NATIONAL RENEWABLE ENERGY LABORATORY





www.nrel.gov/wind

Offshore Renewable Energy R&D

As the United States increases its efforts to tap the domestic energy sources needed to diversify its energy portfolio and secure its energy supply, more attention is being focused on the rich renewable resources located offshore. Offshore renewable energy sources include offshore wind, waves, tidal currents, ocean and river currents, and ocean thermal gradients. According to a report published by the National Renewable Energy Laboratory (NREL) in 2010,[1] U.S. offshore winds resources have a gross potential generating capacity four times greater than the nation's present electric capacity, and the Electric Power Research Institute estimates that the nation's ocean energy resources could ultimately supply about 10% of its electric supply.[2]

For more than 35 years, NREL has advanced the science of renewable energy technologies while building its capabilities to guide rapid commercialization. NREL is now leveraging that experience to advance offshore wind and water power technologies.

NREL's wind and water power research and development efforts include:

- Design review and analysis
- Device and component testing
- Resource characterization
- Economic modeling and analysis
- Grid integration

Design Review and Analysis

NREL researchers assist industry partners with power system design review and analysis, provide technical assistance to solve specific technical problems, and conduct parallel research to provide a foundation for the increasingly complex engineering design and analyses needed in highly advanced system configurations.

NREL's computer-aided engineering tools (CAE) (http://wind.nrel.gov/designcodes/) have become an industry standard for the analysis and development of wind energy systems, and NREL is adapting some of these tools for application to water power devices and arrays. These CAE tools produce realistic models that simulate the behavior of wind and water power systems in complex environments—storm winds, waves, earthquake loading, and extreme turbulence—and model the effects of turbulent inflow,

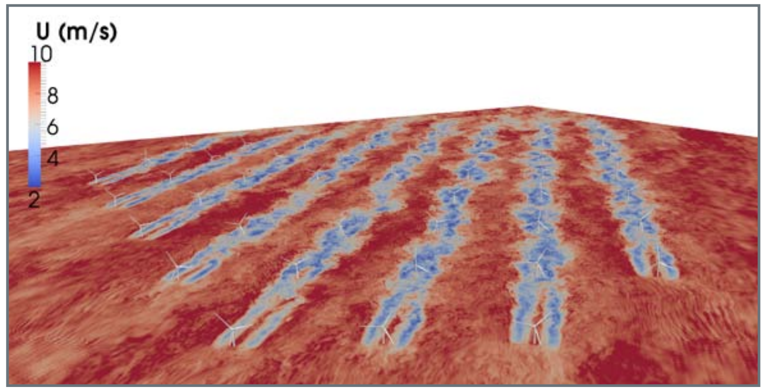

Figure 1. NREL fluid dynamics simulation of the operational 48-turbine Lillgrund wind plant. The contour plane shows velocity in a plane taken at hub height (offset to below hub height for clarity) where blue contours highlight the turbine wakes interacting with downwind turbines.

unsteady aerodynamic and hydrodynamic forces and structural dynamics such as power take-off and control system responses.

Offshore Wind Modeling

Researchers at NREL have developed a new complex modeling and analysis tool capable of analyzing floating platform concepts for offshore wind turbines. The new modeling tool combines the computational methodologies used to analyze land-based wind turbines with the comprehensive hydrodynamic computer programs developed for offshore oil and gas industries. This new simulation tool will enable wind turbine designers to develop competitive offshore technologies capable of harvesting the rich offshore wind resources located farther from shore.

NREL has developed a high-fidelity large-eddy simulation model that simulates wind and water inflows that occur in offshore wind farms (Figure 1) and tidal turbine projects with a higher degree of accuracy than current models. The wind plant modeling tool, which simulates the region within and immediately surrounding the wind plant, will be coupled with a mesoscale weather forecasting tool that simulates the weather on a scale of a few hundred kilometers surrounding the wind farm. Such a coupled tool will allow NREL researchers to simulate events such as frontal passages through a wind plant and their effect on turbine power production and mechanical loading.

1 Large-Scale Offshore Wind Power in the United States, Assessment of Opportunities and Barriers, NREL/TP-500-40745, September 2010.

2 EPRI 2007. EPRI wave, tidal and in-stream study reports developed over the last 5 years are available on the EPRI website. http://www.epri.com/oceanenergy/

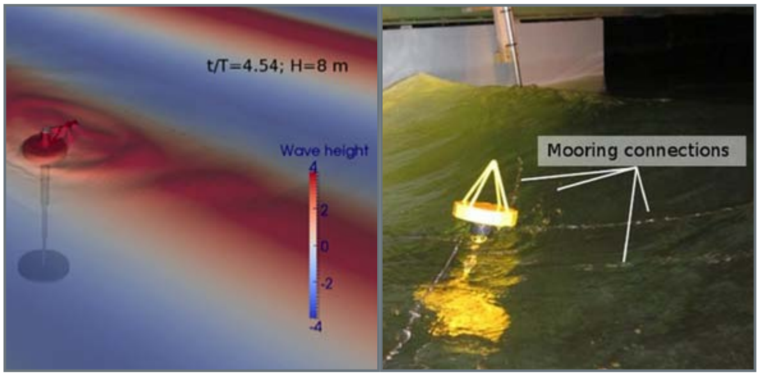

Figure 2. Left: Computational fluid dynamics simulation of the flow field around a floating point absorber. Right: Photo of a point absorber in a test tank at the University of California, Berkeley. *Photo by Li Ye, NREL/PIX 20117*

Marine and Hydrokinetic (MHK) Modeling

Industry is developing a wide variety of MHK devices. These include axial-flow and cross-flow current turbines, oscillating water columns, overtopping devices, floating pitching devices, bottom-hinged devices, and floating point absorbers.

NREL is presently developing integrated CAE tools for wave and current energy converters that will simulate single devices (Figure 2, Left) and arrays for research and development efforts at all technology readiness levels. The CAE tools are available for free download by MHK designers, researchers, and manufacturers from NREL's website (wind.nrel.gov/designcodes/).

Device and Component Testing

NREL has developed a modular offshore instrumentation package that can be customized as needed for specific applications and maintains a staff of offshore-trained test engineers and technicians that conduct a wide range of field measurements to verify system performance and dynamic responses.

In addition to field testing, NREL operates and maintains the nation's premier laboratory facilities where researchers work with industry partners to conduct structural testing of wind and water power systems and components, which include turbine blades/rotors and power take-off and control systems.

NREL is also developing a new controllable grid interface (CGI) test system that can significantly reduce the time to conduct and cost of conducting certification testing for renewable technologies. NREL is fully accredited by the American Association of Laboratory Accreditors (A2LA) to conduct wind turbine certification tests and for the past two decades, has helped its international partners develop and write certification standards.

The CGI will be the first test facility in the United States to have fault simulation capabilities and that allows manufacturers and system operators to conduct certification tests in a controlled laboratory environment. It will be the only system in the world that is fully integrated with two dynamometers and has the capacity to extend that integration to renewable energy devices in the field and to a matrix of electronic and mechanical storage devices, all of which are located within close proximity on the same site.

Economic Modeling and Analysis

NREL researchers conduct economic analysis of renewable energy technologies to quantify the impact of various technical innovations on the levelized cost of energy.

For example, NREL's advanced 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 projects, considering project size, water depth, distance from shore, and turbine technology. NREL also develops discounted cash-flow models to quantify the impact of financing rates, investment or production incentives, and ownership structures on cost of energy.

Ongoing research focuses on strengthening cost model accuracy in all areas of offshore project analysis. NREL is expanding its capabilities to better represent the initial capital investment of offshore projects, and is working to develop offshore balance-of-station and operation and maintenance models to enhance systems engineering models.

Increasing Deployment

To increase deployment of offshore renewable energy technologies, NREL also conducts a wide range of research in the areas of resource assessment, grid integration, using the Regional Energy Deployment System (ReEDS) model to assess the potential of MHK technology, siting, and environmental impacts.

NREL Offshore Wind and Water Power Contacts

Arielle Wolfe
Administrative Coordinator
1-303-384-6925

Walt Musial
Group Manager of Offshore Wind and Ocean Power Systems
1-303-384-6956

Helpful Websites

NREL Wind Research
www.nrel.gov/wind/offshore_wind.html

NREL Water Power Research
www.nrel.gov/water

NREL Wind & Water Power Design Codes
http://wind.nrel.gov/designcodes/

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

Department of Energy Water Power Program
www.water.energy.gov

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

National Renewable Energy Laboratory
15013 Denver West Parkway, Golden, CO 80401
303-275-3000 • www.nrel.gov

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

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

NREL/FS-5000-54659 • April 2012