Title: Marine-Source Integrated Heat Pump System for Remote Coastal and Island Communities

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Focal Area: Water for energy. The topic in this proposed project focuses on developing a marine-source integrated heat pump (MS-IHP) that harnesses the ocean's thermal energy to provide efficient space conditioning, dehumidification with freshwater harvesting, and water heating, thereby improving seawater management for energy cost saving and enhancing grid flexibility and security in remote coastal and island communities.

Existing Challenge: In U.S. marine climate regions, 3.8 million homes use fossil fuel heating, including natural gas furnaces and 1.3 million homes use electric resistance heat [1]. Both technologies have suboptimal energy efficiency, which may lead to expensive energy bills. Moreover, many U.S. coastal communities face significant challenges due to vulnerable energy infrastructure besides high energy costs. This is particularly true for remote coastal and island communities due to their geographic isolation and high risk of energy disruptions. These risks are being exacerbated due to increasing impacts of natural disasters and extreme weather events—such as sea level rise, stronger storms, and shifting precipitation patterns—further intensify these vulnerabilities. Ensuring reliable, efficient, and resilient energy and water systems is therefore critical to sustain the economic stability and grid security of these communities. The oceans are one of the most important natural resources of remote coastal and island communities. Although these communities are geographically diverse, marine energy and abundant moisture in the air is consistent (or mildly variable) and this unique energy source can be effectively developed in an environmentally responsible manner or serve as a complement to existing energy and freshwater sources. Figure 1 shows the world seawater temperature on October 25, 2025 with temperatures ranging from 15-35°C along the coast of the United States [2]. Therefore, innovative technologies enabling reliable and resilient energy and water systems are essential to sustain these regions' economic stability and grid security.

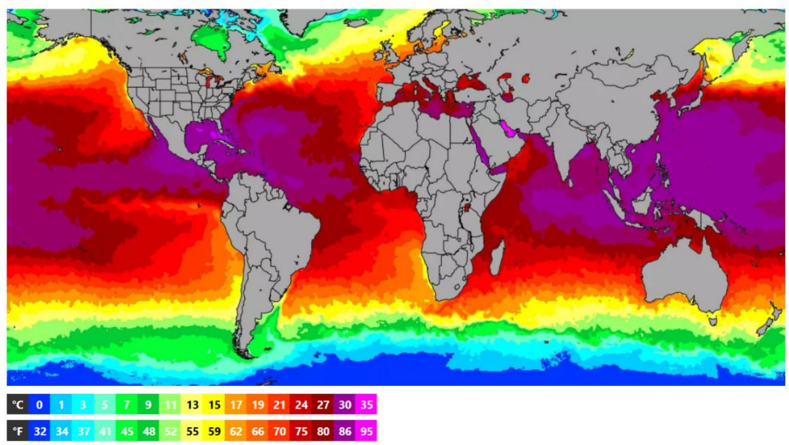

Figure 1. The average sea temperatures from over 7,000 locations and 200 countries around the world, Oct. 25, 2025.

Near-Term Opportunity: A heat pump is a device that can be powered by electricity to transfer heat from one place to another using a refrigerant [3–11], enabling both heating and cooling in a single process and from a single energy source throughout the year as needed. By using ambient air, ground, or seawater heat, heat pumps significantly reduce the need for direct energy consumption, achieving increased energy saving. Moreover, heat pump technology delivers three to four units of heat for every unit of electricity consumed, which makes it very efficient and lowers utility bills. Heat pumps can also be powered by renewable electricity generated from wind or tidal energy, which further fits remote coastal and island communities in reducing energy consumption and sustainability.

The proposed MS-IHP technology [12] transfers renewable heat from seawater into homes or buildings for space and water heating separately or simultaneously in cold weather. The oceans are warmer than air in winter, so a marine source MS-IHP achieves improved efficiency, eliminates frosting and defrosting issues, and provides better thermal comfort compared to an air-source heat pump. Figure 2 shows the proposed MS-IHP system. The system consists of a modulating compressor, a variable-speed fan, two pumps and five heat exchangers (HXs), as well as water heater tank and condensate collector for water harvesting. In the system, the titanium seawater-coolant HX is highly resistant to seawater corrosion. To achieve space heating only, the fan is turned on (❽) and the water pump is turned off (⓫). The system uses the titanium seawater-coolant HX(❷) to transfer ocean heat to the refrigerant in the outdoor coolant-refrigerant HX(❸). The compressor (❺) pressurizes the refrigerant and moves it throughout the desuperheating HX (❻), the indoor air-refrigerant HX (❼), and the expansion valve (❾). By shutting off the fan (❽) and turning on the water pump (⓫), water heating only is achieved by transferring heat from the desuperheating HX (❻) to the water tank (⓬). If space heating and water heating are needed simultaneously, both the fan and the water pumps are turned on and the variable-speed compressor is modulated at high-speed to meet both space and water heating loads.

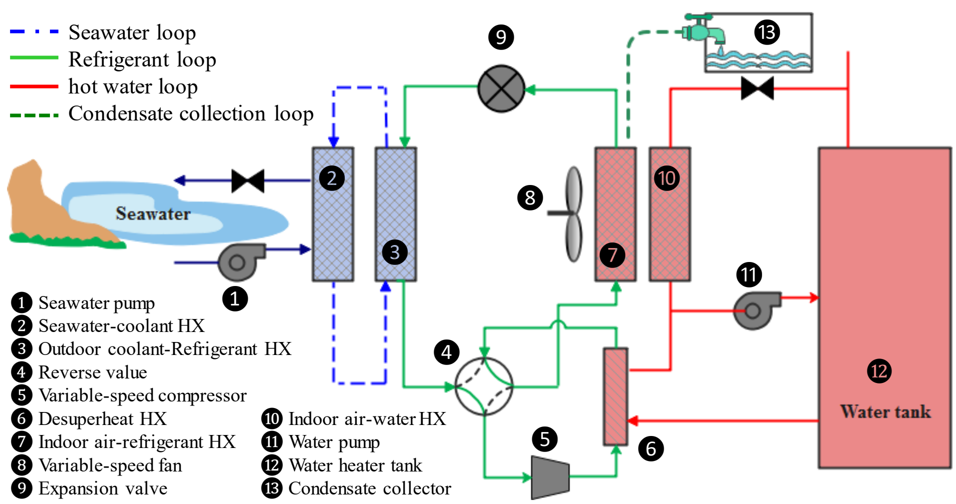

Figure 2, Conceptual system of renewable marine-source integrated heat pump (MS-IHP).

In hot climates, the MS-IHP is switched by reversing valve (❹) to operate space cooling. Hot exhaust heat from MS-IHP provides water heating, and seawater condenses and buffers the excess exhaust heat of condensing refrigerant. In humid environments which are common in coastal communities, the novel system allows a dehumidification-only mode, in which the indoor air-water HX (❿) uses excess hot water generated in the dehumidification to provide space neutral conditions. Fresh water harvesting is achievable via dehumidification and space cooling as a flexible water generation solution for remote coastal and island communities with limited supplies of fresh water.

Thus, the MS-IHP efficiently combines year-round space cooling and heating, dehumidification and water harvesting and water heating as an energy-efficient alternative to separated furnaces, air conditioners, and water heaters. The development and deployment of MS-IHP will assist the communities to step toward energy saving and utility bill reduction, making a major step toward sustaining the economic stability and grid security of these communities.

The project team includes ORNL, HVAC OEMs (such as Carrier Corporation, Trane Technologies, Lennox International, Rheem Manufacturing Company, Johnson Controls International, Honeywell International, and others), University of South Florida, and Florida Coastal communities near Tampa (including Clearwater, St. Pete Beach, Dunedin, and Gulfport). Their participation will provide unique opportunities to conduct innovative MS-IHP research and creative activities, solve the challenges of remote coastal and island communities' energy vulnerabilities, and deliver co-optimization of water-energy systems to coastal communities in Florida and the nation.

Success Measure: The proposed MS-IHP system is a small-scale device that, as a single appliance (see Figure 3), combines space conditioning, dehumidification, and water heating for home or building applications in remote coastal and island communities. It exemplifies such innovation, offering substantial improvements in the efficiency of space heating, cooling, and water heating—by 79%, 48%, and 81%, respectively—compared to conventional systems [12]. Deployment of MS-IHP technologies could reduce energy consumption by more than 60% in a single home, while strengthening grid reliability and security and achieving the economic sustainability of coastal and island communities.

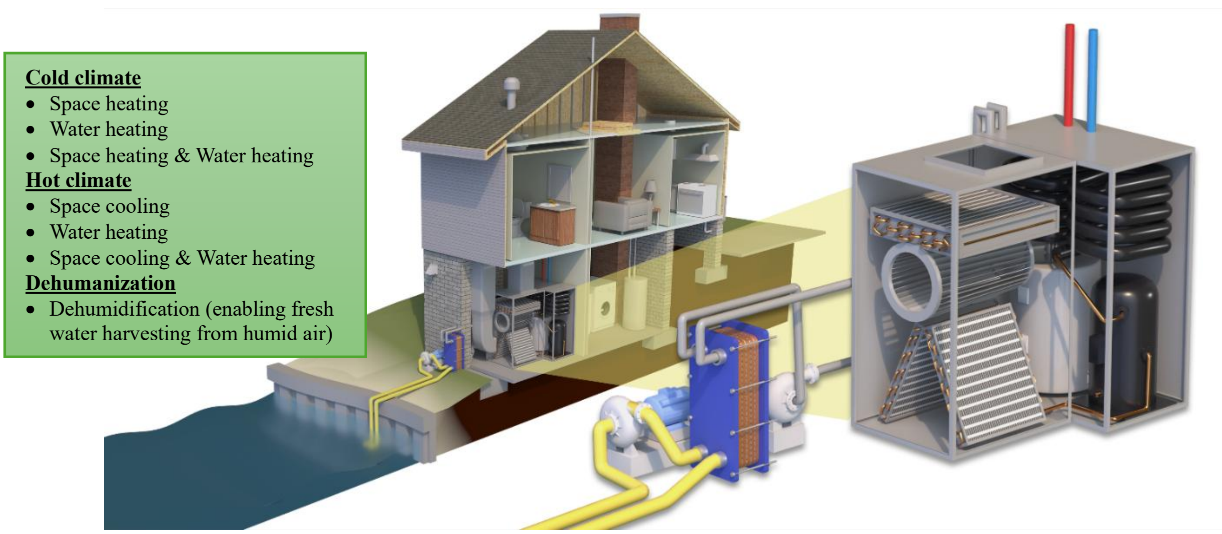

Figure 3. MS-IHP is a single electrical appliance for space conditioning, dehumidification and water heating, enabling reduce energy consumption by 60% in a single home.

in summary, this innovative MS-IHP system can offer significantly higher efficiency and lower costs compared with conventional multiple systems, particularly leading to substantially reduced costs for space conditioning, dehumidification, and water heating by seamlessly integrating a heat pump, heat pump water heater, and dehumidifier by using a single compressor; optimal year-round space cooling and heating, dehumidification, water harvesting, and water heating; and improved thermal comfort and reliable operation without frosting and defrosting because of the ocean's warm temperatures and high heat capacity. Combined renewable marine resources with the advanced systems provides a highly efficient and cost-effective path toward long-term climate adaptation for vulnerable coastal populations, allowing a resilient and low-cost energy system in coastal residential homes.

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