NREL
NATIONAL RENEWABLE ENERGY LABORATORY

NATIONAL WIND
TECHNOLOGY CENTER

www.nrel.gov/wind

Offshore Wind Research

The National Renewable Energy Laboratory is internationally recognized for offshore wind energy research and development (R&D). Its experience and capabilities cover a wide spectrum of wind energy disciplines.

NREL's offshore wind R&D efforts focus on critical areas that address the long-term needs of the offshore wind energy industry and the Department of Energy (DOE). R&D efforts include:

- Developing offshore design tools and methods
- Collaborating with international partners
- Testing offshore systems and developing standards
- Conducting economic analyses
- Characterizing offshore wind resources
- Identifying and mitigating offshore wind grid integration challenges and barriers

NREL documented the status of offshore wind energy in the United States in its recent publication, *Large-Scale Offshore Wind in the United States: Assessment of Opportunities and Barriers* (www.nrel.gov/docs/fy10osti/40745.pdf). The report provides DOE and the U.S. wind industry with a foundation from which to build a national strategy for offshore wind energy development and to set goals that would lead to offshore wind energy becoming a significant contributor to our electric power portfolio.

Offshore Design Tools and Methods

NREL has developed and maintains a robust, open-source, modular computer-aided engineering (CAE) tool, known as FAST. FAST's state-of-the-art capabilities provide full dynamic system simulation for a range of offshore wind systems. It models the coupled aerodynamic, hydrodynamic, control system, and structural response of offshore wind systems to support the development of innovative wind technologies that are reliable and cost effective. FAST also provides dynamic models of wind turbines on offshore fixed-bottom systems for shallow and transitional depths and floating-platform systems in deep water, thus enabling design innovation and risk reduction and facilitating higher performance designs that will meet DOE's cost of energy, reliability, and deployment objectives.

International Collaborations

Institutions worldwide are deploying demonstration projects, developing simulation tools, and designing innovative floating wind systems. NREL collaborates with international partners to share the latest technical information. NREL employs its expertise and broad international contacts to address critical needs for the offshore wind industry and to develop and improve CAE and economic modeling tools for the assessment of offshore wind turbine systems.

In 2012, NREL sent staff to SWAY's offshore wind project in Norway to install scientific equipment on the seabed and the prototype to collect data that will help validate NREL's computer model. *Photo by Robb Wallen, NREL/PIX 22134*

In 2012, NREL collaborated with SWAY, a renewable energy company from Norway, on a demonstration project involving a one-fifth scale prototype of SWAY's floating offshore wind system deployed off the coast of Bergen, Norway. The project provides NREL with a unique opportunity to study one of the world's first floating wind turbines to be deployed and the data collected will speed the development of offshore wind design tools and models.

Testing and Standards

Testing. Applying 35 years of wind turbine testing expertise, NREL has developed instrumentation for high resolution measurements at sea by adapting its existing capabilities. Trained test engineers and technicians verify turbine performance and dynamic responses. In addition to field testing, NREL has the nation's premier laboratory facilities for structural testing of wind turbine blades, drivetrains, and major wind turbine components.

**NREL is a national laboratory of the U.S. Department of Energy,
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NREL'S OFFSHORE WIND TESTING CAPABILITIES

- 35 years of wind turbine testing experience
- Custom high speed data acquisition system integrated for offshore testing
- Trained crew of offshore certified test engineers and technicians
- Colorado- and Boston-based laboratory test facilities for large blade and multimegawatt drivetrain testing
- A2LA accredited certification testing to IEC standards
- Third-party design verification of innovative floating and fixed-bottom wind turbines

Standards. For the past two decades, NREL has helped its international partners develop and write certification standards. In 2009, NREL joined a collaboration led by the American Wind Energy Association (AWEA) to develop recommended practices for design, deployment, and operation of offshore wind turbines in the United States. In 2012, AWEA released its Recommended Practices for Design, Deployment, and Operation of Offshore Wind Turbines in the United States.

Economic Analysis

NREL researchers conduct market and economic analyses of offshore wind projects to quantify the impact of various technical innovations on the levelized cost of wind energy. The lab's Wind Turbine Design Cost and Scaling Model estimates component level costs based on wind turbine size, annual energy production, and operation costs. The model represents the initial capital investment of offshore wind projects, considering project size, water depth, distance from shore, and turbine technology. NREL researchers also develop discounted cash-flow models to quantify the impact of financing rates, investment or production incentives, and ownership structures on cost of energy.

NREL has compiled a database of installed and proposed project costs based on its extensive research on projects in Europe, the United States, and other emerging offshore markets. These data show cost trends that are useful to offshore wind energy stakeholder groups including DOE, manufacturers, developers, and financial institutions.

Offshore Wind Resource Characterization

For more than 15 years, NREL's meteorologists, engineers, and Geographic Information System experts have led the production of wind resource characterization maps and reports used by policy makers, private industry, and other government organizations to inform and accelerate the development of wind energy in the United States. NREL recently published an *Assessment of Offshore Wind Energy Resources for the United States* (www.nrel.gov/docs/fy10osti/45889.pdf).

To provide data on design conditions, NREL is assessing the potential contribution of techniques such as remote sensing and modeling. Research includes comparing the data provided by remote sensing devices and models to data collected by traditional methods to establish their accuracy and increase acceptability to certification and banking institutions. Building on lessons learned from European offshore wind facilities, NREL teams create and refine mesoscale modeling and computational fluid dynamics tools to predict array effects on wind turbines and wind resources in operating facilities.

Grid Integration Challenges and Barriers

NREL is a world-renowned leader in grid integration of variable generation resources such as wind and solar. Understanding the regional grid impacts of offshore wind both to the existing onshore grid and to the offshore grid as it evolves is essential for smooth grid integration. NREL's foreknowledge of grid integration issues, as well as transmission system planning and expansion issues will lead to more effective interconnection and integration of offshore wind energy. Offshore grid interconnection should include an assessment of proposed radial versus backbone wind plant connections, and the assessment of offshore renewable energy resource zones or lease areas that integrate the planning and construction of offshore wind with the installation of needed transmission. As wind farms grow in size and move farther from shore, NREL will lead efforts to analyze the behavior and modeling of offshore electrical transmission systems with respect to grid-system reliability, grid losses, and grid-architecture options.

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Helpful Websites

NREL's National Wind Technology Center
www.nrel.gov/wind/offshore_wind.html

Department of Energy
Wind Power Program
www.wind.energy.gov

Photos front page, top row, left to right: Dennis Schroeder, NREL/PIX 19007; Lee Jay Fingersh, NREL/PIX 15005; Warren Gretz, NREL/PIX 12415; Lee Jay Fingersh, NREL/PIX 14691; Dennis Schroeder, NREL/PIX 18937

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