Upgrading the nation's transmission system is like upgrading the interstate highway system. The costs are substantial, and the upgrades cross many organizational boundaries. Obtaining funding and developing regulations for the recovery of costs of large interstate transmission upgrades associated with integrating renewable energy resources is highly complicated. The fact that the costs should be spread broadly among a large class of regional beneficiaries that may be outside of the traditional electric market sector also complicates matters.

Table 18 lists market barriers addressed by the program's SI activities.

Table 18. Summary of Market Challenges and Barriers Addressed by SI Activities

Barrier Number	Barrier Description
M1	Utility and regulatory unfamiliarity with nondispatchable, variable output technologies
M2	Punitive imbalance penalties levied on variable generator output
M3	Cumbersome interconnection study requirements
M4	Grid integration issues vary regionally
M5	Transmission tariffs and cost allocation structures are not aimed at a variable energy based resource
M6	Difficult transmission siting processes
M7	Capital cost of new transmission is difficult to allocate among multiple generators and end-users
M8	Costs are not equitably distributed to those benefiting from the use of renewable technology

Utility and regulatory unfamiliarity with nondispatchable variable output technologies – One aspect of variability that disadvantages wind energy is that scheduling generation service, normally required one day or more in advance, is difficult for wind plants because of limits in the ability to forecast wind plant output. Conventional units can be turned on or off based on the operator's decisions, while a wind project generates energy based on wind speed. Existing scheduling practices are based on conventional technologies. For example, transmission access is either firm, priced in $/MW/yr, or "as available" priced in $/kWh. With a capacity factor of 0.25 to 0.35, a wind project developer cannot afford to purchase firm capacity, yet if the developer is using as-available or non-firm transmission rates, financing will be difficult or impossible. In addition, in many areas of the country, firm transmission is simply not available under existing evaluation methods. Recent Federal Energy Regulatory Commission (FERC) rulings may lead to some resolution through conditional firm products, but without long-term availability, their usefulness may be limited. As part of our efforts, we will examine the effect of conditional firm tariffs on wind energy transmission access.

Punitive imbalance penalties levied on variable generator output – FERC Order 888 established penalties for a generator that deviate more than one tenth of one percent from its previous day schedule. The state-of-the-art in wind forecasting does not allow this precision, making it impossible for wind to avoid such penalties. FERC has recently issued modifications to these imbalance provisions for wind and other technologies. Implementation of these changes will need to be monitored to determine if the problems have been fully addressed.

Cumbersome interconnection study requirements – The interconnection study required by reliability organizations is capacity-based and assumes worst case system conditions. While system dynamic response is important, wind is mainly an energy source and reliability criteria for the full nameplate of a wind plant does not make sense. In addition, the serial and lengthy nature of the typical interconnection study queue is problematic for wind because of the short construction lead times.

Grid integration issues vary regionally – Diverse market rules and structures across the country make it difficult for stakeholder and regulatory groups to get the information they need. The program is supporting regional-based integration studies and will expand its effort to distribute technical results to key stakeholder groups through such mechanisms as the UWIG and International Energy Agency (IEA) Tasks.

Transmission tariffs and cost allocation structures are not aimed at a variable energy based resource – Long-distance transmission is subject to pancaking rates (paying of multiple transmission tolls), not based on cost, that may preclude long-distance transactions. In addition, variable energy sources are most often charged capacity-based rates.

Difficult transmission siting processes – Siting, financing, and construction of new transmission as part of wind energy development often requires the coordination of private and public organizations at all national, regional, state, and local levels. Working with these organizations to develop a set of plans to follow during implementation of a wind energy project is a barrier to development.

The capital cost of new transmission is difficult to allocate among multiple generators and end-users – The development of new transmission is expensive (one to three million dollars per mile), and is likely to cross state, utility, and power control boundaries. Developing financing for such a project while ensuring cost recovery for the parties involved is a barrier to the development of new transmission. With multiple generators, such as would be expected at a multigigawatt wind site, developing commitments for an economic high-voltage line is problematic. Recent trends at the state and regional levels to designate renewable energy zones and build lines to resource areas rather than generators are forthcoming. Out assistance is requested to assist this effort by conducting multi-state case studies of wind energy integration.

Costs are not equitably distributed to those benefiting from the use of wind technology – Because the benefits of the increased use of renewable technology go beyond those traditionally considered in the power sector, new regulations should be developed to require that the costs and benefits of transmission upgrades associated with integrating renewable energy resources be spread broadly among regional beneficiaries.

2.3.4 SI Technical (Non-Market) Challenges and Barriers

Twenty years ago, it was generally accepted by the utility industry that only a small amount of energy on a power system could come from wind plants. The rule of thumb was five percent. More detailed studies that looked at explicit representations of risk, wind power, and impact on utility operation suggested that the five percent figure was a conservative limit, and that penetrations up to 20% could be achieved if power system operation were changed to accommodate wind energy. At the five percent level, once the actual performance of wind plants is known, there is sufficient regulating capacity in typical utilities to compensate for short-term fluctuations. Reserves can compensate for the total loss of a typical wind plant. As instantaneous wind energy penetration increases, the units operating on economic dispatch are backed off, i.e. fuel is saved, while those units that compensate on a minute by minute basis for imbalances between load and generation must vary their operation more frequently. Recent data suggests that the impact of wind projects on regulation is small. In some regions, the regulation service is paid for by the wind plant operator. In other regions, regulation is provided as a service by the power system or the regional transmission organization (RTO), with costs paid by load-serving entities, not by the wind generator. In still other regions, the costs of regulation and other ancillary services are implicitly paid by customers where there are no other provisions, such as in much of the west and southeast where few, if any, RTOs have been formed. Recently, promising trends on reserve and regulation sharing may benefit wind without the formation of an RTO. However, it is imperative the benefits of such arrangements be quantified.

The need for SI activities arises due to the barriers presented because wind is a naturally variable power technology. In the short term, wind will be challenged by traditional power-system planning and operating procedures. As the industry seeks to supply up to 20% of the nation's electrical generation, the issues of integrating wind into the nation's electrical system will become more acute and extensive.

The integration wind energy into long-haul transmission lines includes additional operator and technical challenges.

- *Operational Challenges* – As with integrating wind farms into the electric grid, the development of new transmission lines requires the assessments of interconnection impacts, operating strategies, and system planning on a regional or national scale. These issues must be studied and addressed through a coordinated effort with private and public stakeholders before solutions can be implemented.
- *Technical Challenges* – Large losses will be associated with the long-haul transmission of power from rural areas, such as from the northern Great Plains to eastern load centers. SI activities present an opportunity to support the research, development, and deployment of new technologies that will dramatically improve system performance and the viability of clean energy resources by addressing issues such as variability, controllability, and environmental impact.

Table 19 lists technical challenges and barriers addressed by SI activities.

Table 19. Summary of Technical Challenges and Barriers Addressed by SI Activities

Barrier Number	Barrier Description
T1	Wind's reliability and needs for incremental balancing are poorly documented
T2	Traditional power system operation is not designed to accommodate wind
T3	Interconnection impacts are often overestimated
T4	The perception that wind plants cannot contribute to system reliability
T5	Poor understanding of ancillary costs imposed by wind
T6	A shortage of real-world operational data
T7	A shortage of regional penetration studies
T8	Limited experience with operating wind near grid stability limits
T9	Poor understanding of the benefits of large-scale geographical diversity
T10	Inconsistent transmission and generation impact assessment results

Wind's reliability and needs for incremental balancing are poorly documented – Since the inception of the program in the early 1970s, wind energy has been considered a fuel-saver, i.e. the economic and environmental benefit of wind energy is to reduce fuel consumption by other generators. However, due to wind's variability, utility operators often mistakenly assume that the full output of a wind plant can be lost at any second, and thus capacity for the full wind farm output must be on reserve. Because some utility operators believe that the wind plant's output can drop to zero almost instantly, they also believe that 1 MW of reserve capacity is required for each MW of wind. These types of assumptions result in less than realistic valuation of wind in the grid system.

The power system operation is not designed to accommodate wind – Power system operating and market rules must be redesigned so that the electric power industry can more easily accommodate the characteristics wind generation.

Overestimation of interconnection impacts – Without models that capture modern controls and wind generator characteristics, interconnection impacts are overestimated. This causes the permitted capacity to be lower than if characteristics were accurately represented. Also, existing interconnection models do not handle a large number of wind plants.

Perception that wind plants cannot contribute to system reliability – The perception that a wind plant does not contribute to reliability ignores the realities of geographic diversity and statistical correlations of wind plants output.

Poor understanding of ancillary costs imposed by wind – The shape of the wind penetration curve, how ancillary services costs vary with penetration, and the size of the market balancing area largely determine the limits of wind energy penetration in a given geographic region. Note, penetration can be expressed as the ratio of wind energy to instantaneous load, i.e. 100% penetration of wind in Western Denmark on some days, but is typically represented on an annual energy basis—the fraction of energy that wind displaces, i.e. about 20% of energy in Western Denmark.

Shortage of real-world operational data - Geographically diverse, time synchronized, hourly wind plant data sets are needed for transmission system studies and stability studies.

Shortage of regional penetration studies – Existing studies are based on small actual penetrations that are scaled up to larger penetration through simulation, which is inaccurate. More high-penetration studies are needed, like those recently completed by Xcel in Colorado and in the states of Minnesota and California. Once a 20% regional penetration level in energy is reached, impacts should be validated and mitigation addressed if needed.

Limited experience with operating wind near grid stability limits –Much of the Western U.S. grid is limited by stability. Techniques to operate closer to the limit or to identify lines that are not being utilized at the contracted level, would assist wind energy deployment.

Poor understanding of the benefits of large-scale geographical diversity – It is possible to simulate large geographically dispersed wind plants onshore and offshore. This type of data is key in making sure wind is a player in large grid expansion planning.

Inconsistent transmission and generation impact assessment results – Transmission impact assessments tend to be worst system case, 100% nameplate output analyses, while generation assessments assign statistical reliability or zero capacity credit. The contrast in analysis assumptions appears inconsistent and inaccurately represents wind plant power characteristics. In addition to conventional reliability evaluations, recent trends in examining potential carbon constraints may help drive systems planners to a more energy-based examination of future needs.

2.3.5 SI Strategies for Overcoming Challenges and Barriers

The SI strategy is to help regional electric system planning and operations personnel make informed decisions about the integration of wind energy. Supporting wider access to transmission infrastructure can help wind become a major supplier of the nation's electrical energy. In previous years, the program has adapted wind technology to allow its use in areas that limit the need for transmission enhancements (low wind speed and offshore wind). In light of the AEI and EPAct 2005, the program is focusing on efficient use of the existing power delivery network and representing wind's interests in expanding the nation's energy infrastructure. FY 2007 is the start of a major push in this direction that will extend over the next several years.

The program is working on markets, policies, technology, outreach, and education in coordination with the Department's Electricity Delivery and Energy Reliability Office and electric sector organizations and stakeholders. Separate program activities are being initiated to consider issues related to long-haul transmission.

The objectives of the four primary SI activity areas are as follows:

Markets: To assist market transformation in the power transmission industry that will enable higher quantities of wind power to be available to the electric power consumer.

Policies: To break down transmission and integration barriers to wind energy development through Federal policies and to encourage regions and states to do the same.

Technology: To ensure that state-of-the-art wind models for grid integration are available, accepted, and actively used in system planning and operation.

Outreach and Education: To ensure that the electricity industry is provided with adequate wind integration information to enable progress toward meeting partnership goals.

Program personnel will continue to work with organizations such as independent system operators (ISOs), RTOs, regulators, legislators, and state and local utility planners to have wind considered in their resource planning and rulemaking proceedings in a fair and equitable manner. The program also coordinates with the American Wind Energy Association (AWEA), which is proactive in this area because of its implications for future wind development, and with UWIG, which works in partnership with the electric utility industry. As future markets and applications are considered, the program will integrate these organizations' needs into the activities conducted under the program's target areas.

Outreach to stakeholders is a key element of the program's SI strategy. Ongoing communication: (1) ensures a thorough understanding of major needs and issues related to wind's integration into the nation's energy infrastructure; (2) defines and refines program activities in response to these needs; (3) delivers relevant program products and expertise to those who can use them; and (4) increases key stakeholders' awareness of wind power's actual integration impacts and its evolving maturity. This outreach is conducted through participation in relevant projects with electric utility industry representatives, either by providing funding, technical consultants, reviewers, or a combination of these; participation in meetings where relevant issues are discussed or where power system rules are being deliberated; support of and participation in relevant activities of key stakeholder groups such as UWIG and NWCC; and interactions with AWEA and members of the wind industry.

A regional focus has been adopted because of the increased importance of regional planning entities in electric system planning and market operation. The program's strategy is to define and complete activities on a region-by-region basis that provide system operators, planners, and relevant decision makers with the information and tools needed for equitable treatment of wind power in the energy marketplace. These are the outputs of the activity.

Each region of the nation's electricity grid has different needs. In setting priorities, the program considers factors such as: regional wind resource potential; presence or absence of regional partners; degree of regional funding support; likely impact relative to program resource requirements; and the potential for expansion into new locations or markets. For example, a region with excellent wind potential may already have substantial activity with state or local funding to facilitate wind integration. In this situation, because program support may offer only marginal value, it should be directed where needs are greater. On the other hand, in some cases, the program might provide critical support or technical review at minimal cost that substantially increases the validity and acceptance of regional work. In such cases, the program would provide its support even though committed resources in the region are already large.

The program will sponsor research and collect operational data when a major public benefit exists. In other cases, the responsibility may lie with wind turbine manufacturers and power system operators in developing simulation models for wind turbines. In such cases, the program may play a facilitating role. In other cases, primary responsibilities must lie with regional stakeholders, power system operators, and regional regulators in developing integrated resource plans that utilize wind, while the program will provide supporting technical data and encourage fair treatment of wind.

As the nation turns to more domestic sources of energy production, as called for in the AEI and EPAct, transmission will play an increasing role. Although the program has always had activities addressing transmission limitations between high wind resource areas and major load centers, in the last year this activity has expanded in scope. The program is working with representatives from Federal power administrations, electric utilities, state policy makers, and trade and advocacy organizations to define a program that will help facilitate the efficient use of existing lines and the development of new transmission projects to multigigawatt wind resource areas.

Because of the multi-jurisdictional nature of long-haul transmission, both regional and multi-regional transmission issues must be addressed. The program assists state-based and regional wind integration studies to support the development of small transmission projects that could, if planned properly, be elements of a larger multi-regional project. In partnership with appropriate stakeholders, the program is planning to support larger multi-regional assessments that will be required for the development of larger projects.

The SI activities undertaken by the program to address the barriers are shown in Table 20.

Table 20. Barriers Addressed by SI Activities

Program Activity	Related Barriers
Market	M 1, 2, 4, 6, 7, 8 T 1, 3, 4, 5, 6
Policy	M 1, 2, 3, 4, 5, 6, 7 T 5
Technology	M 1, 3, 4, 7 T 1, 2, 4, 6, 7, 8, 9
Outreach & Education	M 1, 2, 3, 5, 6, 7 T 1, 8, 9
Transmission Development and Support	M 1, 2, 5, 6, 7 T 1, 2, 4, 5, 7, 10

Market

To assist market transformation that will enable higher quantities of wind power to be available to the electric power consumer, the program will use the data, models, and methods developed through SI activities to address issues facing wind integration. These tasks will facilitate good engineering practice through technical analysis and support of rulemaking processes, assessment of the impact of high wind penetration levels, and consideration of mitigation strategies for barriers to increased wind project development.

Wind plant effects on utility operations, analysis and planning support **–** A key issue affecting wind integration is the development of planning documents assessing impacts at the state and regional levels. The development of procedures and best practice guidelines for these studies has become a major portion of the program's work. As interest in the development of further planning documents incorporating wind increases, the program will continue to participate in methods development and review for system integration studies sponsored and led by outside agencies. Activities promoting state-of-the-art analyses and results will continue through sponsorship of UWIG and integration with organizations such as IEEE. The program will participate in an activity initiated by the IEA to review the design and operation of systems with large amounts of wind power. Program activities in coming years will include funding and sponsorship of large regional integration studies, including associated wind power profile simulation work.

Operational impact mitigation strategies – As wind deployment expands, costs for the integration of wind onto the power system operations may increase, especially at higher penetrations. Both short- and long-term mitigation of variability issues, including wind plant forecasting, which has seen considerable progress in the private sector; selective curtailment and wind plant ramp control; balancing area cooperation; and the amalgamation with existing energy storage (such as pumped hydro) could reduce additional integration costs. In the longer term, the program may consider additional activities with advanced storage options.

Wind and hydropower integration **–** While fluctuating power levels and transmission constraints may hamper adoption of wind energy, the hydropower industry faces constraints such as fluctuating regional water resources, growing obligations, and market pressures on water uses (i.e. need for flood controls, environmental issues, and recreation). Most experts agree that the value of wind and hydropower could be mutually enhanced by working together. For example, variations in power delivery levels caused by natural wind speed changes could be damped or eliminated. Hydropower facilities could provide system balancing for wind power by storing water during high-wind periods and increasing output when wind power goes down. Similarly, periods of low-water resources or policy pressures on water use can be mitigated by using wind to provide the energy normally generated by the hydropower systems.

DOE began exploring potential synergies between wind and hydropower resources in 2003 when it sponsored an IEA Topical Expert Meeting on the Integration of Wind and Hydropower Systems This led to the approval of IEA Wind Task XXIV (Integration of Wind and Hydropower Systems) with United States leading the effort as the operating agent. The program has since been involved in several case studies of wind/hydro interaction, for example with Grant County Public Utility District and the Arizona Power Authority. Broader regional studies, in cooperation with BPA and Western Area Power Authority (Western), are anticipated as part of program expansion.

Wind and hydrogen integration **–** In both transmission connected and distributed applications, wind technology has the potential to be a major energy supplier for the creation of hydrogen for both the electric and transportation sectors. In collaboration with the DOE Hydrogen Technologies Program and private companies, the Wind Energy Program will investigate the integration of wind turbines into hydrogen systems and identify the most appropriate ways to link wind turbines and electrolyzers.

Policy

Policy will play a key role in the future expansion of wind technologies into all levels of the national electric system. The program is cognizant of the implications of governmental activities influencing local, state, and Federal policies. Providing information to help decision makers better understand wind technologies through educational outreach and the development of clear and fair studies will give wind technologies a chance to develop in a competitive market. Activities to be undertaken in this area support the development and demonstration of policy options for wind technology.

Wind initiatives and critical issues support – Technical support will be provided to government organizations developing or implementing large wind integration projects. Examples include follow-on actions to recommendations by the wind task force of the Western Governors Association, the Northwest Wind Integration Action Plan technical activities led by Bonneville Power Administration (BPA) and the Northwest Power Pool (NWPP), and other organizations undertaking regional wind integration initiatives. The program also works with organizations to identify and mitigate critical market issues. The program will broadly facilitate market transformation opportunities to achieve higher percentages of wind powered generation. These activities all support the AEI-motivated wind road mapping and vision work related to transmission and integration barriers to 20% national wind energy.

Transmission and generation planning – Continued growth in electric loads drives the need to plan for and install new generators and transmission lines. Wind generation is a relatively new wholesale power source, so planning organizations often do not include wind in their planning methods. Future utility resource plans and regional planning should include wind energy in their generation mix. The program is developing tools to conduct market penetration analyses considering the expansion of wind, the impact of 20% wind penetration scenarios, where wind will likely be developed, and the integration and possible delivery options for such scenarios. The program has been representing wind interests and characterizing wind data needed for proposed grid expansion plans, mainly in the Western interconnect and the Midwest Independent Transmission System Operator (MISO) areas.

Traditional transmission planning tends to be reactive rather than proactive. Planners respond to requests for interconnection of new generators individually rather than estimating future regional needs in an integrated fashion. The program has encouraged and facilitated proactive planning, for example through support of transmission work performed by the NWCC. Progress on this front will provide benefits to the entire power system and to the public, and it will enable expanded use of wind power. Regional efforts through the Midwest Independent System Operator, Rocky Mountain Area Transmission Study, and the broader Western Electric Coordinating Council (WECC) have benefited from NREL technical support in formulating wind generation scenarios.

Characterizations of wind resource locations and power delivery profiles are critical to the accurate assessment of power delivery needs for getting the energy to market. Regional surveys of wind geographic diversity through mesoscale modeling will require federal support. In addition, the reliability characteristics (capacity credit) resulting from wind and utility load temporal profile matches affect the valuation of wind in planning processes. Most of the foregoing can be handled by existing utility practices, as illustrated in past program work, as long as data is available. The role of the Wind Energy Program is to provide technical information and assistance where needed.

One problem for wind developers is that existing practice for interconnection requires the same level of interconnection studies for a 25-MW wind plant as for a 1000-MW coal-steam plant. Further, as each project is completed, the dynamics of the network change, rendering earlier studies invalid. This becomes an expensive, time-consuming hurdle for most wind projects. For cost-effective deployment of wind power, each region should have an integrated study such as the recently completed Midwest Independent Systems Operator/Wind-On-the-Wires/AWEA study of 10,000 MW of wind, or the preliminary work of this type that was done in PJM, the regional transmission organization that serves the mid-Atlantic and adjoining regions.

Activities in technology development are covered by two tasks: Grid Operational Impact Analysis and Generation Planning. The inherently variable, uncontrollable nature of wind generation as compared to conventional power plants raises issues with regard to additional costs imposed during real-time operation and correct representation of wind in generation and transmission resource planning. The program works to develop tools and methods to help generation and transmission organizations address these issues.

Market rules development – With its low capacity factor and variable resource often located far from loads, wind power can be adversely impacted by wholesale market structures and by changes to those markets that are enacted or contemplated by organizations such as RTOs, which set the rules for how wind is marketed. Until recently, penalty-based rules proffered in FERC Order 888 to drive good market behavior have inappropriately disadvantaged wind. Recently FERC has issued reforms in imbalance penalties that help remedy the situation. The Wind Program's role is to provide objective data and analysis for wind energy stakeholders to allow participation in interim and future rule development processes. Methods developed in other regions can and should be presented and applied to grid rule development processes.

Without such activity, wind energy will inevitably be subjected to arbitrary and unsubstantiated reductions in value. This is a major challenge for the entire wind energy community, and the program is providing a critical support role.

Technology

The program is participating in the collaborative development and refinement of models, tools, and methods for utility analysis of wind integration. These activities gather and provide publicly available basic data and models of generator electrical characteristics, wind farm temporal power profiles, and wind resource geographic variability. Accurate representations are critical to correctly assessing wind power impacts on grid operations and planning. The program cooperates with various stakeholders including hardware manufacturers, grid operators and planners, developers, and the associated engineering consultants.

Wind and system analysis, stability, and plan development support **–** The program represents wind technology and its characteristics in a variety of forums, including regional transmission planning processes. The program assists with development of nondiscriminatory reliability methods, and collaborates with organizations such as the Western Governors Association, which is adding detail to its Clean and Diversified Energy Initiative that is developing energy plans incorporating wind technologies. Many sub-regional efforts are beginning or are ongoing. The program will continue to provide data and analysis, work with electric utility stakeholders, and provide technical support to wind transmission organizations such as Wind on the Wires and West Wind Wires. The program is also seeking other methods to advance the development of the energy infrastructure, including private/public partnerships with organizations such as the Northwest Integration Action Plan that are seeking to develop regional transmission plans.

Interconnect wide mesoscale modeling and power flow analysis **–** Planning and development of wind energy far from the load requires an understanding of how wind power flows on long-haul transmission systems. The ability to have time-synchronized load and wind resource data over wide areas will allow regional assessment of the power flow and energy balance required to support the development of transmission lines to bring wind energy to market. This also requires the analysis of conventional generation sources and the development of wind resource maps at the 100-m heights typical of modern wind farms.

Wind generator and plant modeling – The program is working with the wind industry to provide utilities and utility operation organizations with better electrical models of individual wind generators and whole wind plants to enable evaluation of interconnection and system impacts of proposed wind farms. Valid wind turbine and wind plant models are essential for evaluating impacts on electric system stability. Without these, the grid evaluations will use unsophisticated outdated parameters, unnecessarily limiting the amount of wind capacity that will be allowed to interconnect. Non-generator-specific models do not accurately capture fault ride-through capability or the advantages of variable-speed power electronics, including their ability to provide voltage support (VARs) to the system.

As an example of this modeling, the program is working to examine system limitations in the Tehachapi region of California and to better understand the effects of installing induction turbines on operational stability. The goal is to develop a better understanding of the interaction of wind generators with local system operation and to identify ways to mitigate operational issues confronting that region.

Key issues that need to be addressed include representing the benefits of fast evolving turbine designs, capturing the electrical effects of multi-machine and wind plant collection systems, representing collection bus-level mitigation devices, and validation testing of the wind generator models.

This work is integrated and conducted in close coordination with many private industry, utility and national and international stakeholders such as WECC, MISO, IEEE, UWIG and the IEA.

Wind farm data monitoring – The principal concern by electric utilities unfamiliar with wind energy is that the plant output can suddenly fall to zero. Data on second-by-second power fluctuations from commercial wind farms has not historically been available. The program cooperated with FPL Energy at Lake Benton II (MN) and Storm Lake (IA) to provide power data with one-second resolution to fill this need. The data gathering effort has been expanded to include plants in Texas, the Northwest, and California. Data for the Northwest is being collected in cooperation with BPA. Over the past year, the program added locations in New Mexico and Alberta. The program has published statistical data reports that provide a reference for development of wind farm impact models. Without long-term data sets from various wind resource regimes, evaluation of the grid impacts of variability cannot be performed.

Resource profile characterization – The program will work to provide representations of the wind resource, including seasonal, diurnal and hourly shapes, where possible, to allow models to better characterize the potential benefits and impacts that wind can have on system operation, and to assess transmission needs on a regional basis. These wind profiles are essential for evaluation of wind plant contributions to overall system reliability. Time-series databases used in validation of recent state maps can provide a basis for this new effort. The data collected for wind farm monitoring will also contribute to resource characterization. Over the next few years, the program will expand the resource characterization effort to include sites with different characteristics, and will ensure that this data meets the needs of the wind forecasting work described later in this section.

System operational impact analysis – The Wind Energy Program will address the normally uncontrollable variable nature of wind power plant output and the additional needs that its operation imposes on the system balancing. This work is essential to allay fears about backup generation requirements and excessive increases in ancillary services costs. At present, the generation and operational impacts that occur because of wind variability are not well quantified. At lower penetrations these impacts have rarely been an issue, but as the industry moves to higher levels of penetration more consideration will be required. This research will seek to quantify and allocate impacts in both an engineering and cost sense. These analysis methods are at an early stage of development. Without realistic analysis and cost allocation, utilities often overestimate wind's operational costs, resulting in the undervaluing of wind power. Unrealistically high ancillary cost evaluations will result in lower wind deployment rates.

The first public engineering-based operating impact study was completed in 2003 by UWIG with funds mostly contributed by utility members. The program provided methodology support and review, a process that has expanded since that time. High penetration examinations for Xcel Colorado and the California ISO were nearly completed at the time of this writing. For all of these studies, and other similar work, the program has provided critical input data, technical support, and detailed technical review.

Larger regional studies are needed to examine multi-state geographic dispersion and tradeoffs associated with planning high voltage transmission lines. Expanded program activities are expected to allow the program to play a major financial sponsorship role in these needed areas.

Outreach and Education

As renewable power becomes more economic and interest in further wind development more common, the need for information regarding the proper integration of wind technologies will demand more of the program's resources. In addition to the collaborative activities described above, the program will develop a communications plan and common DOE messages concerning wind integration for use in written and oral communications to stakeholders and interested parties. This will include the development of communications and information for the electric power industry, regulators, legislators, and other stakeholders.

***Regional transmission organization collaboration* –** The program's expanded efforts to advance the nation's energy infrastructure will require more collaboration with RTOs such as MISO and other power marketing agencies like Western. Direct collaboration with these organizations will expand transmission access for wind technologies.

***Industry Cooperation and Policy Support* –** Through collaboration with many private industry, utility, and national stakeholders such as WECC, MISO, IEEE, UWIG and the NWCC, the program will work to educate regulators, state officials, and other energy market decision makers by facilitating open forums and other outreach activities. The goal of this activity is to provide clear and accurate information about the appropriate use of wind technologies.

2.3.6 SI Milestones and Decision Points

The SI milestones provide planning guidance and a means by which progress can be tracked. Stage gates at which projects are evaluated include the following 2007 – 2012 milestones.

<u>2007 Milestones</u>

- Participate in analysis and publish two case studies examining the value and implementation of wind forecasting in electric operations
- Publish results of collaborative work addressing mitigation methods for system impacts of wind at high penetration
- Provide support to BPA wind integration studies and regulation tariff
- Provide support to the Xcel/PSCO wind integration study
- Report trends in historical wind power costs.

2008 Milestones

- Develop meso-model data set for a large-scale regional wind integration study
- Report and database characterizing line loadings and potential for increased wind energy usage
- Complete recommendations for long-range power system planning that optimizes the realization of wind power's overall benefits from a comprehensive IRP perspective
- Complete and publish comprehensive summaries of wind's impacts on electric-system operation and ancillary services costs.

2009 Milestones

- Complete evaluation and recommendations for high-wind penetration scenarios based on production of electricity and hydrogen

2010 Milestones

- Complete and publish comprehensive summaries of wind's impacts on electric-system operation and ancillary services costs.

2011 – 2013 Milestones

- Collaborate with manufacturers and system operators in development and validation of electrical models for advanced wind plants and supporting equipment used in mitigation of high-penetration wind impacts
- Complete evaluation and recommendations for wind's impacts on -system operation and ancillary services costs
- 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
- Options for high efficiency linkages between substantial agrarian wind power regions and urban load centers will enable siting, permitting, and integration of wind power on a national scale by 2012.

2.4 Technology Acceptance

The Technology Acceptance program area provides information about wind energy technology and its benefits to the stakeholder community to allow informed decision making and to reduce barriers to the use of wind power. The success of the program's efforts to remove nontechnical barriers is seen as critical to the long-term success of land-based, offshore, and distributed wind technologies, as well as emerging wind applications. The program has recently increased its efforts to overcome near-term deployment barriers and will expand its efforts to reduce environmental and siting issues, in FY2008.

2.4.1 Technology Acceptance Strategic Goals

The strategic goal of the Technology Acceptance (TA) activity is to lower the cost of energy for wind generation systems by easing market barriers to the increased use of wind. This activity also seeks to enable a sustainable U.S. wind market beyond states with significant installed capacity, stimulate rural economic development through project development, enhance tribal energy self-sufficiency, and explore emerging markets and applications for wind generation systems.

2.4.2 Technology Acceptance Performance Goals

The current performance goal of TA is that by 2010, at least 100 MW of wind capacity (100 MW indicates a mature market that can support wind's continued growth) will be installed in 30 states. Although the goal only uses installed capacity to measure success, it also gauges the market in terms of indicators such as overall awareness, legislative and regulatory environment, resource assessment, and wind resource potential. Even with the current explosion in the use of wind energy, as installed capacity within a state exceeds 100 MW, other technology acceptance issues arise. The program is currently working on a new programmatic goal to be implemented in the FY09 timeframe that will address these expanded challenges.

Since the initiation of the Wind Powering America (WPA) project, three phases of wind acceptance have been used to measure progress based on a state's wind installed capacity: less than 20 MW, 20 to 100 MW, and more than 100 MW. Because several variables in addition to installed capacity contribute to the maturity of state wind markets, and there are emerging markets for wind power, the Wind Energy Program is reevaluating its measures of success. In the future, TA progress will be measured in four new phases. The first phase is characterized as the time before significant levels of awareness or adoption are evident in a state. The second phase is when awareness of wind's potential to contribute to a state's energy needs is increasing. The third phase is the time between initial WPA-supported activities in a state and when the state-based efforts become self-sufficient. This phase is characterized by intense WPA support and an increasingly active wind market. When the fourth and final phase is reached, mature markets conducive to wind are established, TA activities are reduced, and focus can be shifted to other states. At that point, in-state expertise has reached a level sufficient to continue the momentum built by DOE's TA activities. WPA's experience suggests that this level corresponds roughly to when the installed capacity reaches the 100 MW level, the proposed mature wind market goal. There may be strategic reasons to continue activities in a state after achievement of the goals.

Table 21 lists the annual target levels that have been used to measure TA's progress since the initiation of the Wind Powering America Project.

Table 21. TA Goal and Annual Targets

Year	Number of States With Mature Wind Markets (Goal)	Number of States With Active Wind Markets (Supporting Targets)
2002	8	13
2003	10	19
2004	12	25
2005	16	32 (interim target)
2006	19	34
2007	22	36
2008	25	38
2009	27	39
2010	30 (goal)	40

As the TA effort achieves its goals, the focus of TA will change. For example, the need for 50-meter resource maps and 20-meter anemometer loans will end as momentum builds. In addition, new markets will emerge where wind technology, particularly using new low wind speed turbines, will play a role in applications such as offshore generation, cleaning and moving water, and hydrogen production. The program expects that TA efforts will transition from state-based technical assistance to a more regional focus on emerging markets.

2.4.3 Technology Acceptance Market Challenges and Barriers

Numerous institutional and informational barriers slow the adoption of wind power (see Table 22). These barriers are distinct from technology cost and performance issues, but could prove to be equally important. For example, some states have adopted policies and undertaken barrier reduction actions to facilitate the deployment of wind energy. Other states have not explored their wind resources or the potential for wind to stimulate economic activity. The challenge for TA is to develop, disseminate, and support an appropriate mix of technical information and outreach for states where there is a good wind resource, yet little public or private wind momentum. The guiding principle is to develop fact-based information on wind technology and the benefits and challenges of wind energy to enable stakeholders to make informed decisions on their energy future.

Another challenge is to bring the wind message to potential users of distributed wind technology. By reaching out to farmers, ranchers, Native Americans, and other state and local stakeholders, WPA can help build state-levels coalition necessary to create consensus on the development of a sustainable wind market.

To reduce barriers on a national level, WPA works with groups such as the National Wind Coordinating Committee (NWCC), the Utility Wind Interest Group (UWIG), the American Public Power Association (APPA), and the National Rural Electric Cooperative Association (NRECA).

The Wind Program's TA efforts complement other elements of the Wind Program, including SI, as both are aimed at mitigating barriers to the use of wind power. The SI work targets technical barriers, while TA efforts address issues associated with state, local, and consumer-owned utility lack of familiarity with the technology.

Table 22. Summary of Market Challenges and Barriers Addressed by TA Activities

Barrier Number	Barrier Description
M1	Lack of understanding about the role wind energy can play in the nation's energy future
M2	Misconceptions and lack of understanding of local wind resource
M3	Siting wind turbines presents varying challenges depending on their size and location
M4	Environmental benefits and impacts are not fully understood or valued adequately
M5	Lack of awareness and infrastructure for small wind
M6	Capital markets are unfamiliar with wind and take conservative financial approaches to wind output prediction
M7	Challenging policy and regulatory environment

Market challenges and barriers addressed by TA activities include:

Lack of understanding about the role wind energy can play in the nation's energy future – Opponents use misconceptions about wind energy, such as that wind plants are too small to make a difference, to confuse the public on the role that wind energy can play in meeting the nation's energy needs.

Misconceptions and lack of understanding of local wind resource – The attention given to wind farm development in high-wind areas has convinced some people that they must have an exceptional resource to benefit from wind technology. However, distributed wind turbines are designed to operate effectively in lower wind speed areas. Wind maps have inadvertently exacerbated the problem by classifying wind regimes according to their potential for wind farm development.

Siting wind turbines presents varying challenges depending on their size and location – When siting is poorly planned or managed, there is a social equity issue in that buyers and sellers of wind energy get benefits, while those who endure siting impacts of wind turbines or transmission lines may receive fewer or no benefits.

Environmental benefits and impacts are not fully understood or valued adequately – Scientific information that would allow wind-related environmental impacts to be fairly assessed relative to alternate energy sources is not available.

Lack of awareness and infrastructure for small wind – To enable the development of small wind technologies, regional awareness must be developed at all levels. The landowner must have the knowledge to use the technology. The local utility must accept PURPA regulations. The local planning board must allow permitting. State legislators must provide legislation for incentives or approve net metering. Significant infrastructure development is required to enable landowners to purchase, install, and maintain wind turbines.

Capital markets are unfamiliar with wind and take conservative financial approaches to wind output prediction – The variation in annual output from a wind plant adds uncertainty to a project and creates a major financial hurdle. Financing organizations deal with this uncertainty in their due diligence processes by assuming that annual project revenues associated with a minimal wind year are representative of the entire project lifetime. The capital intensity of wind and discounting practices for evaluating alternatives allocate risk disproportionately to ratepayers, or do not recognize the fuel price risk hedge value of wind. This means that the cost of wind generated electricity does not change when fuel prices fluctuate, as with natural gas in recent years.

Challenging policy and regulatory environment - Onshore wind development requires regulatory approval at the state and local levels, which have different policies and regulatory requirements. To enable fair, uniform, sustainable wind development across the country, best practice regulations will be discussed and shared by the program among local, state, and Federal stakeholders.

2.4.4 TA Technical (Non-Market) Challenges and Barriers

TA program activities are devoted to addressing market barriers to the use of wind technology, while technology barriers are addressed by other program activities. However, the TA activity addresses a limited number of technically related activities discussed below. Table 23 lists these key technical barriers.

Table 23. Summary of Technical Challenges and Barriers Addressed by TA Activities

Barrier Number	Barrier Description
T1	Interference with radar installations
T2	Poor understanding of impacts of wind turbines on specific animal species and habitat
T3	Lack of understanding of wind turbine technology, dynamics, and available resource
T4	Complexity in assessing the economics benefits of wind technologies

Interference with radar installations – At some sites, wind turbines can interfere with civilian or military radar by causing clutter. In March 2006, concerns about the impacts of wind turbines on radar systems led the Department of Defense and the Department of Homeland Security to issue an Interim Policy that contested the establishment of wind farms within line of site of the National Air Defense and Homeland Security Radars. This Interim Policy halted progress on the development of hundreds of projects. Although efforts on the part of DOE, the America Wind Energy Association (AWEA), the Federal Aviation Administration, and the Department of Defense (DoD) restarted development of about 1,000 MW of wind projects, a DoD report released in September 2006 failed to adequately address mitigation strategies for wind turbine/radar interactions.

Poor understanding of impacts of wind turbines on specific animal species and habitat – A wind project's impact on different animal species, including avian and aquatic life or habitat, is not usually well known. The inability to assess this risk makes it difficult for regulators to approve some development projects.

Lack of understanding of wind turbine technology, dynamics, and available resource– A lack of understanding of wind energy is a barrier to implementation and more general public acceptance. Although detailed engineering information is not usually required, a general understanding of turbine operation and dynamics is helpful in informing the public about wind technology, especially in comparison to conventional energy generation technology, which is more commonly understood at a basic level. This lack of understanding allows wind energy skeptics to mislead/misrepresent the benefits and determents to wind technology. Additionally, people are generally more wary of technologies that they don't understand. Misconceptions regarding local wind resources and ways to accurately measure those recourse are also common. Most proposed projects may require the installation of measurement stations or data analysis techniques that are not commonly understood by local representatives and planners, and this may also hinder the potential development of wind resources in their area.

Complexity in assessing the economics benefits of wind technologies – Because the decision to install wind turbines, either in a distributed application or as part of a larger development project, is a complex matter requiring information regarding resource, technical criteria, and energy consumption, it can be difficult for individuals, regulators or local planners to assess the economic potential and impact of wind development. Without this understanding and the tools to allow local assessments, it becomes very difficult for individuals or state based organizations to justify supporting wind projects, especially in the face of organized criticism.

2.4.5 Technology Acceptance Strategies for Overcoming Challenges and Barriers

The strategy of the TA effort is to build state-level support for increased wind power in all applicable regions of the country. A state-focused strategy acknowledges the critical role that states have played in wind power's development through policies, incentive adoption, and stakeholder involvement. The primary mechanisms for pursuing this strategy are WPA and the NWCC.

The WPA team has developed technical assistance and outreach activities aimed at key user communities – farmers and ranchers, Native Americans, rural electric cooperatives and consumer-owned utilities, and publicly-owned facilities. DOE and its National Laboratories work with these stakeholders and state and local officials to develop interest in wind power, identify needs, and form state-level wind working groups that build the local presence required to accelerate widespread adoption. WPA's operating principles include: focusing work where there are good wind resources, but there is little development (working at the margin of the market); leveraging and building institutional partnerships; developing innovative pilot applications; replicating successes; utilizing existing national, regional, and local expertise; and coordinating with established wind institutional resources.

The strategy of the NWCC, a consensus-based collaborative formed in 1994 and supported by the program, is to establish dialogue among key stakeholders and catalyze activities to support the development of environmentally, economically, and politically sustainable commercial markets for wind power. NWCC members include representatives from electric utilities and support organizations, state legislatures, state utility commissions, consumer advocacy offices, wind equipment suppliers and developers, green power marketers, environmental organizations, agriculture and economic development organizations, and state and Federal agencies. The Wind Energy Program provides the largest share of financial support for the NWCC, but does not determine its research and outreach agenda.

The program is pursuing five activities under the TA element to address barriers. Table 24 lists these activities and shows which barriers are addressed by the activity.

Table 24. Barriers Addressed by TA Activities

Program Activity	Related Barriers
Outreach to State-Based Organizations	M 1, 2, 3, 4, 5, 6, 7 T 1, 2, 3, 4
Small Wind	M 1, 2, 3, 5, 7 T 2, 3
Institution Building Through Utility Partnerships	M 1, 2, 3, 4, 5, 6, 7 T 1, 2, 3, 4
Support for Native American Interest in Wind Power	M 1, 2, 3, 4, 5, 7 T 1, 2, 3
Environmental and Siting Considerations	M 1, 3, 4, 7 T 1, 2

Outreach to State-Based Organizations

Over the past several years, the program has worked to foster the formation of state wind working groups to serve as focal points and a local presence for outreach to local communities and stakeholders. By the end of FY 2006, formal groups had been established in 28 states, from Virginia to Hawaii. Some of these have become self-sufficient, and TA support for them has been reduced. However, the majority of states still do not have self-sustaining, technically mature groups.

The state groups provide their regions with a mix of WPA-supported technical and general activities. For example, understanding the wind resource is the first among many steps toward increasing installed wind capacity. WPA has found that many state, county, and local stakeholders are unaware of their wind resources or are using information developed almost 20 years ago. To address this information deficit, WPA launched an anemometer loan program with states to increase familiarity with wind energy and to create the intellectual infrastructure necessary for development. Similarly, WPA began to cost-share development of updated state wind resource maps that show public and private officials, as well as landowners and other stakeholders, the extent of the wind resource in their state. By the end of FY 2006, there will be 36 validated state wind resource maps.

Wind provides substantial rural economic development opportunity because of the significant overlap of wind resources and rural areas. WPA directly engages state-based agricultural organizations as natural partners for rural wind development to leverage pre-existing contacts with the farming and ranching communities. Wind farms in rural areas provide annual payments to the landowners, state and local tax revenues, local revenues during construction, and quality long-term jobs. WPA has developed an economic development analysis tool called JEDI that is used to estimate the economic development impacts of wind development in state and county specific cases. The NWCC has played an important role in developing a better understanding of the transmission and distribution system infrastructure required to support rural wind development. This effort is coordinated with, and complements, SI activities to engage the regulatory community on wind issues.

WPA has established partnerships with national, state, and local agriculture sector interests. A number of these have joined to form the Agriculture-Wind Outreach Group. WPA also works with the U.S. Department of Agriculture (USDA) and others to take advantage of their extensive contacts with stakeholders in the rural community and to increase access to USDA’s rural power systems funding programs. Since February 2003, the Wind Energy Program has collaborated with the USDA to implement its Farm Security and Rural Investment Act of 2002 (section 9006 of the the Farm Bill) through a 5-year program to foster the greater use of renewables in rural communities.

WPA, in conjunction with the National Conference of State Legislatures, has provided legislative briefings on technical aspects of wind energy systems. The NWCC has an ongoing wind farm siting work group that is detailing best practices for permitting wind generation facilities. An early NWCC focus on avian issues has played an important role in providing a factually and methodologically sound basis for debate.

Small Wind

TA works to remove barriers to the increased use of distributed and small wind technology in support of the program's distributed wind technology (DWT) efforts. The small wind outreach activities provide important nontechnical support to the industry's small wind roadmap, as described in the DWT section of this document. TA activities to overcome the barriers to the use of small wind systems include focused small wind energy workshops and meetings, development of a small wind calculator, development of customized wind resources maps, and development of state-specific Small Wind Guides containing resource, policy, and technical information and state contacts. As technology development under the Wind Program's DWT element leads to more cost-effective small wind turbines, small wind outreach efforts will grow in importance.

Institution Building through Utility Partnerships

The TA effort has established partnerships with public power organizations such as the APPA and rural cooperatives associated with NRECA. Sharing of experience among the members of this community has helped build momentum for utility acceptance and support for wind. For example, NRECA has sponsored workshops in more than 10 states to facilitate discussion. Basin Electric Power Cooperative, with its pioneering support for 80 MW of wind in South Dakota and North Dakota, has become an important champion of the technology, and has recently adopted a 10% corporate renewable portfolio standard (RPS). Each year WPA recognizes leadership in the public power sector by presenting an award to the municipal power company and the rural electric cooperative that provided outstanding support for wind power. TA efforts also coordinate closely with and take advantage of Utility Wind Interest Group (UWIG) activities. In the long term, outreach and communication partnerships with utilities will be an important element of program support to regional groups fostering greater integration of wind power.

Support for Native American Interest in Wind Power

There is only one large-scale wind development on Native American lands, despite the wide availability of excellent wind resources on those lands. Following the installation of the first large Native-American owned wind turbine, a 750-kW unit, on the Rosebud Sioux Indian Reservation in 2003, the largest wind farm on Native American lands, a 50-MW project, was installed on Campo Band of Kumeyaay Indian land near San Diego, California, in 2005.

Technical assistance and outreach efforts to expand tribal wind activities are underway, from planning and resource assessment to project development options, with over 30 tribes from 13 states and regions with good wind resources. The program helped establish a Native American Wind Interest Group (NAWIG) that encourages tribal experts to engage tribal representatives on all aspects of wind energy. WPA administers a Native American anemometer loan program that also provides technical assistance to help tribes understand their wind resource and development options. WPA has provided guidance to tribal officials seeking financial awards for wind exploration and business plans, and provides a means for Native Americans to attend wind energy training programs under DOE-supported Wind Energy Applications and Training Symposium (WEATS) activities. The Wind Energy Program works with other EERE programs, such as DOE's Tribal Energy Program, to increase the use of wind power on tribal lands. WPA also engages numerous tribal organizations, such as the Intertribal Energy Network (ITEN), to augment existing activities.

Environmental and Siting Considerations

Wind energy provides a net environmental benefit to the communities in which it operates and to the nation overall: it emits no air pollution or greenhouse gases, reduces dependence on imported sources of energy, contributes to local economic development, and does not present a security threat. However, as with any development project, it can have adverse environmental impacts.

Many of these effects are under study, and are being quantified to allow mitigation. Wind projects have the potential to reduce, fragment, or degrade habitat for wildlife, fish, and plants directly or indirectly causing harm to biotic communities. Birds and bats have experienced the strongest impacts. The program leads peer-reviewed research efforts to understand, avoid, and minimize these impacts. Recognizing the net environmental benefit of wind development, as well as the potential for environmental impacts, the program will pursue strategies to meet several environmental objectives for wind energy. These objectives include: identifying and supporting scientific research priorities relating to the impact of wind energy facilities on wildlife and helping to ensure that responsible environmental compliance can be achieved by wind power developers without disadvantaging the economic outlook for wind growth.

Assessing siting and consumer acceptance impacts also plays a role in the further development of wind technologies. To support efforts to remove barriers to wind turbine siting and address sources of consumer resistance to large-scale deployment of wind, the program works with other Federal agencies to develop and support mechanisms that enable developers to meet the statutory, regulatory, and administrative requirements that protect wildlife, national security, and public safety. An example of these activities is the recent collaboration to address the impact of wind turbines on defense and civilian radar systems.

The program has made a significant effort in the last 6 months to accelerate market penetration of wind energy through collaboration with other Federal agencies and hopes to improve that collaboration by:

- Continuing work already underway to address wind project siting issues between interested/vested Federal entities
- Enabling exchange of technical, environmental, market information, regulatory and/or policy requirements related to siting wind turbines on public, private, and tribal lands, air, and sea
- Identifying future cooperative actions to inform and support Federal agency decision-making related to wind turbine siting

The program will also work through outside organizations such as the NWCC and UWIG to ensure that accurate information and open dialog are available to those interested in the proper use of wind technologies.

2.4.6 Technology Acceptance Milestones and Decision Points

The milestones for WPA provide planning guidance and a means for tracking progress. Stage gates at which projects are evaluated include the following 2007 – 2013 milestones.

<u>2007 Milestones</u>

- Complete one public power outreach and technical assistance activity
- Complete one regional state leadership issue forum
- Complete one Native American outreach and technical assistance activity
- 20 states with greater than 100 MW installed
- 30 Wind Working Groups, 25 of which have announcements and information posted on websites.

<u>2008 Milestones</u>

- 25 states with greater than 100 MW installed.

<u>2009 Milestones</u>

- 27 states with greater than 100 MW installed.

<u>2010 Milestones</u>

- 30 states with greater than 100 MW installed.

<u>2011 – 2013 Milestones</u>

- Not applicable as WPA activities will be completed in 2010.

2.5 Cross-Cutting Issues

The following section describes program activities that cross all specific program research areas, primarily communication and outreach.

2.5.1 Communications and Outreach

The Wind Energy Program communications and outreach effort promotes wind energy and is a critical strategy in providing reliable, affordable, and environmentally sound energy for the nation. The program publishes and distributes communication products to appropriate audiences including government officials, researchers, members of the wind energy industry, utility engineers and planners, and other stakeholders interested in the Wind Energy Program and its research activities. The communications effort coordinates with the EERE Office of Communication and Outreach (OCO) in the production and publication of technical papers, outreach brochures and materials, journal articles, web sites, and conference papers and exhibits. Through this effort, the program also facilitates communication of programmatic goals, activities, and research highlights.

Information dissemination, communications, and outreach activities are also coordinated and carried out through the OCO. OCO works to communicate information on the EERE mission, program plans, accomplishments, and technology capabilities to a variety of stakeholder audiences including Congress, the public, educational institutions, industry, and other government and non-government organizations. In addition, OCO prepares speeches and presentations by the Assistant Secretary and others when requested; manages the EERE public website and EERE's centralized public information clearinghouse; manages official correspondence; and coordinates reviews of EERE-related statements by other DOE offices and Federal agencies.

OCO coordinates outreach and information activities across EERE, integrating communications efforts from all programs to provide a unified approach. Thus consumers learn about all relevant EERE technologies rather than receiving information on only one aspect of energy efficiency or renewable energy. Such coordinated efforts are designed to: target opportunities where rising prices or tight energy supplies may spur acceptance of new technologies; remove barriers to technology acceptance and implementation; and provide accurate information regarding EERE technologies.

3.0 Program Portfolio Management

3.1 Program Portfolio Management Process

The program combines industry input, technical assessment, and peer review as central pillars of its portfolio decision-making process. Figure 15 provides an overview of this strategic planning framework. As shown, the program has an ongoing technical assessment process to monitor the status of wind technology and progress in achieving program cost goals, evaluate that status within the context of marketplace needs, and identify technological pathways that will lead to successful marketplace competition. The program also uses a formal peer-review process to benefit from the guidance of industry and the research community and to provide an outside view of the program. As shown in Figure 15, both the technical assessment and peer-review processes provide inputs that the program management team considers in making decisions about strategic program directions and funding priorities.

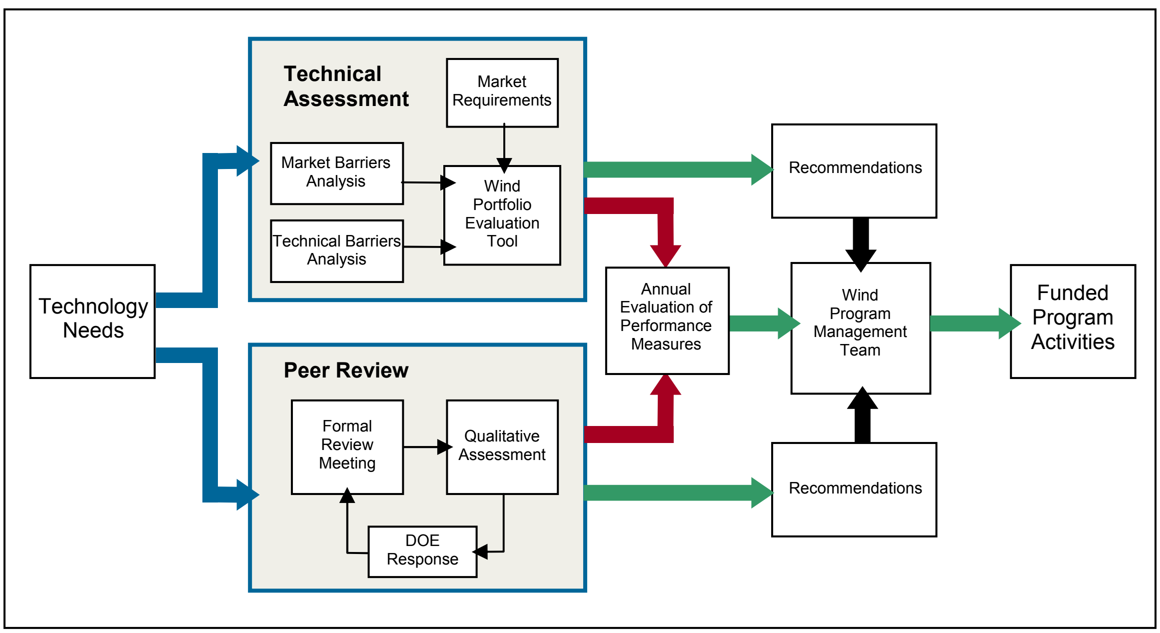

Figure 15. Strategic Planning Framework

The peer-review process, provides formal feedback on program efforts. Peer reviews are conducted in conformance with DOE guidance using unaffiliated individuals with a wide range of experience in industry and research. Although the review is organized by Wind Energy Program staff, an impartial peer-review director oversees the review process to ensure conformity with DOE guidelines. This peer-review director works with program personnel to select the peer-review team, which has approximately five members.

The peer-review meeting is an intensive multiday technical event with topical sessions structured around major program research efforts. Program speakers make formal presentations on their research projects and are subjected to questions from a facilitated peer-review panel. The panel then presents its findings in a Peer-Review Report to which the program responds. The peer-review efforts are incorporated into the program's annual report and play an important role in the finalization of the program's annual operating plan. The review results are also considered when the management team evaluates potential adjustments to program direction.

In addition to the peer-review meeting, the program conducts a formal strategic planning meeting as part of the planning process for out-year funding. This meeting, which takes place every winter, includes representatives from industry, research staff, and the peer-review panel. Discussions are held on program direction and strategic planning to ensure that industry partners are able to provide timely and critical insight into market trends that the program should consider when developing the next year's research plan.

The combined efforts of the decision-making process results in four key program documents:

- *Program Annual Report*: A broad overview of each year's strategic planning and peer-review meetings.
- *Multiyear Program Plan* (MYPP): This document, which is a detailed description of program activities, schedules, milestones, and performance metrics for each research activity. The MYPP is a forward-looking document that outlines the program's goals, objectives, and priorities while providing limited insight into specific activities.
- *Annual Operating Plan* (AOP): A detailed plan describing current-year activities. The AOP offers a detailed explanation of all program activities. It differs from the MYPP in that it reflects the actual program activities and the status of research efforts.
- *Annual Turbine Technology Update* (ATTU): An annual report on key LWT activity progress made toward program technology performance goals or technology improvements from the reference point.

Through the publication and presentation of peer-reviewed program strategic planning and management documents, the program works to ensure that there is wide-based acceptance of its research portfolio.

3.2 Program Analysis

Program analysis activities fall into two areas. The first area involves active tracking of program activities to provide guidance on their progress and the appropriateness of program activities. The second area is long-term strategic planning to ensure that the program is making appropriate long-term decisions to support the missions of DOE, EERE, and the development of a viable wind energy option for the Nation.

In this process, the program uses assessment tools developed through the program or adapted from outside applications. For example, the program uses the NEMS[27] market analysis tool to assess the impact of different programmatic wind opportunities both within the structure of the EERE's program portfolio analysis activities and outside of it. The program has also supported the development and use of the NREL-developed WinDS[28] software that allows market-based analysis down to the county level to help focus program outreach. In addition, the program has developed a detailed technical assessment process to provide analytic oversight for technical R&D activities. Because all LWT goals and annual targets are based on COE calculations, the program has invested heavily in the refinement of financial models based on the EPRI-TAG methodology and maintained by Princeton Energy Research International[29]. This helps the program ensure that the COE calculations both meet DOE's need for a constant dollar-based research metric and provide an accurate assessment of future market-based energy costs.

3.3 Performance Assessment

The Wind Energy Program monitors its research efforts to improve program performance and increase accountability. Through EERE's Corporate Planning System (CPS) and other milestone tracking methods, each program activity (with the exception of SI) is tracked against clearly defined performance measures and annual targets. Agreement and project level milestones are also maintained for all program sub-key activities to ensure progress towards quarterly milestones, and annual targets where appropriate.

Only three of the programs sub-key activities (LWT, DWT, and TA) have annual targets. After the question of expanding offshore activities has been decided in FY09, all program work in shallow water offshore technologies will be covered under the LWT activity. At the request of the Office of Management and Budget (OMB), the SI sub-key activity does not have an annual target, but it is tracked through project- and agreement-level milestones.

3.3.1 Performance Assessment Strategy and Plan

The program has developed a technical assessment process for each sub-key activity to ensure that every research activity supported by the program can demonstrate a direct link to achieving the top-level strategic goals of the Wind Program, EERE, and DOE.

Although different approaches are used to conduct technical assessments of each program area, the approaches are similar within the two key activities. Technology R&D uses a technical pathway analysis to show the impact of private-public partnerships and ensure that research activities are directly applicable to Technical Improvement Opportunities

[27] Project Benefits of Federal Energy Efficiency and Renewable Energy Programs FY 2006 Budget Request, National Renewable Energy Laboratory, Golden, CO. NREL/TP-620-37931, May 2005.
[28] Short, W.; Blair, N.; Heimiller, D.; Singh, V. Modeling the Long-Term Market Penetration of Wind in the United States. 15 pp.; NREL Report No. CP-620-34469, 2003.
[29] T. Schweizer and K. George, Primer: The Wind Energy Program's Approach to Calculating Cost of Energy. NREL Technical Report. To be published fall of 2006.

(TIOs) identified through detailed market and technical assessments[30]. Thus, for each TV activity area, the program has established a portfolio evaluation process that:

- Sets program COE or performance goals based on analysis of opportunities for technology improvement through program-sponsored R&D and outreach
- Tracks progress toward those goals using outside market information and the same analysis tools as are used for setting goals, and reports that progress annually in terms of cost of energy using a standard methodology developed to approximate market-based projects[31]
- Provides program funding guidance on activities that may no longer be contributing, or have the potential to contribute to, technology progress
- Ensures that all program-sponsored subtasks can be shown to contribute to achievement of program targets for increased implementation, technology cost reduction, energy production enhancement, or operation and maintenance (O&M) cost reductions.

For the TA portion of the program, a maturity index is used to assess how well key market barriers are being addressed at state or regional levels. In both programs, this methodology is used for internal program tracking and prioritization and has not been implemented as a formal OMB tracking activity. The maturity index uses the status of conditional market and technical barriers to assess wind market maturity on a state-by-state or regional basis.

In FY06, all program work in shallow water offshore technologies is covered under the LWT program, and thus is included in LWT program technology assessment activities. The program is analyzing TIOs for shallow water offshore applications such as foundation design and turbine reliability. At least through FY09, improvements in technologies relevant to shallow water applications will be incorporated in the technology assessment process used for land-based applications.

The TA sub-key activity uses a simple capacity threshold to indicate the acceptance of wind technology in each state. Priority states are identified through an assessment of market barriers based on the expert knowledge of a program steering committee. The use of a simple state-based threshold makes it hard to identify the direct impact of program activities, and as the PTC cycle has demonstrated, wind installations are largely driven by market forces rather than program outreach activities. At the direction of OMB, the SI sub-key activity does not have a set programmatic goal. The basic technical assessment structure developed to measure progress has not been implemented.

The program does not have a model to analytically compare sub-key activities. For example, it is not possible to compare the long-range benefits of technology R&D conducted under the TV program area to the benefits of technology deployment activities completed under TA. Strategic decisions on funding and program priorities across sub-key activities are based on discussions with key program stakeholders, research, and

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[30] Schreck, S.; Laxson, A. (2005). Low Wind Speed Technologies Annual Turbine Technology Update (ATTU) Process for Land-Based, Utility-Class Technologies. 29 pp.; NREL Report No. TP-500-37505.

program management staff.

Important elements of the technical assessment process for sub-key activities include annual activity-level assessments and incorporation of peer-review feedback into program prioritization activities. When appropriate, the analyses conducted under this technical assessment process are also used in program estimates of annual benefits under GPRA. The program uses these tracking methodologies to guide multi-year planning and track annual progress toward the goals. Details of performance measurement processes for each program element are provided in Section 3.

3.3.2 Data Collection to Support Routine and Periodic Performance Assessment

The Wind Energy Program is expanding its effort to collect real-time data on the wind power market through the compilation and analysis of information on the development and deployment of wind projects, the price of wind power in regulated and spot markets, and the myriad performance, component cost, finance and policy elements that help determine both supply and demand for wind. The insights gained from this analysis allow the program to better understand which specific elements of the market present the most significant barriers to wide-scale wind deployment and how resources can best be allocated to remove these barriers. The collection and dissemination of these data is also intended to benefit the entire wind power sector through greater market transparency.

As part of this effort, the program will also publish a new annual report on U.S. wind power installation, cost, and performance trends. The need for such a report has become apparent in the past few years, as the wind power industry has entered an era of substantial growth, both globally and in the United States. Drawing from a variety of sources, this report provides information on a variety of topics, including wind project installation trends, costs of installed wind project, wind turbine prices and project performance.

As part of program activities, other key data, such as information on the cost and availability of transmission, the financing structures of wind projects, policy information and analysis, and market data on distributed wind technologies will be collected and disseminated in a series of internal and outreach products, such as the report mentioned above and pragmatic turbine cost models.

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