National Renewable Energy Laboratory's experienced staff, unique research capabilities, and specialized state-of-the-art equipment provide industry partners and stakeholders with resources to take marine energy technology from conceptual design to commercialization. *Photo from Northwest Energy Innovations*

NREL Data, Modeling, and Tools Empower Marine Energy Analysis

The National Renewable Energy Laboratory (NREL) performs research and development and economic analyses to drive and empower the development of wave energy and tidal, ocean, and river current energy technologies. These technologies deliver renewable electricity to the grid and provide energy solutions that support the evolving blue economy.

NREL researchers collaborate closely with wave and current energy communities and leverage their extensive expertise in numerical modeling, laboratory testing, and open-water validation. Marine energy researchers benefit from NREL's decades of experience developing wind and solar energy technologies and helping accelerate the pace of marine energy technology and industry development.

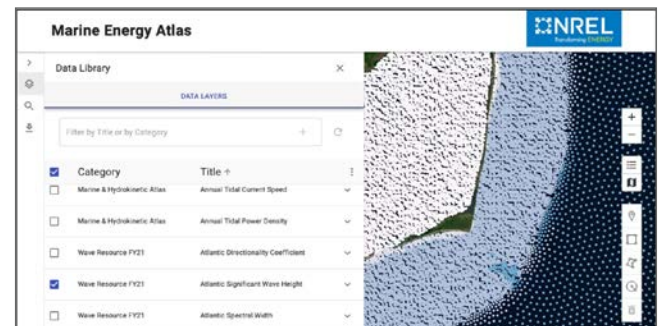## Marine Energy Dives Deep Into Novel Technologies

Resource Characterization Project Delivers Essential Marine Energy Data

Motivated by its pioneering work on the importance of turbulence in wind turbine design, NREL's resource characterization team of oceanographers, engineers, and data scientists work to measure the resource details important to designing the next generation of marine energy devices. NREL's experts develop new measurement systems that resolve the statistics of marine resources that are important for device design.

In Fiscal Year 2021, NREL published a technical report providing a consolidated summary of the location and quantity of utility-scale wave, tidal current, ocean current, ocean thermal, and river hydrokinetic resources in the United States.

In January 2021, NREL released a publicly accessible hindcast dataset of ocean surface waves with high spacial resolution in collaboration with the Pacific Northwest National Laboratory and Sandia National Laboratories. This dataset will improve the understanding of the nation's wave energy resources and provide the basis for important tools for advancing marine renewable energy technologies.

NREL incorporated this dataset into the upgraded Marine Energy Atlas, an interactive, publicly accessible mapping tool that helps users explore marine energy resources. NREL led the tool's development, and the dataset generation was completed by the Pacific Northwest National Laboratory, Sandia National Laboratories, North Carolina State University, and the University of Hawai'i. NREL released the Marine Energy Atlas in May 2021.

NREL's Marine Energy Atlas depicts and maps marine energy resources, like wave heights (darker colors indicate larger waves) offshore of Cape Hatteras, North Carolina. *Photo courtesy of NREL*

The new Marine Energy Atlas has several new features designed to enhance the user experience, including: a filterable and searchable data library; new data layers, including wave models for Pacific, Atlantic, and Hawai'ian regions; and back-end upgrades that increase performance for on-the-fly visualization of high-resolution datasets. The Marine Energy Atlas can help designers determine how well their devices are suited for a particular part of the ocean and assist project developers in identifying promising sites for building wave energy farms. By making this valuable data available to the public, the atlas can help the marine energy industry chart a smooth course forward.

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Marine Energy SAM Now Features Marine Energy Atlas

NREL's System Advisor Model (SAM) is a free, publicly available modeling software designed to help project developers, engineers, policymakers, equipment manufacturers, and researchers evaluate renewable energy system design, performance, and project economics. Since the software's launch in 2007, new SAM versions have been released yearly, adding to the collection of technologies and financing options it can accommodate. SAM's Marine Energy module is a standardized, user-friendly modeling platform that estimates annual energy production and the levelized cost of energy for wave and tidal energy systems.

The December 2021 new version of SAM contains upgrades that augment the tool's functionality. The upgrades for SAM's marine energy tidal module include two new macros: the Tidal Report macro and the Tidal Compare Cases macro. In addition, the marine energy wave module has a new resource modeling capability, tapping into the Marine Energy Atlas tool, which enables a user to model a wave energy device at thousands of locations using a latitude and longitude. Finally, when modeling a resource site, users can calculate energy production with a joint probability distribution or time series data for the selected site. The bridge between SAM and Marine Energy Atlas offers greater selection of resource site locations and enhances energy modeling capabilities for wave energy systems.

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WEC-Sim Tool Receives R&D 100 Award

NREL develops open-source numerical modeling tools that are validated and customizable to meet the marine energy community's needs. These tools are used to analyze wave energy conversion (WEC) power performance and predict extreme loading on systems under critical wave environments.

In October 2021, NREL received two *R&D World* magazine annual R&D 100 Awards for research innovations. One of the awardees, Wave Energy Converter Simulator (WEC-Sim), is the first open-source code allowing wave energy developers to simulate WEC dynamics and performance, dramatically reducing the uncertainty around how WECs will perform in real-world marine environments, which can lower costs and reduce R&D time in this pivotal and growing field.

WEC-Sim can also support applications beyond wave energy conversion. In 2021, WEC-Sim helped prepare the Orion module to ensure the safety of the crew, who, as part of the Artemis I mission, will orbit the moon for several days before landing in the Pacific Ocean. The National Aeronautics and Space Administration and Lockheed Martin are using WEC-Sim to determine how the module can turn itself right-side up upon landing, which will support the crew's swift, safe recovery.

The WEC-Sim project is a collaboration between NREL and Sandia National Laboratories. WEC-Sim had its first release to the public in December 2014 and its latest release, v4.4, in October 2021.

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Marine and Hydrokinetic Toolkit

The Marine and Hydrokinetic Toolkit (MHKiT) is an open-source software for rapid data processing, visualization, quality control, resource assessment, and device performance.

In December 2020, NREL, in collaboration with Sandia National Laboratories and the Pacific Northwest National Laboratory, developed an MHKiT outreach and training plan for Fiscal Year 2021 that maximizes the dissemination to the marine energy sector. A key part of this outreach plan was a series of webinars conducted in February 2021 highlighting MHKiT's functionality and demonstrating the use of the code base. In spring of 2021, the MHKiT team created a development roadmap that publicly outlines future development priorities. These priorities are determined based on user input, existing marine renewable energy code and International Electrotechnical Commission Technical Specification 114 specifications. In June 2021, the MHKiT team tagged a new release of MHKiT (v0.4) that allows users to download and process data from the high-resolution wave hindcast, Coastal Data Information Program, and Simulating WAves Nearshore, as well as updated wave resource processing capabilities. These activities will accelerate marine energy technology development and reduce costs by providing more information to feed modeling, design, and validation activities.

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Essential to the development of new technologies, like the pictured wave energy converter, are the tools and software required to model and validate them. MHKiT is helping to fill this need in the marine energy industry. *Photo from Curtis Rusch, U.S. Department of Energy*