Waves crash at Jennette's Pier during the Waves to Water Prize DRINK Finale in North Carolina's Outer Banks. *Photo by Werner Slocum, NREL*

Securing Our Water Future: NREL's Research in Desalination of Nontraditional Water Sources

Today's water supply is built on a 20th century model of freshwater sources, centralized treatment, and wastewater discharge. But that model—especially in remote coastal communities or in disaster relief scenarios—is quickly becoming unsustainable. That's why researchers are looking to nontraditional water sources and new desalination technologies to provide our nation's industries and communities with a resilient, cost-effective water supply for the 21st century.

Nontraditional water sources are abundant across the United States, from the coasts to landlocked states where wastewater is produced in vast amounts from the power and manufacturing sectors. Desalinating water sources such as these requires a broad approach, one that NREL researchers are tackling from a variety of angles.

Getting Creative With Desalination

NREL Tests Wave-Powered Desalination Device

Researchers at NREL have completed construction of a hydraulic and electric reverse osmosis (HERO) wave energy converter (WEC) device. The modular device is compact and portable and can desalinate ocean water using wave energy—without the need for an external fuel supply. The WEC's modular nature enables the research team to compare the benefits and drawbacks of using the two different configurations—one hydraulic and one electric—to run the reverse osmosis desalination system.

As NREL's first marine-powered desalination device to weather real ocean waters, the HERO WEC signals significant advancements for marine renewable energy and desalination technologies. *Photo from Andrew Simms, NREL*

The HERO WEC is undergoing additional testing to evaluate and document its capabilities. The intent is to assist other innovators by pinpointing what does and does not work and provide a basis from which others can build and modify their own designs. Industry can apply lessons learned from this device to produce future technologies that can provide power at sea and build resilient coastal communities, evolve ocean observation, or support post-disaster relief efforts.

NREL created the HERO WEC alongside teams competing in the American-Made Waves to Water Prize. While the NREL researchers were not competitors, they did abide by the prize guidelines to better understand what was required of competitors. A trial run at the prize finale site also prepared the crew to help prize finalists safely deploy their own prototypes in the water.

Waves to Water Prize finalists deployed and tested their wave-powered desalination prototypes in North Carolina in April 2022. *Photo by Werner Slocum, NREL*

Waves to Water Prize Encourages Desalination Innovation

Supported by the U.S. Department of Energy's (DOE's) Water Power Technologies Office (WPTO) and administered by NREL, the five-stage, $3.3 million Waves to Water contest aimed to accelerate innovation in small, modular, wave-powered desalination systems, much like the HERO WEC. The prize was part of DOE's Powering the Blue Economy™ Initiative, which seeks to develop marine energy systems to support the power needs of coastal and ocean applications.

The finale of the inaugural Waves to Water competition, hosted by the Coastal Studies Institute (CSI), was held in April 2022 in North Carolina. Four finalist teams successfully deployed their prototype desalination systems, which were judged on their weight and portability, the amount of clean water produced, and the speed of assembly and deployment. The results from testing these devices will help WPTO, NREL, and CSI identify future research opportunities.

The grand prize was awarded to the Oneka Snowflake, a rectangular, raft-like device that can be assembled without tools, is easily installed, adapts to most ocean conditions, and is designed to produce up to 10,000 liters of clean water per week (enough for about 450 people)—making it ideal for disaster and recovery situations.

WPTO has prioritized funding this critical foundational desalination research and development to help understand the types of environmental constraints WECs face and ultimately improve system processes and technologies. The goal is to continue advancing small-scale desalination devices that can be deployed on demand and in varied environments.

Accelerating the Testing of Commercial Reverse Osmosis Membranes

In collaboration with Colorado School of Mines, NREL has developed a membrane characterization system that allows researchers to evaluate off-design conditions for reverse osmosis membranes. By subjecting the membranes to variable/oscillating conditions for extended periods of time, researchers can investigate the operation's impact on the durability of the membranes and on the quality of water produced.

The equipment has been designed to mimic the inputs that a wave energy converter, or any other renewable energy system, would provide to a reverse osmosis desalination plant. As such, the system can provide a real-world representation of membrane permeability, pressure fluctuations, and even membrane degradation in these conditions. By accelerating the testing of reverse osmosis membranes, researchers are one step closer to efficiently desalinating all types of nontraditional water sources.

The Future of Desalination Research at NREL

NREL continues to work on these initiatives to expand the potential for desalination of both ocean water and other nontraditional water sources. To that end, NREL has already initiated further ocean trials of the HERO WEC; the vessel was deployed again in August 2022 to better understand its anchor limitations. NREL has also started disseminating results from the WEC, and researchers are currently refining device components to prepare for another deployment in 2023.

To further progress on their prototypes, Waves to Water teams are encouraged to seek further funding and validation opportunities (such as through the WPTO's Testing Expertise and Access for Marine Energy Research, or TEAMER, program) to ready their innovations for private investment or commercial scale-up.

NREL researchers will continue their work to fully characterize membranes and their limits and to test fatigue and membrane life. This ongoing research is vital to ensuring water security for generations to come.

Contact

Scott Jenne, dale.jenne@nrel.gov

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

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