Economical water system could bring fresh water and renewable energy storage to drought-stricken coastal regions

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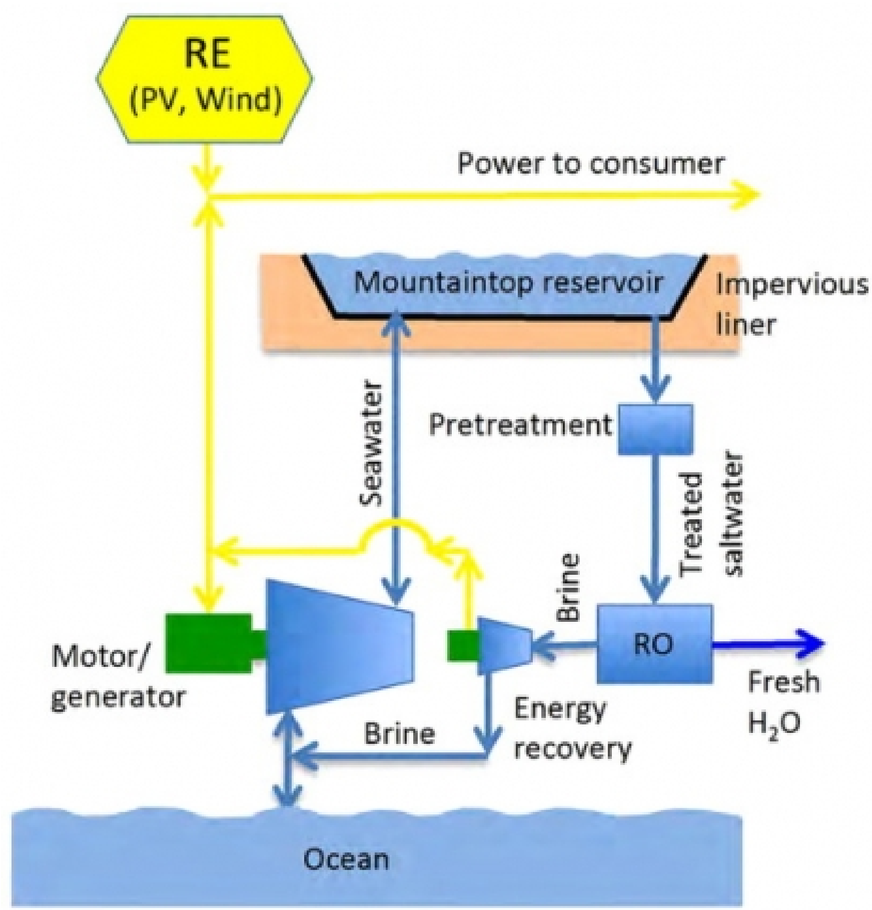

An integrated pumped hydro reverse osmosis (IPHRO) system produces both freshwater and electric power from renewable energy sources, such as solar power and wind power, by combining a pumped hydro energy storage system with a reverse osmosis desalination plant. Credit: Alexander Slocum

Many highly populated coastal regions around the globe suffer from severe drought conditions. In an effort to deliver fresh water to these regions, while also considering how to produce the water efficiently using clean-energy resources, a team of researchers from MIT and the University of Hawaii has created a detailed analysis of a symbiotic system that combines a pumped hydropower energy storage system and reverse osmosis desalination plant that can meet both of these needs in one large-scale engineering project.

The researchers, who have shared their findings in a paper published in Sustainable Energy Technologies and Assessments, say this kind of combined system could ultimately lead to cost savings, revenues, and job opportunities.

The basic idea to use a hydropower system to also support a reverse osmosis desalination plant was first proposed two decades ago by Kyoto University's Masahiro Murakami, a professor of synthetic chemistry and biological chemistry, but was never developed in detail.

"Back then, renewables were too expensive and oil was too cheap," says the paper's co-author Alexander Slocum, the Pappalardo Professor of Mechanical Engineering at MIT. "There was not the extreme need and sense of urgency that there is now with climate change, increasing populations and waves of refugees fleeing drought and war-torn regions."

Recognizing the potential of the concept now, Slocum and his co-authors—Maha Haji, Sasan Ghaemsaidi, and Marco Ferrara of MIT; and A Zachary Trimble of the University of Hawaii—developed a detailed engineering, geographic, and economic model to explore the size and costs of the system and enable further analysis to evaluate its feasibility at any given site around the world.

Typically, energy and water systems are considered separately, but combining the two has the potential to increase efficiency and reduce capital costs. Termed an "integrated pumped hydro reverse osmosis (IPHRO) system," this approach uses a lined reservoir placed in high mountains near a coastal region to store sea water, which is pumped up using excess power from renewable energy sources or nuclear power stations. When energy is needed by the electric grid, water flows downhill to generate hydroelectric power. With a reservoir elevation greater than 500 meters, the pressure is great enough to also supply a reverse osmosis plant, eliminating the need for separate pumps. An additional benefit is that the amount of water typically used to generate power is about 20 times the amount needed for creating fresh water. That means the brine outflow from the reverse osmosis plant can be greatly diluted by the water flowing through the hydroelectric turbines before it discharges back into the ocean, which reduces reverse osmosis outflow system costs.

As part of their research, Slocum's team developed an algorithm that calculates a location's distance from the ocean and mountain height to explore areas around the world where IPHRO systems could be installed. Additionally, the team has identified possible IPHRO system locations with potential for providing power and water—based on the U.S. average of generating 50 kilowatt-hours of energy and 500 liters of fresh water per day—to serve 1 million people. In this scenario, a reservoir at 500 meters high would only need to be one square kilometer in size and 30 meters deep.

The team's analysis determined that in Southern California, all power and water needs can actually be met for 28 million people. An IPHRO system could be located in the mountains along the California coast or in Tijuana, Mexico, and would additionally provide long-term construction and renewable energy jobs for tens of thousands of people. Findings show that to build this system, the cost would be between $5,000 and

$10,000 per person served. This would cover the cost of all elements of the system—including the renewable energy sources, the hydropower system, and the reverse osmosis system—to provide each person with all necessary renewable electric power and fresh water.

Working with colleagues in Israel and Jordan under the auspices of the MIT International Science and Technology Initiatives (MISTI) program, the team has studied possible sites in the Middle East in detail, as abundant fresh water and continuous renewable energy could help bring stability to the region. An IPHRO system could potentially form the foundation for stable economic growth, providing local jobs and trade opportunities and, as hypothesized in Slocum's article, IPHRO systems could possibly help mitigate migration issues as a direct result of these opportunities.

"Considering the cost per refugee in Europe is about 25,000 euros per year and it takes several years for a refugee to be assimilated, an IPHRO system that is built in the Middle East to anchor a new community and trading partner for the European Union might be a very good option for the world to consider," Slocum says. "If we create a sustainable system that provides clean power, water, and jobs for people, then people will create new opportunities for themselves where they actually want to live, and the world can become a much nicer place."

More information: Alexander H. Slocum et al. Integrated Pumped Hydro Reverse Osmosis systems, *Sustainable Energy Technologies and Assessments* (2016). DOI: 10.1016/j.seta.2016.09.003

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