Wave-Driven Carbon Sequestration: System Requirements and Modeling

As marine energy research continues to evolve, wave energy converters (WECs) have emerged as a promising technology for promoting grid resilience, powering remote and coastal communities, and supporting the Blue Economy. This paper explores the integration of WECs with the growing demand for carbon sequestration, proposing a novel approach to marine carbon dioxide removal (mCDR). This approach, CArbon Sequestration Harvesting Energy from Waves, or CASHEW, seeks to directly utilize the mechanical energy produced by WEC oscillations to pump carbon dioxide into eligible geographies.

The CASHEW system includes a wave energy converter, pump, and pipe. Our system design assumes that CASHEW receives pre-captured CO2, meaning that carbon capture technologies lie outside the system boundary. This system was proposed at last year's UMERC. In this presentation, we share our refined system design, updated modeling results, and location-specific case studies that demonstrate the technical and economic feasibility of CASHEW.

We seek to determine the ideal CO2 trapping method (gravitational, structural, chemical, etc), phase of pumped CO2 (liquid, supercritical, gas), and local geological conditions (basalt crust, saline aquifers, etc), to achieve the identified functional requirements. To reach viability, CASHEW must meet a variety of functional requirements determined through a literature review and stakeholder conversations. These requirements include, sequestering 1 gigaton of CO2/year at scale, ensuring the stability of CO2 sequestration, and harnessing sufficient wave power to drive the process. We also seek to determine the pressure required to pump CO2 into the identified regions. This pressure will serve as a key functional requirement, as it informs the phase of captured CO2 we will use, as well as the minimum pressure value we need to make our technology feasible.

To evaluate these options, we utilized decision matrices, leading us to the two following feasible method and medium combinations: (1) Saline Aquifer (medium) + Structural Trapping (method), and (2) Saline Aquifer (medium) + Gravitational Trapping (method). For either method, the CASHEW system must meet identified requirements, withstand corrosion and damage during the system lifetime, and achieve financial viability (approximately $6-$12/ton of CO2 sequestered (Bachu 2008)).

Additionally, this study builds on the modeling work presented last year by incorporating WEC-Sim (an open source WEC dynamics solver) and geographic information system (GIS) to further quantify system viability. To evaluate each method, we utilize WEC-Sim coupled with our pump, pipe, and aquifer models to estimate the rate of sequestration for our system. We then conduct location case studies to identify feasible locations that meet the requirements for a specific medium-method combination. After choosing a location, we focus on three primary goals: (i) determining the power requirement given the location parameters, (ii) integrating the wave power availability data to test feasibility using the WEC-Sim integrated model, and (iii) determining the location capacity and potential sequestration timeframe. Lastly, we conduct high-level economic modeling by performing a suitability of power analysis for each case study location, allowing us to evaluate economic and environmental viability.