U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

WIND AND WATER POWER TECHNOLOGIES OFFICE

U.S. Department of Energy's Wind Program Funding in the United States:

# Wind Integration, Transmission, and Resource Assessment and Characterization Projects

Fiscal Years 2006 - 2014

# Introduction

## Wind and Water Power Technologies Office

The Wind and Water Power Technologies Office (WWPTO), within the U.S. Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE), supports the development, deployment, and commercialization of wind and water power technologies. WWPTO works with a variety of stakeholders to identify and support research and development (R&D) efforts that improve technology performance, lower costs, and—ultimately—deploy technologies that efficiently capture the abundant wind and water energy resources in the United States. WWPTO is one office that contains two distinct focus programs: wind and water. The Wind Program and the Water Power Program operate as integrated, but separate entities within WWPTO.

The Wind Program is committed to developing and deploying a portfolio of innovative technologies for clean, domestic power generation to support an ever-growing industry.

The Wind Program provides R&D funding across six broad areas:

1. Offshore Wind Projects
2. Testing, Manufacturing, and Component Development Projects
3. Integration, Transmission, and Resource Assessment and Characterization Projects
4. Environmental Impacts Projects
5. Market Acceptance Projects
6. Workforce Development Projects.

The breakdown of Wind Program funding is presented in a series of reports that showcase the projects funded in each of the six abovementioned areas. The Offshore Wind Projects Report was released in April 2014 and the Testing, Manufacturing, and Component Development Report was released in April 2014. This report focuses on the third area by highlighting R&D efforts in integration, transmission, and resource assessment and characterization, projects.

The Wind Program's research and development (R&D) projects are typically financed through two primary sources of funding: Congressional Appropriations and Congressionally Directed Projects (CDPs). Congressional Appropriations determine the operating budgets for each EERE program. Program-funded R&D projects are typically awarded to recipients as cooperative grants through competitive Funding Opportunity Announcements (FOAs) that are dedicated to specific topic areas. CDPs are also funded by Congress, but are outside of the annual federal budget process. Frequently, there is a cost-share requirement for recipients of both competitive cooperative agreements resulting from FOAs and CDPs.

In addition to these two primary funding sources, the projects may be financed directly through specific legislation passed by Congress. In Fiscal Year (FY) 2009, for example, Congress passed the American Recovery and Reinvestment Act of 2009 (ARRA/Recovery Act). A portion of Recovery Act funding was dedicated to the Wind Program's R&D projects.

The program also funds research projects at DOE's national laboratories through the laboratories' annual operating plans. This funding is not detailed in this report. However, a national laboratory may be lead or a partner on a competitively-awarded project covered in this report. In these instances, their funding is included in the total DOE funding amount.

The Small Business Innovation Research (SBIR) program in DOE's Office of Science provides competitive awards-based funding for domestic small businesses engaging in R&D of innovative technology. SBIR has funded several projects with relevance to the wind industry; however, these projects are not covered in this report.

*Photo from NREL*

*Photo from NREL*

## Wind Integration, Transmission, and Resource Assessment and Characterization Projects

The strong, consistent, and abundant winds within the United States are providing a clean, domestic, and renewable source of power for the nation. As of the end of 2012, the United States had more wind turbine generating capacity installed on land than almost any other country, with an installed capacity of more than 60,000 MW. In 2012, wind energy became the number one source of new U.S. electricity generating capacity for the first time—providing approximately 43% of new generation—and represents the second largest renewable contribution to overall electricity generation in the United States (behind hydropower), providing 3.6% of the nation's electricity in 2012 and nearly 5% for the first half of 2013. In addition, wind energy costs in areas with good wind resources have been reduced from more than 55 cents (current dollars) per kilowatt-hour (kWh) in 1980 to less than six cents/kWh today. Increasing use of the nation's abundant wind resources for electric power generation will help the nation reduce its emissions of greenhouse gases and other air pollutants, diversify its energy supply, provide cost-competitive electricity to key regions across the country, and reduce water usage for power generation. In addition, wind energy deployment will help revitalize key sectors of the economy by investing in manufacturing and infrastructure and creating long-term, sustainable skilled jobs. To deploy greater penetrations of wind energy, the Wind Program focuses on removing barriers to grid integration through studies, modeling, demonstrations, and assessments.

A crucial factor in the development, siting, and operation of a wind farm is the ability to assess and characterize available wind resources. The Wind Program supports efforts to accurately define, measure, and forecast the nation's land-based and offshore wind resources. More accurate prediction and measurement of wind speed and direction help wind farms to supply clean, renewable power to businesses and homeowners at lower costs. The program works with other government agencies, universities, and industry members to assess and characterize U.S. wind resources. Assessment results are then made available to the public, enabling the wind industry to identify areas best suited for the development of future land-based and offshore wind farms.

Another vital function of the program is to advance wind energy integration into U.S. power systems by providing input and assessment of electric power market rules, interconnection impacts, operating strategies, and system planning needed for wind energy to competitively serve the nation's energy needs. The program works with electric grid operators, utilities, regulators, and other industry stakeholders to create new strategies for incorporating increasing amounts of wind energy into the power system while maintaining reliable operation of the grid. Program researchers work with industry partners on projects aimed at increasing utilities' understanding of integration issues and confidence in the reliability of new wind turbine products. The program supports research projects in wind forecasting, plant performance characterization, grid planning, and grid operational impact analysis to provide critical information for utilities and the industry to facilitate integration of increasing amounts of wind generation in the nation's power systems.

From 2006 to 2014, DOE's Wind Program announced awards totaling more than $30 million for 44 projects focused on integration, transmission, and resource assessment and characterization. Table 1 provides a brief description of each of these 2006-2014 projects. There are three sources of funding for wind technology projects covered in this report: competitive Funding Opportunity Announcements (funded by Congressional Appropriations), Congressionally Directed Projects (CDPs), and the American Recovery and Reinvestment Act of 2009 (ARRA/Recovery Act). See "Types of Funding Sources" on previous page for more information.

Table 1: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **ABB, Inc.** | National Offshore Wind Energy Grid Interconnection Study | $900,000 | FY11: U.S. Offshore Wind: Removing Market Barriers FOA | Multi-State (North Carolina, Pennsylvania, New York, Colorado) |
| Project Description | | | | |
| ABB identified viable offshore wind development sites and associated wind production profiles; performed an initial integration analysis and assessed the applicability of traditional integration study methods; and evaluated various potential energy collection and delivery technologies to aid integration of offshore wind resources to the national grid. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Alaska Energy Authority** | Alaska Wind Energy Project | $349,410 | Multi-Year CDP | Alaska |
| Project Description | | | | |
| Alaska Energy Authority will use modeling and analysis to determine the best performing wind energy systems for Alaska. This project includes upgrading the HOMER wind-diesel-solar hybrid modeling software; performing long-term meteorological tower studies for icing impacts and turbine performance; collecting performance data for remote power systems; and evaluating a Light Detection and Ranging (LiDAR) wind detection system to inform future improvements. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Analatom, Inc.** | Remote Structural Health Monitoring and Advanced Prognostics of Wind Turbines | $172,000 | FY09: American Recovery and Reinvestment Act (part of the 20% Wind by 2030 FOA) | California |
| Project Description | | | | |
| Analatom developed an electrical fault and failure detection and diagnostic data collection system that provides early indications of unscheduled emergency shutdown of wind turbine systems. The company determined various ways to measure abnormal behaviors in components and applied it to a system that can provide earlier detection of pitch rate failure, low oil pressure failure, and gearbox gear-tooth failure. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **AREVA Federal Services and Alstom Grid** | Best Practices and Advances in Strategies and Decision Support Systems for Integrating Wind Energy for Reliable Grid Operations | $278,610 | FY09: American Recovery and Reinvestment Act (part of the 20% Wind by 2030 FOA) | Maryland |
| Project Description | | | | |
| AREVA and a team of investigators surveyed 33 operators of electric power systems in 18 countries about wind integration, their operating policies, best practices, examples of excellence, lessons learned, and decision support tools now in place to formulate overall recommendations for utilities. These recommendations were provided in a final report — which can be found at wind.energy.gov/pdfs/reliable_grid_operations — and support the effective use of wind forecasts to facilitate increased wind penetration. | | | | |

[a] DOE Funding Amounts identified in this table reflect the total DOE funding planned for award to each project for the total period of project performance that may span multiple years. DOE Funding Amounts shown in this table may be subject to change.

*continued >*

Table 1: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **AWS Truepower, LLC** | Enhancing Short-Term Wind Forecasting for Improved Utility Operations | $2,151,013 | FY10: Short-Term Wind Forecasting FOA | Multi-State (Texas, Colorado, Oklahoma) |
| Project Description | | | | |
| AWS Truepower is working in conjunction with the National Oceanic and Atmospheric Administration (NOAA) and DOE to foster improvements in wind power forecasting. This research project involves a one-year field measurement campaign throughout two regions; enhancement of NOAA's experimental 3-km High-Resolution Rapid Refresh model by assimilating the data from the field campaign; and evaluation of the economic and reliability benefits of improved forecasts to grid operators. Project results will be disseminated to interested stakeholders through a nationwide mesonet observation system devoted to wind energy applications as part of the greater Wind Forecast_Improvement_Project: http://www.esrl.noaa.gov/psd/psd3/wfip/ | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **AWS Truepower, LLC** | National Offshore Wind Energy Resource and Design Condition Data Campaign | $900,000 | FY11: U.S. Offshore Wind: Removing Market Barriers FOA | Multi- State (New York, Colorado, Oklahoma, Texas) |
| Project Description | | | | |
| AWS Truepower is establishing a Web-based, national met-ocean wind energy resource and design conditions data inventory. The project will determine data needs, identify existing sources of relevant data, and execute a gap analysis to establish long-term requirements for new data to be gathered and disseminated through national public-private collaboration initiatives. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Case Western Reserve University** | Great Lakes Offshore Wind: Utility and Regional Integration Study | $540,000 | FY11: U.S. Offshore Wind: Removing Market Barriers FOA | Multi-State (Ohio, Colorado, New York, Pennsylvania) |
| Project Description | | | | |
| Case Western University is evaluating potential impacts of offshore wind on the electric grid in the Great Lakes region and determining requirements for interconnection, control systems, and the application of additional support for different transmission systems. The project is providing regional stakeholders with the knowledge base and capabilities to develop state-of-the-art, long-range strategies for mitigating the impacts of offshore wind interconnection, as well as realizing the economic cost reductions and benefits that can be achieved through implementing these strategies. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **DNV Renewables, Inc.** | Creation of a Model for Interaction of Bottom-Mounted Wind Turbines with Surface Ice for Use with Common Simulation Codes | $306,192 | FY11: U.S. Offshore Wind: Technology Development FOA | Washington |
| Project Description | | | | |
| DNV Renewables is creating a computational tool to simulate how an offshore wind turbine platform may be structurally impacted by interactions with ice on the surface of the water in regions such as the Great Lakes or sub-Arctic. The project will lead to a publicly-accessible design code for ice loading on the towers of offshore, bottom-mounted wind turbines that can interface with common simulation codes. | | | | |

*continued >*

Table 1: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Duke Energy Business Services, LLC** | Carolinas Offshore Wind Integration Case Study | $534,910 | FY11: U.S. Offshore Wind: Removing Market Barriers FOA | North Carolina |
| **Project Description** | | | | |
| Duke Energy Business Services conducted a study that examined the potential system impacts of offshore wind development on the Duke Energy Carolinas system, determined the costs of upgrading the transmission system to support large-scale offshore projects, and assessed strategies for system integration and management. The first phase of the study — which can be found at http://nctpc.org/nctpc/document/REF/2013-06-06/COWICS_Phase_1_Final_Report1%5B1%5D.pdf — found that new high-voltage transmission infrastructure is needed to reliably integrate offshore wind resources. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **East Penn Manufacturing** | Advanced Power Cube for Wind Power and Grid Regulation Services | $500,000 | FY10: CDP | Pennsylvania |
| **Project Description** | | | | |
| East Penn Manufacturing is researching and testing materials for advanced battery anodes for energy storage applications. This project involves performing trials for the development and evaluation of anode fabrication methods. Following the successful fabrication trials, batteries will be built and tested to determine their charge and discharge behavior at partial states of charge. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Electric Power Research Institute** | Integrating Midwest Wind Energy into Southeast Electricity Markets | $398,351 | FY09: American Recovery and Reinvestment Act (part of the 20% Wind by 2030 FOA) | Tennessee |
| **Project Description** | | | | |
| The Electric Power Research Institute analyzed the benefits of different balancing approaches with increasing levels of interregional cooperation. Scenarios were defined, modeled, and investigated to address production variability and uncertainty, and the associated balancing of large quantities of wind power in one region and delivery to energy markets in another. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **EnerNex** | Documentation, User Support, and Verification of Wind Turbine and Plant Models | $749,868 | FY09: American Recovery and Reinvestment Act (part of the 20% Wind by 2030 FOA) | Tennessee |
| **Project Description** | | | | |
| EnerNex validated the appropriate use of generic wind turbine models for transmission network analysis. The project allowed transmission planning engineers to apply with confidence the generic models for network studies involving commercial wind turbines sold into the U.S. market, in full compliance with North American Electric Reliability Corporation (NERC) standards and guidelines. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Grand Valley State University** | Michigan Alternative and Renewable Energy Center Offshore Wind Demonstration Project | $1,427,250 | FY09: CDP | Michigan |
| **Project Description** | | | | |
| To lower critical data collection costs, Grand Valley State University is validating state-of-the-art floating LiDAR instrument measurements using conventional onshore meteorological data. The University is also conducting research on the unique engineering challenges and environmental conditions found in the Great Lakes. | | | | |

*continued >*

Table 1: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Hawaiian Electric Company** | Hawaiian Utility Integration Initiatives (H.U.I) to Enable Wind | $750,000 | FY09: American Recovery and Reinvestment Act (part of the 20% Wind by 2030 FOA) | Hawaii |
| **Project Description** | | | | |
| Hawaiian Electric Company initiated a collaborative process to design more responsive grids with real-time information and advance control benefits. This design allows the system operator to detect, measure, and reliably respond to wind variability. The project aligned resources from its various partners to ensure adequate planning of future infrastructure changes and reliable integration of resource flexibility for maintaining and operating a sustainable island grid. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Indiana University Trustees** | An Integrated Approach to Offshore Wind Energy Assessment: Great Lakes 3D Wind Experiment | $700,000 | FY11: U.S. Offshore Wind: Removing Market Barriers FOA | Multi-State (Indiana, Ohio) |
| **Project Description** | | | | |
| Indiana University, in partnership with Case Western University, Clarkson University, and Arizona State University, is conducting a project to integrate wind data from remote sensing, aerial and satellite measurements, and meteorological towers in producing a high resolution wind characterization of Lake Erie. The project will also analyze the effectiveness of various measurement instruments and develop best practices for each type. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Kotzebue Electric Association, Inc.** | Vanadium Red-Ox Flow Battery Energy Storage System | $147,600 | FY08: CDP | Alaska |
| **Project Description** | | | | |
| Kotzebue Electrical Association installed and demonstrated a 2 megawatt-hour Vanadium Redox Flow Battery in an existing micro-grid environment. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Michigan Aerospace Corporation** | Turbine Reliability and Operability Optimization through the Use of Direct Detection LiDAR | $748,000 | FY09: American Recovery and Reinvestment Act (part of the 20% Wind by 2030 FOA) | Michigan |
| **Project Description** | | | | |
| Michigan Aerospace Corporation is developing a next generation ultraviolet LiDAR system. Under this project, the company performed LiDAR performance modeling, as well as LiDAR feed-forward control system modeling and simulation. The company's LiDAR unit provided multi-range volumetric measurement of wind speed, direction, temperature, and density simultaneously at both long and short ranges. Michigan Aerospace is now refining their system using the results of the modeling and simulation, and has been awarded a DOE Phase 2 Small Business Innovation Research (SBIR) award to demonstrate the total system solution for wind turbine control, involving the UV LiDAR, condition monitoring and decision-making software, and advanced control techniques. | | | | |

*continued >*

Table 1: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **National Center for Atmospheric Research** | Impacts of Stratification and Non-Equilibrium Winds and Waves on Hub-Height Winds | $702,000 | FY11: U.S. Offshore Wind: Removing Market Barriers FOA | Colorado |
| **Project Description** | | | | |
| The National Center for Atmospheric Research is evaluating surface level to hub-height level wind speed extrapolations and methods in an effort to evaluate and improve the siting and design of turbines, as well as the accuracy of wind energy predictions. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **National Center for Atmospheric Research** | Investigating Marine Boundary Layer Parameterizations by Combining Observations with Models via State Estimation | $702,000 | FY11: U.S. Offshore Wind: Removing Market Barriers FOA | Colorado |
| **Project Description** | | | | |
| The National Center for Atmospheric Research is examining the layer of the atmosphere that has direct contact with the ocean (marine boundary layer) to determine how temperature changes can impact wind energy production and facility design parameters. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **National Renewable Energy Laboratory (operated by Alliance for Sustainable Energy, LLC)** | Coupled Wind/Wave Simulation Models to Characterize Hurricane Load Cases | $400,000 | FY11: U.S. Offshore Wind: Technology Development FOA | Colorado |
| **Project Description** | | | | |
| The National Renewable Energy Laboratory-led team is developing a Coupled Hydro-Aerodynamic Interface for Storm Environments using the fully-coupled atmosphere-wave-ocean forecast model now used for hurricane research and prediction, linked to the Laboratory's FAST wind turbine simulation software. This will facilitate improved systems designs and lowered risk for offshore wind turbine systems located in extreme weather areas. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **National Renewable Energy Laboratory (operated by Alliance for Sustainable Energy, LLC)** | Simulator for Plant Applications | $1,200,000 | FY11: U.S. Offshore Wind: Technology Development FOA | Colorado |
| **Project Description** | | | | |
| The National Renewable Energy Laboratory improved and validated that industrial wake models will lead to more accurate prediction of energy losses and turbine loading within wind plants. Wind plant control has the potential to increase plant energy capture and reliability. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **New Mexico State University, Board of Regents** | Investigating Short Circuit Models for Wind Turbine Generators | $272,816 | FY09: American Recovery and Reinvestment Act (part of the 20% Wind by 2030 FOA) | New Mexico |
| **Project Description** | | | | |
| New Mexico State University researched the control strategy of power converters used in wind turbine generators (WTGs), device protection features within the converters, and the control of the reactive support devices. This research enables more effective planning for grid integrated wind turbines. These data were incorporated into generic simulated models of the WTGs. The University also simulated the connection of such models to an equivalent grid and estimated realistic, time-dependent, short-circuit models for each type of WTG. | | | | |

*continued >*

Table 1: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Pennsylvania State University** | A Cyber-Wind Facility for Turbine-Platform-Wake Interactions with the Atmosphere and Ocean | $1,200,000 | FY11: U.S. Offshore Wind: Technology Development FOA | Pennsylvania |
| Project Description | | | | |
| Pennsylvania State University plans to develop, validate, and distribute an open-source "Cyber-Wind Facility" for land and offshore extreme fidelity simulation that couple atmospheric turbulence eddy passage. The final product will consist of hierarchical modeling strategies for prediction of atmosphere-forced wind plants to develop new design and control concepts to enhance power capture and reduce component failure. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **The Research Foundation of the State University of New York (led by Stony Brook University)** | Improving Atmospheric Models for Offshore Wind Resource Mapping and Prediction Using LiDAR, Aircraft, and In-Ocean Observations | $675,219 | FY11: U.S. Offshore Wind: Removing Market Barriers FOA | Mulit-State (New York, Massachusetts) |
| Project Description | | | | |
| State University of New York is verifying instrumentation and developing an improved understanding of modeling and boundary layer physics through intensive data collection around the Cape Wind site. The improved modeling will be applied to constructing more accurate wind resource maps for the East Coast of the United States. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Stevens Institute of Technology** | Field Evaluation and Validation of Remote Wind Sensing Technologies: Shore-Based and Buoy Mounted LiDAR Systems | $702,000 | FY11: U.S. Offshore Wind: Removing Market Barriers FOA | New Jersey |
| Project Description | | | | |
| Stevens Institute of Technology is evaluating the capability of scanning and vertically-profiling LiDAR instruments to accurately measure wind fields in three dimensions, in comparison to fixed meteorological towers. The project is also quantifying variability in offshore winds off the coast of New Jersey. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Texas Tech University** | The Incubation of Next-Generation Radar Technologies to Lower the Cost of Wind Energy | $1,389,900 | FY14: Technology Incubator for Wind Energy Innovations FOA | Texas |
| Project Description | | | | |
| Texas Tech University in Lubbock will develop a first-of-its-kind, radar-based prototype to measure the flow of wind through wind farms, which will increase data availability and lead to improved modeling. While radar platforms have been used extensively in meteorological applications, this will be the first radar system specifically designed for wind energy research. This new design for a modular and portable system will require less power to operate and be able to measure larger areas than currently utilized conventional radar systems. The project complements the Energy Department's ongoing Atmosphere to Electrons (A2e) Initiative, which aims to improve wind plant performance by increasing understanding of how wind moves throughout wind farms. | | | | |

*continued >*

Table 1: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **University of Colorado, Board of Regents** | Upstream Measurements of Wind Profiles with Doppler LiDAR for Improved Wind Energy Integration | $233,082 | FY09: American Recovery and Reinvestment Act (part of the 20% Wind by 2030 FOA) | Colorado |
| Project Description | | | | |
| The University of Colorado has produced new upstream measurements of wind profiles over the altitude range of wind turbines using a scanning Doppler LiDAR technology. These long-range, high-quality measurements are providing improved wind power forecasts for wind energy integration into the power grid. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **University of Delaware** | Mid-Atlantic Offshore Wind Interconnection and Transmission | $540,000 | FY11: U.S. Offshore Wind: Removing Market Barriers FOA | Delaware |
| Project Description | | | | |
| The University of Delaware is examining the potential effects of offshore wind penetration on the Mid-Atlantic electric grid, and facilitating grid operations planning by identifying necessary system upgrades and grid management strategies to ensure reliable and efficient operation of the electric system. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **University of Denver** | Multi-Level Energy Storage and Controls for Large-Scale Wind Energy Integration | $265,677 | FY09: American Recovery and Reinvestment Act (part of the 20% Wind by 2030 FOA) | Colorado |
| Project Description | | | | |
| The University of Denver facilitated wind energy integration at different levels through the design and control of suitable energy storage systems for the balancing control center, wind power plant, and wind turbine generator levels. The project designed innovative energy storage architectures and associated controls for high wind penetration to increase reliability and market acceptance of wind power. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **University of Michigan** | Bottom Fixed Platform Dynamics Models Assessing Surface Ice Interactions for Transitional Depth Structures in the Great Lakes | $399,998 | FY11: U.S. Offshore Wind: Technology Development FOA | Michigan |
| Project Description | | | | |
| The University of Michigan is developing a modeling tool to simulate surface ice impact on innovative wind turbine substructure designs. The project is developing an ice-loading design module simulating interaction of freshwater ice features with offshore wind turbine structures in the Great Lakes. | | | | |

*continued >*

Table 1: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **University of Michigan, Board of Regents** | Measurement and Analysis of Extreme Wave and Ice Actions in the Great Lakes for Offshore Wind Platform Design | $692,782 | FY11: U.S. Offshore Wind: Removing Market Barriers FOA | Michigan |
| Project Description | | | | |
| The University of Michigan is evaluating the conditions that form freshwater ice in the Great Lakes and their impact on offshore wind energy support structures. The project is evaluating the seasonal and decade-long trends in historical icing data through field measurements and by evaluating extreme loading that results from combined wind, wave, and icing effects. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **University of Michigan, Board of Regents** | Strategies for Voltage Control and Transient Stability Assessment | $413,534 | FY09: American Recovery and Reinvestment Act (part of the 20% Wind by 2030 FOA) | Michigan |
| Project Description | | | | |
| The University of Michigan is establishing systematic analysis techniques for assessing the impact of wind-induced fluctuations on grid voltages and transformer tapping. The project establishes methods for determining the optimal balance between static and dynamic reactive resources for controlling voltage. The project is also developing procedures for assessing the impact of large-scale wind generation on the dynamic performance of power systems. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **University of Minnesota, Board of Regents** | High-Resolution Computational Algorithms for Simulating Offshore Wind Farms | $1,200,000 | FY11: U.S. Offshore Wind: Technology Development FOA | Minnesota |
| Project Description | | | | |
| The University of Minnesota is developing computational tools to simulate wave and wind interactions within various floating offshore wind farm configurations. The project is validating computational models using data from laboratory measurements specifically tailored to emulate the key dynamic features of floating wind turbines and farms, as well as field data from a land-based field site. The computational tools will be tailored to take full advantage of high-performance computing and will thus enable industry to design efficient and reliable offshore turbines and optimize turbine arrays on a site-specific basis. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **University of Mississippi** | High Speed Wind Turbine Noise Model with Suppression | $1,000,000 | FY10: CDP | Mississippi |
| Project Description | | | | |
| Development of rapid response SODAR system to obtain real time wind velocity profiles. Array of ground based infrasound sensor arrays to predict wind velocity profiles. Prediction of sound from large scale wind turbine with optimization of rotor geometry for low noise and high performance. Health monitoring system for rotor blades using wireless flush mounted sensors. | | | | |

*continued >*

Table 1: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **University of Nebraska—Lincoln** | An Online Intelligent Prognostic Health Monitoring System for Wind Turbines | $1,499,981 | FY14: Technology Incubator for Wind Energy Innovations FOA | Nebraska |
| Project Description | | | | |
| The University of Nebraska—Lincoln will develop an online health monitoring system that uses the electric current signals produced by a turbine's generator in order to track the generator's performance and help determine when it needs to be repaired. This technology could reduce operating costs by decreasing unscheduled downtime due to unplanned maintenance. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **University of Nebraska-Lincoln, Board of Regents** | Online Nonintrusive Condition Monitoring and Fault Detection for Wind Turbines | $380,398 | FY09: American Recovery and Reinvestment Act (part of the 20% Wind by 2030 FOA) | Nebraska |
| Project Description | | | | |
| The University of Nebraska-Lincoln has developed online nonintrusive condition monitoring and fault detection (CMFD) methods for wind turbines. The technologies developed were based on advanced signal processing and statistical analysis techniques and used wind generator electrical measurements. The project's proposed technologies provide an alternative to vibration-sensor-based CMFD and can reduce the cost and hardware complexity of wind turbine CMFD systems. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **University of Texas-Austin** | Techno-economic Modeling of the Integration of 20% Wind and Large-scale Energy Storage in ERCOT by 2030 | $507,628 | FY09: 20% Wind by 2030 FOA | Texas |
| Project Description | | | | |
| The University of Texas-Austin identified the economic and technical considerations for operating an electric grid in a reliable manner as more wind power capacity is installed and as more wind energy is generated within the grid. The project provided an understanding of the role that large scale energy storage technologies, such as compressed air energy storage, can technically and economically play in the context of the Electric Reliability Council of Texas's (ERCOT's) system. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **The University of Wisconsin-Milwaukee** | Lithium-Ion Ultracapacitors integrated with Wind Turbines Power Conversion Systems to Extend Operating Life and Improve Output Power Quality | $402,266 | FY09 American Recovery and Reinvestment Act (part of the 20% Wind by 2030 FOA) | Wisconsin |
| Project Description | | | | |
| The University of Wisconsin-Milwaukee developed a scaled model that pulls mechanical power surges off the drivetrain and into a lithium-ion capacitor. The capacitor dispatches the surges to the grid, protecting wind turbine performance during power system surges. By characterizing an integrated system of lithium-ion capacitor energy storage and power conversion that extends mechanical operation, this project can help to provide higher power efficiency for wind turbines, and improve the quality of their energy and power output. | | | | |

*continued >*

Table 1: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Utah State University** | Wide Area Wind Field Monitoring | $60,925 | FY09: 20% Wind by 2030 FOA | Utah |
| Project Description | | | | |
| Utah State University created a prototype scanning LiDAR system that creates three-dimensional dynamic wind fields for characterization and monitoring of wind energy sites. An existing LiDAR system was adapted and reformatted to successfully generate dynamic volume images. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **V&R Energy Systems Research, Inc.** | Improving Reliability of Transmission Grid to Facilitate Integration of Wind Energy in Tri-State G&T and AECI | $390,004 | FY09: 20% Wind by 2030 FOA | California |
| Project Description | | | | |
| V&R Energy Systems Research conducted a study to ensure reliable operation of the transmission grid while integrating high levels of wind generation. The study established and demonstrated a comprehensive framework for transmission planning analysis of wind interconnection impacts using the Physical and Operational Margins (POM) Suite, the fastest commercially-available application for contingency analysis and transmission system optimization. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Vaisala** | Wind Forecasting Improvement Project in Complex Terrain | $2,500,000 | FY14: Wind Forecasting Improvement Project in Complex Terrain FOA | Colorado, Washington, Oregon |
| Project Description | | | | |
| Vaisala will research the atmospheric processes that generate wind in mountain-valley regions to improve the wind industry's weather models for short-term wind forecasts, especially for those issued less than 15 hours in advance. Vaisala and its partners will use advanced meteorological equipment to analyze specific environmental characteristics that affect wind flow patterns in the Columbia River Gorge region of Washington and Oregon. Data collected during the project will be shared in near real-time with the National Oceanic and Atmospheric Administration (NOAA) and the Energy Department's national laboratories, and will be used to develop improved atmospheric simulations for the Weather Research and Forecasting model, a widely used weather prediction system. These new wind measurements and simulations will also be incorporated into NOAA's Numerical Weather Prediction models to improve short-term wind forecasts in complex terrain. | | | | |

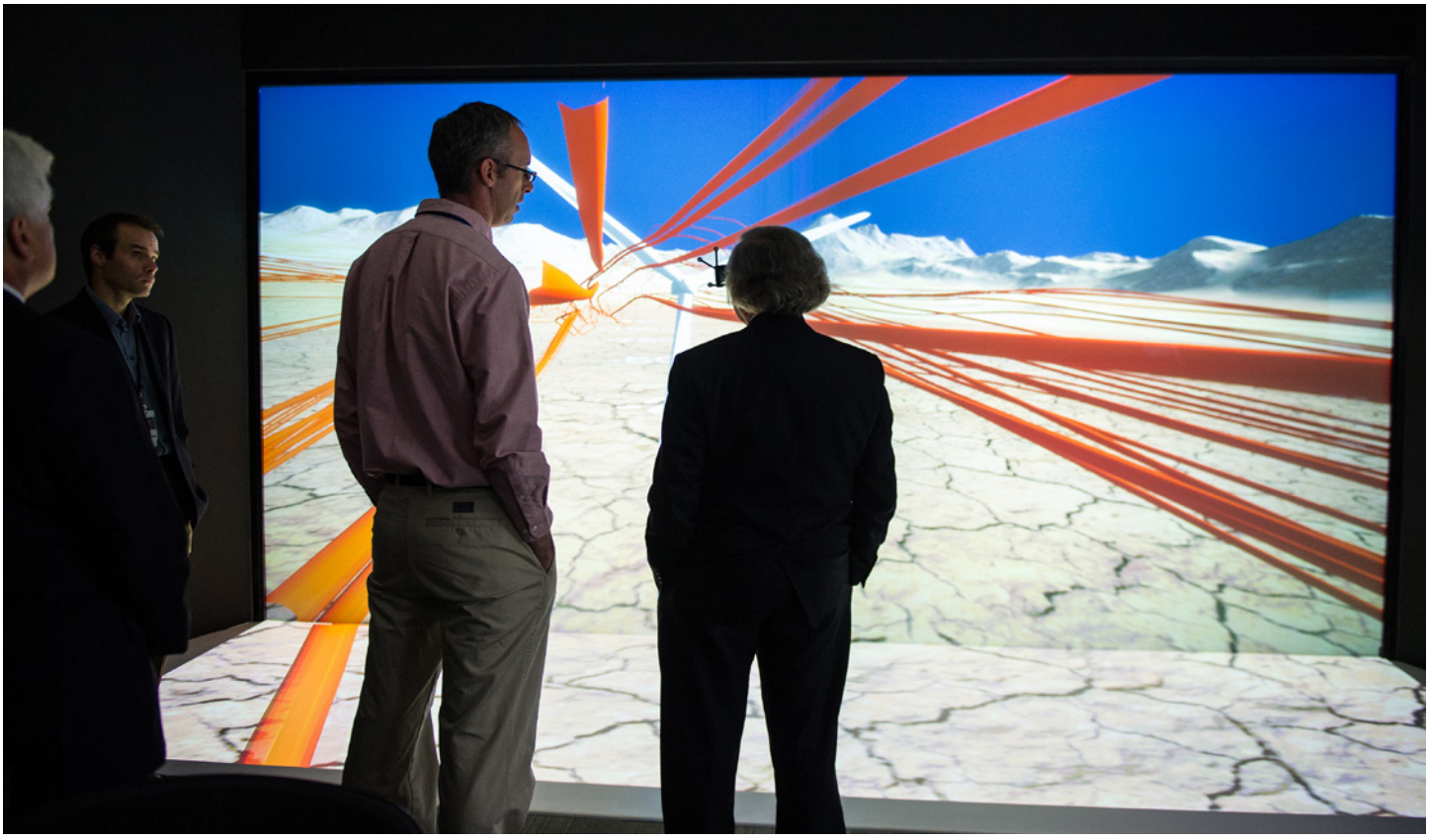
| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **Western Electricity Coordinating Council** | Balancing Authority Cooperation Concepts to Reduce Variable Generation Integration Costs in the Western Interconnection | $319,200 | FY09: 20% Wind by 2030 FOA | Utah |
| Project Description | | | | |
| The Western Electricity Coordinating Council researched, on an interconnection-wide basis, the effects of various balancing cooperation strategies. The project — which can be found at energyexemplarcom/wp-content/uploads/publications — investigated a market of cooperative mechanism to efficiently deliver electrical services and compared various integration strategies, reducing integration costs and improving regional reliability. | | | | |

*continued >*

Table 1: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **WINData, Inc.** | Use of Real-Time Off -Site Observations as a Methodology for Increasing Forecast | $398,966 | FY09: American Recovery and Reinvestment Act (part of the 20% Wind by 2030 FOA) | Montana |
| **Project Description** | | | | |
| WINData demonstrated the value of well-located, off-site, real-time sensors in reducing the uncertainty in the short-term forecasting of ramp events, or unforeseen phenomena that result in a temporary, measurable reduction in generation. The project identified the advantages of leveraging data from the OSIsoft Process Information System into next-generation data retrieval and its subsequent integration into power system operations centers. | | | | |

| Project Recipient | Project Title | DOE Funding Amount | Funding Source | Project Location |
|---|---|---|---|---|
| **WindLogics Inc.** | Enhancing Short Term Wind Energy Forecasting for Increased Utility Operations | $1,247,034 | FY10: Short-Term Wind Forecasting FOA | Multi-State (Minnesota, North Dakota, South Dakota, Iowa) |
| **Project Description** | | | | |
| WindLogics is conducting research to increase the accuracy of predicted wind direction and speed change in short-term forecasts; analyze the impact of improved short-term forecasts on wind plant power output predictions; determine resultant economic benefits to electric power system operations; and inform efforts to define data systems used by national-scale, automated, meteorological measuring stations to support wind energy forecasting. By quantifying the benefits, the project will provide insight to inform potential investments in additional weather observations, data sharing, and forecast models as part of the greater initiative. Hyperlink to click on: http://www.esrl.noaa.gov/psd/psd3/wfip/ | | | | |



# Funding Distribution

DOE has funded 44 integration, transmission, and resource assessment and characterization projects through the Wind Program from 2006–2014. These projects are categorized in the following sections by topic area, geographic region and division, state, recipient type, and funding source.

## Funding by Topic Area

This report covers wind technology development projects which broken down into topic areas: Monitoring and Controls; modeling, simulation, and analysis; transmission planning, integration, and interconnection studies; and resource assessment and characterization. Projects in these topic areas help the industry understand how they can reliably integrate large quantities of wind energy into system operations, and develop capabilities that enable these new wind installations to actively improve the power quality of the electric grid.

More than a third of the projects focused on modeling, simulation and analysis. The resource assessment and characterization projects and transmission planning, integration, and interconnection projects represent approximately an even share of the portfolio, with 58%.

*Photo from NREL*

**Table 2: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects by Topic Area**

| Topic Area | Total Funding | Percent of Total |
|---|---|---|
| Resource Assessment and Characterization | $10,711,901 | 34% |
| Tranmission, Planning, Integration, and Interconnection Studies | $7,454,317 | 24% |
| Monitoring and Controls | $2,699,981 | 9% |
| Modeling, Simulation, and Analysis | $10,382,415 | 33% |
| Total | $31,248,614 | |

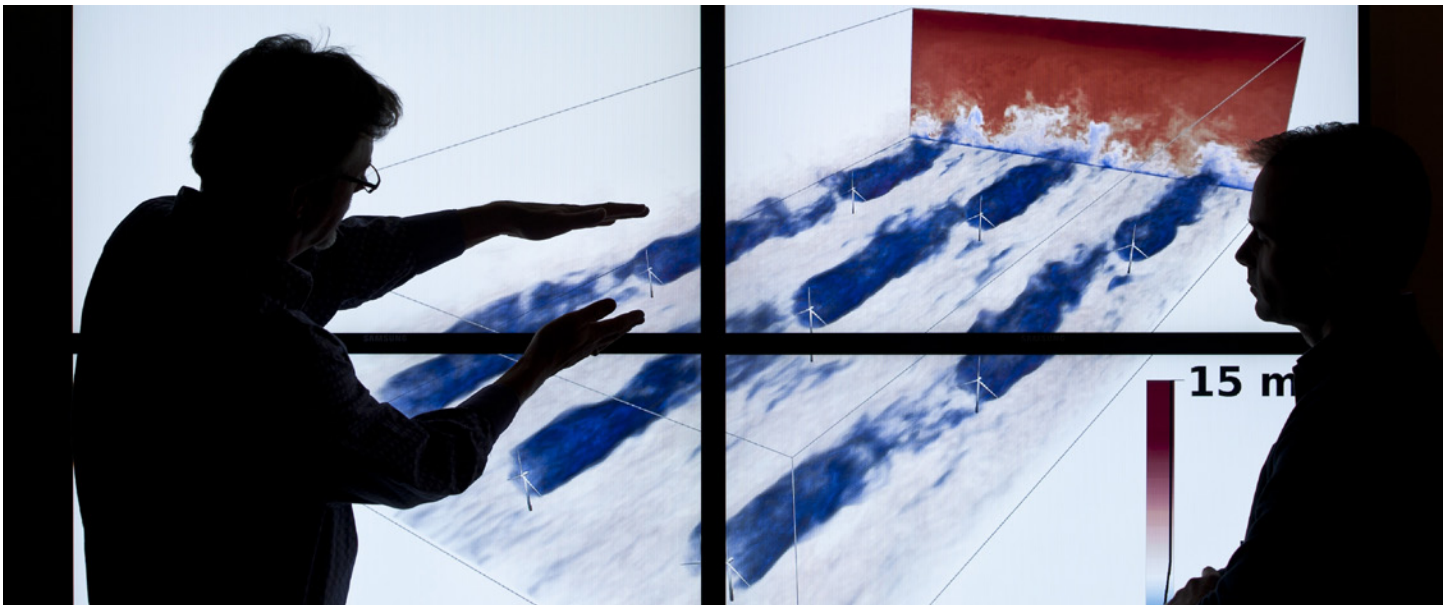



*Photo from NREL*

## Funding by Geographic Region & Division

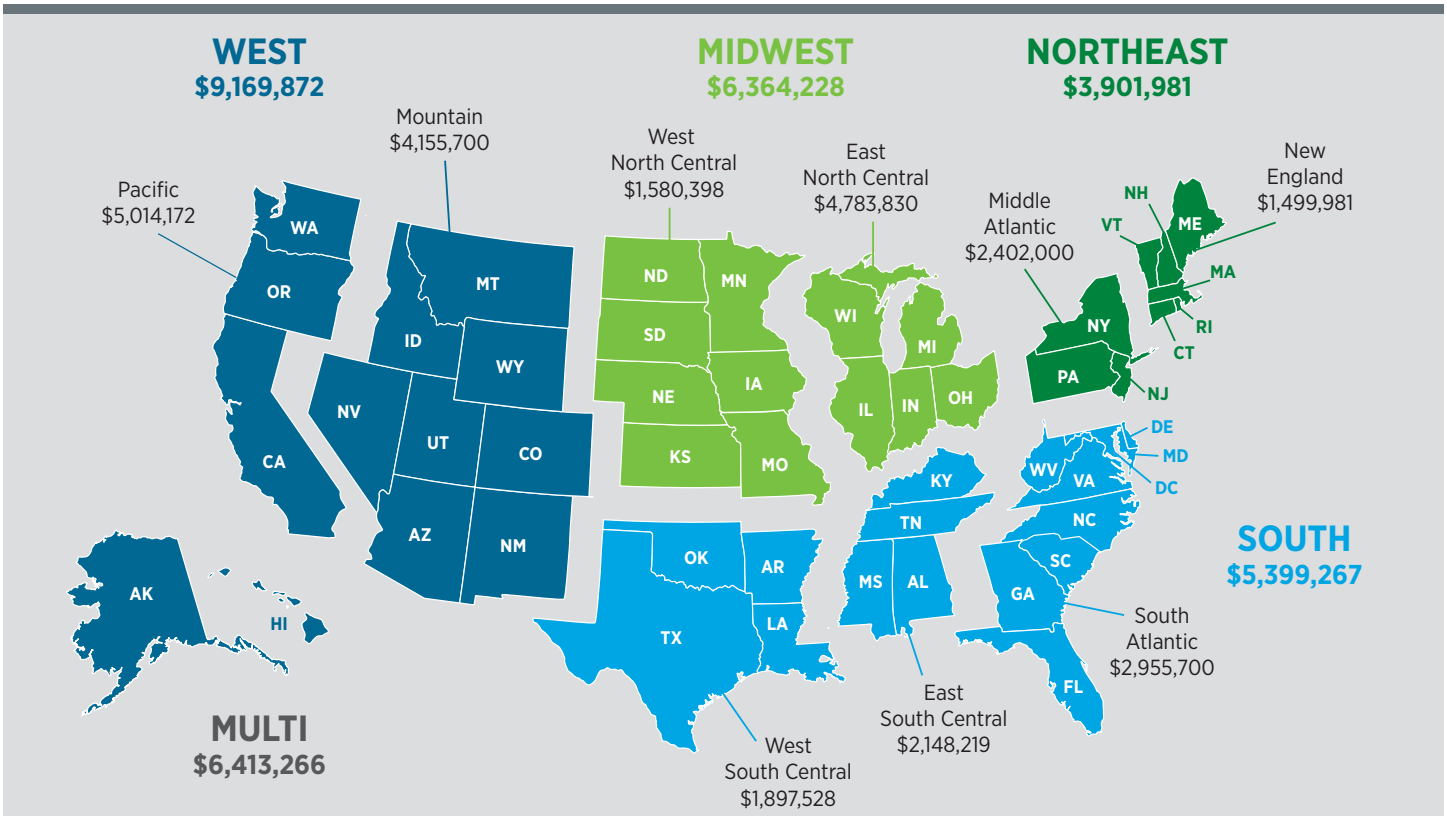
Integration, transmission, and resource assessment and characterization project funding was awarded in each of the nation's four geographic regions, with the West receiving the largest share at 26%, followed closely by the Midwest and multi-region projects, each with 25% of the funding. Table 3 provides details on how the Wind Program's funding was distributed within regions and divisions. The geographic regions and divisions used to present the distribution of the Wind Program's funding are based on the U.S. Census Regions and Divisions.[1]

Exhibit 1 provides a map that shows how the Wind Program's funding for these projects was distributed throughout the United States.

**Table 3: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects by Geographic Region and Division**

| Region | Region Total Funding | Division | Division Total Funding |
|---|---|---|---|
| West | $9,169,872 | Mountain | $4,155,700 |
| | | Pacific | $ 5,014,172 |
| South | $5,399,267 | South Atlantic | $1,353,520 |
| | | West South Central | $1,897,528 |
| | | East South Central | $2,148,219 |
| Northeast | $3,901,981 | Middle Atlantic | $2,402,000 |
| | | New England | $ 1,499,981 |
| Midwest | $6,364,228 | East North Central | $4,083,830 |
| | | West North Central | $1,580,398 |
| Multi | $6,413,266 | Multi | $6,413,266 |
| | | **Total** | **$31,248,614** |

**Exhibit 1: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects by Geographic Region and Division**



## Funding by State

Wind Program funding for the 44 integration, transmission, and resource assessment and characterization projects was broadly distributed to organizations in 20 states, with eight projects listed as multi-state. Table 4 outlines funding by state.

The states with the largest individual share were Michigan and Colorado, receiving a combined total of more than $5 million (or nearly 25% of the total funding). The eight multi-state projects received nearly a third of the funding for this portfolio as well.

**Table 4: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects by State**

| State | Total Funding |
|---|---|
| Alaska | $497,010 |
| California | $562,004 |
| Colorado | $3,502,759 |
| Delaware | $540,000 |
| Hawaii | $750,000 |
| Maryland | $278,610 |
| Michigan | $3,681,564 |
| Minnesota | $1,200,000 |
| Mississippi | $1,000,000 |
| Montana | $398,966 |
| Nebraska | $1,880,379 |
| New Jersey | $702,000 |
| New Mexico | $272,816 |
| North Carolina | $534,910 |
| Pennsylvania | $1,700,000 |
| Tennessee | $1,148,219 |
| Texas | $1,897,528 |
| Utah | $380,125 |
| Washington | $306,192 |
| Wisconsin | $402,266 |
| Multi | $9,613,266 |
| **Total** | **$31,248,614** |

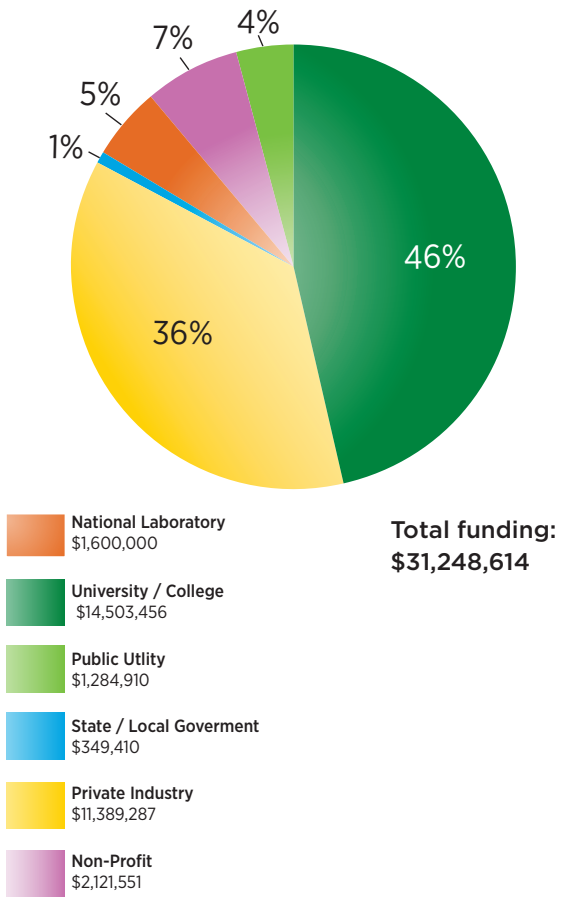
## Funding by Recipient Type

DOE provided funding to a variety of recipient types, including private industry, nonprofit organizations, universities and community colleges, investor-owned utilities and public utilities, and local and state governments, as well as DOE national laboratories, other federal agencies, and interstate government agencies.

Nearly half of the $31 million in funding was awarded to universities and colleges. Private industry received more than one third of the funding, while the remaining recipient types received less than 20% of the funding combined.

Exhibit 2 outlines funding by recipient type.

**Exhibit 2: 2006–2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects by Recipient Type**

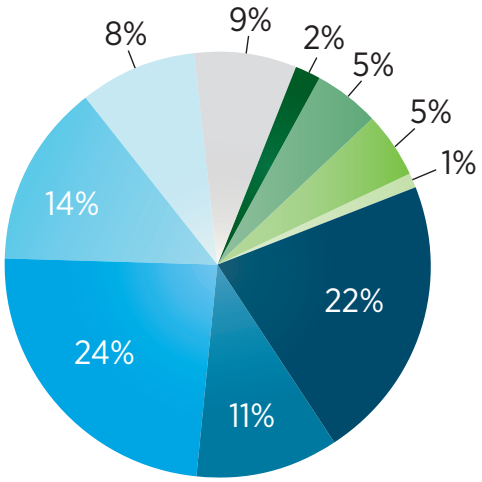


## Funding Sources

Exhibit 3 below provides details on the sources of funding for the Wind Program's 41 integration, transmission, and resource assessment and characterization projects awarded from FY 2006–FY 2014.

From 2006–2014, the Wind Program issued numerous competitive FOAs; six of these FOAs are represented in this report, receiving nearly $28 million of the total funding for 38 projects. Nearly $4 million was awarded to six projects through Congressionally Directed funds. The American Recovery and Reinvestment Act did not directly fund projects in this area. More than $5 million in ARRA funds were directed through competitive FOAs. In Exhibit 3, those projects are listed under the corresponding FOA.

**Exhibit 3: FY 2006 – FY 2015 Wind Integration, Transmission, and Resource Assessment and Characterization Projects**




**Total funding: $31,248,614 | Total number of projects: 44**

FOA 88%

- **FY09: 20% Wind by 2030 FOA*** $6,741,325 Number of Projects: 17
- **FY10: Short-Term Wind Forecasting FOA** $3,398,047 Number of Projects: 2
- **FY11: U.S. Offshore Wind: Removing Market Barriers FOA** $7,588,911 Number of Projects: 11
- **FY11: U.S. Offshore Wind: Technology Development FOA** $4,306,190 Number of Projects: 5
- **FY14: Technology Incubator for Wind Energy Innovations FOA** $2,889,881 Number of Projects: 2
- **FY14: Wind Forecasting Improvement Project in Complex Terrain FOA** $2,500,000 Number of Projects: 1

CDP 12%

- **CDP: Multi-Year** $497,010 Number of Projects: 2
- **CDP: FY09** $1,427,250 Number of Projects: 1
- **CDP: FY10** $1,500,000 Number of Projects: 2
- **CDP: FY11** $400,000 Number of Projects: 1

* The FY09: 20% Wind by 2030 FOA received partial funds through the American Recovery and Reinvestment Act. In the 20% Wind by 2030 FOA, 14 of 18 projects were funded by the Recovery Act. This total is reflected in the FOA category in this chart.

# Accomplishments

The Wind Program has allocated more than $31 million in funding for 44 integration, transmission, and resource assessment and characterization projects since FY 2006, with numerous projects operating over multiple years. The Wind Program has already realized significant return on federal investments to date and anticipates significant key accomplishments in years to come.

A few of the Program's project accomplishments include the following:

- **ABB, Inc.: National Offshore Wind Energy Grid Interconnection Study**. ABB led a study team that includes AWS Truepower, Duke Energy, the National Renewable Energy Laboratory (NREL), and the University of Pittsburgh to assess offshore wind development around the U.S. coastal regions, including the Atlantic, the Gulf of Mexico, the Great Lakes, and the Pacific. During this 2012-2014 study, ABB identified viable offshore wind development sites and associated wind production profiles, performed an initial integration analysis and assessing the applicability of traditional integration study methods, and evaluated various potential energy collection and delivery technologies. The study found that the United States has sufficient offshore wind energy resources to consider having at least 54 GW of offshore wind and appropriate technologies exist for interconnecting large amounts of wind energy to the U.S. grid. The final report can be found at http://energy.gov/eere/downloads/national-offshore-wind-energy-grid-interconnection-study-nowegis.

- **AWS Truepower and WindLogics: The Wind Forecasting Improvement Project (WFIP).** Working together under WFIP with the Wind Program and the National Oceanic and Atmospheric Administration (NOAA), AWS Truepower and WindLogics are working with meteorologists, climatologists, and atmospheric scientists to learn more about our earth's atmosphere, to more accurately characterize and predict wind speed and direction, and provide more realistic views of the wind energy potential of any given site. Over the course of twelve months, the teams used advance radar and sodar to measure wind speeds and characteristics in the Upper Midwest and in Texas. NOAA incorporated the data into an advance weather forecasting model—which can be found at http://www.esrl.noaa.gov/psd/psd3/wfip/—to provide more accurate meteorological inputs into wind power forecasts. This effort can lead to significant improvements in the operational efficiency of fossil

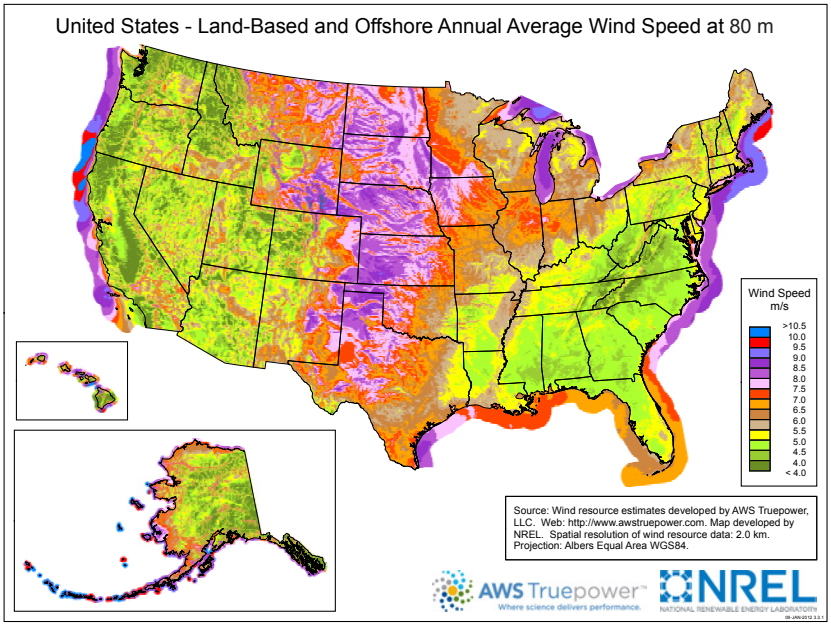
fuel plants used to balance wind plant variability, as well as the entire electrical grid system, resulting in lower costs and lower $CO_2$ emissions. In 2015, DOE announced that Vaisala, Inc. will continue this WFIP effort by researching the atmospheric processes that generate wind in mountain-valley regions to improve the wind industry's weather models for short-term wind forecasts.

- **AREVA Federal Services and Alstom Grid: Best Practices and Advances in Strategies and Decision Support Systems for Integrating Wind Energy for Reliable Grid Operations.** AREVA and a team of investigators surveyed 33 operators of electric power systems in 18 countries about wind integration, their operating policies, best practices, examples of excellence, lessons learned, and decision support tools now in place to formulate overall recommendations for utilities. The study, a first-of-its-kind review, found that the ability to forecast variable energy output is vital to successfully integrating variable energy into the electrical grid. The study also found that decision support tools are also essential to helping grid operators incorporate wind forecasts and obtain optimal power flow in their grids. The study described several decision support tools that are used by grid operators. However, existing decision support tools in the United States need to evolve further as more domestic variable energy enters the electrical grid. Despite these challenges, the grid operators interviewed had a positive outlook for integrating variable energy and are eager to share and apply best practices with other operators. All of these findings were released in a final report - which can be found at wind.energy.gov/pdfs/reliable_grid_operations.

- **The University of Denver: Multi-Level Energy Storage and Controls for Large-Scale Wind Energy Integration.** The University of Denver designed and controlled innovative energy storage systems to facilitate wind energy integration at three different levels. The three levels of wind power system integration facilitated were Balancing Control Center level, Wind Power Plant level, and Wind Power Generator level. The project resulted in the development of a new intelligent controller that can reduce energy exchanged between a battery and DC-link, reduce charging/discharging cycles, reduce depth of discharge, increase the time interval between charge/discharge, and lower battery temperature. These outcomes demonstrate an improvement in the overall lifetime of battery energy storages.

For more information, including updates and results from national laboratory research not detailed in this report, see the following Wind Program Web pages:

- Wind Resource Assessment and Characterization: energy.gov/eere/wind/wind-resource-assessment-and-characterization
- Renewable Systems Integration: energy.gov/eere/wind/renewable-systems-integration.




# End Notes

[1] Energy Information Administration, U.S. Census Regions and Divisions. June 14, 2000. http://www.eia.gov/consumption/residential/maps.cfm

# Notes

# Notes

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

eere.energy.gov
wind.energy.gov

DOE/EE-1093 • May 2015

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