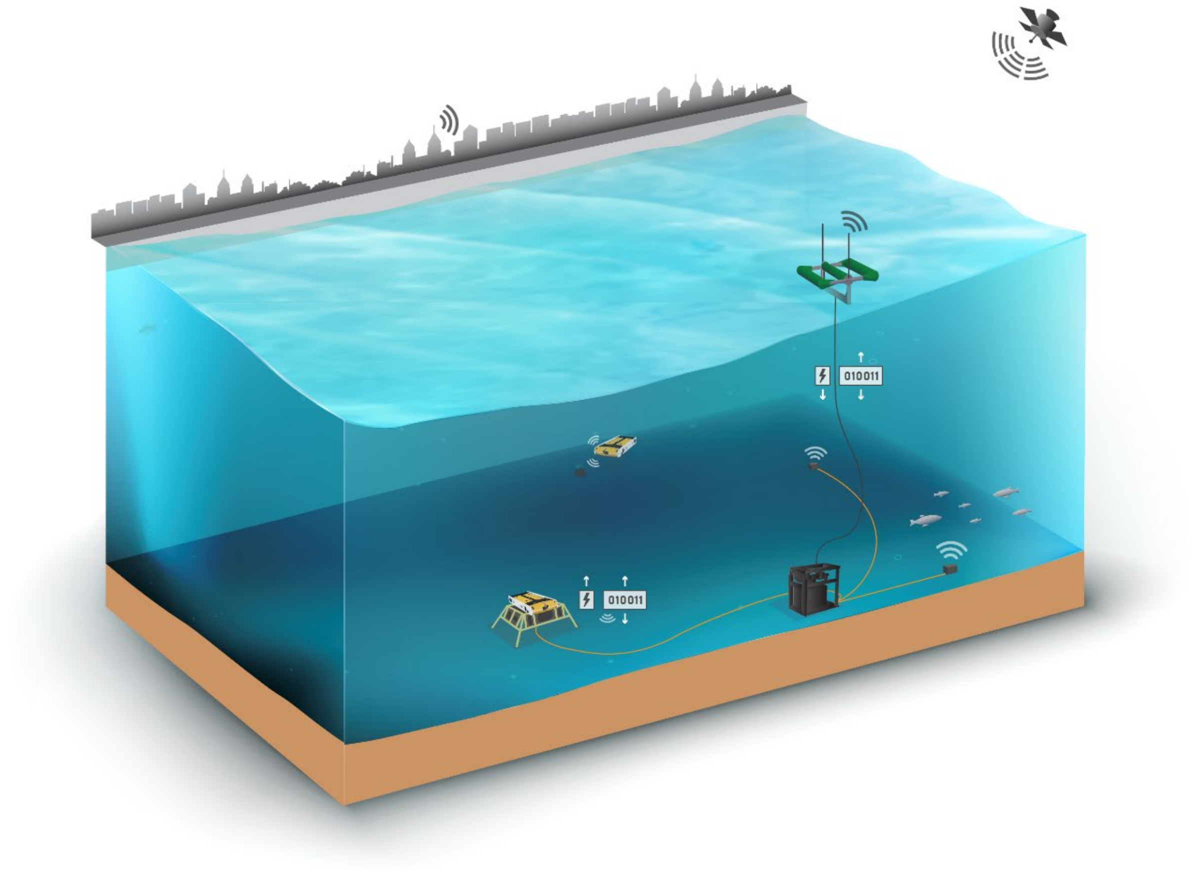
DE-EE0008627 – Design, Build and Test of Novel, Remote, Low-Power Wave Energy Converter for Non-Grid Applications



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Project Overview

Project Summary

- The project will design, deliver, and test a prototype Autonomous Offshore Power System (AOPS) at WETS. An AOPS is intended to lower the cost, complexity, and carbon emissions for operating resident, unattended mobile and static assets offshore, such as data-gathering and inspection systems. The AOPS is primarily composed of a SeaRAY WEC, and a unique mooring system that contains a seafloor base unit (SBU). The SBU is the gravity anchor and energy storage system. In this project, the assets are connected to the SBU. The AOPS provides the assets power and bi-directional data communications, effectively connecting the seafloor to the data cloud.

Intended Outcomes

This project is intended to prove that an AOPS can unlock a substantial “powering the blue economy” market opportunity through:

- demonstration of the SeaRAY AOPS' ability to support seafloor assets in a market-desirable configuration and its extensibility to various sea states, power requirements, data and communication protocols, and payload electrical interfaces
- validation of the value proposition afforded by such a system

Project Information

Principal Investigator(s)

- Erik Hammagren

Project Partners/Subs

- NREL, Verlume, EOM Offshore, Sea Engineering, 48 North, Cardinal Engineering, Malin Marine, Northwest Power, Sunwize Power and Battery, Saab, Fugro, BioSonics, Franatech, Hibbard Onshore

Project Status

Ongoing

Project Duration

- Project Start Date: May 1, 2019
- Project End Date: November 30, 2022

Total Costed (FY19–FY21)

$3,753K

Project Objectives: Relevance

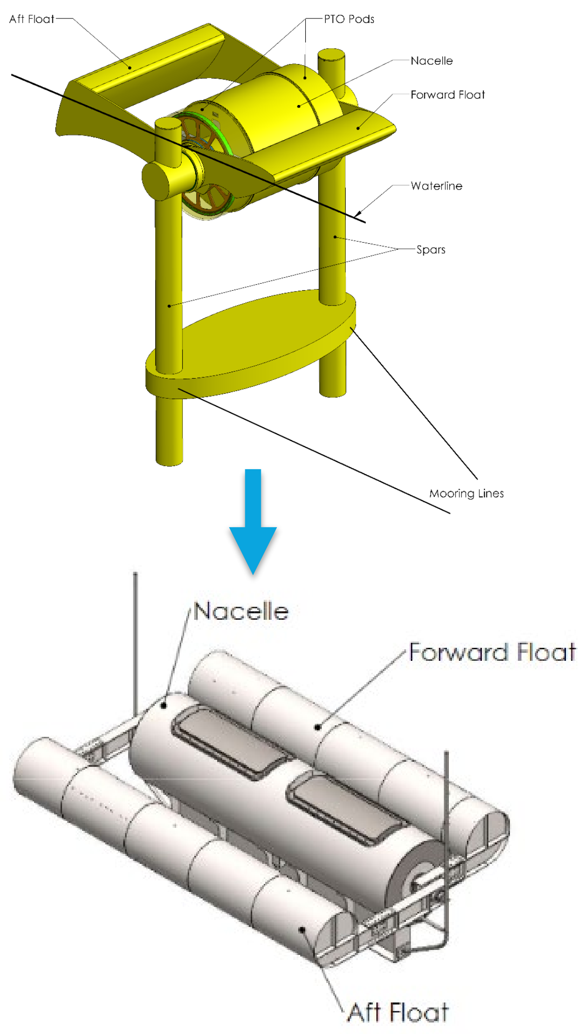
Relevance to Program Goals:

- Use of advanced computational design tools for improved energy extraction – C-Power utilizes publicly available sea state data as an input into the hydrodynamic models. These models are then used to optimize structural dimensions and mass distribution to increase performance and minimize loading. During sea trials, the onboard pressure sensors, load cells, and accelerometers record data used to validate and calibrate the hydrodynamic models. This cyclic process enables future projects to be more accurate.
- Growth of Blue Economy – Through market outreach, C-Power has been at the forefront of developing the vision for ocean energy systems supporting remote, unattended marine assets. This project demonstrates a new means of operation, cost and emissions reductions for the ocean economy.
- Utilization of international standards – The SeaRAY AOPS products are intended to be a scalable design to fit customers' needs. During this project, a method was developed to easily input loading and outside dimensions into a spreadsheet with outputs of hull thicknesses and stiffener sizes. The spreadsheet utilizes DNV standards (DNV-RP-C202 Buckling Strength of Shells and DNV-OS-C101 Design of Offshore Steel Structures) which enable a well-developed first pass design to get estimates on mass and manufacturing costs.
- Reduced design and testing cycle timelines by enhancing testing facilities – Low-power WEC's that utilize a rotary Power Take Off (PTO) have a unique demand for testing, as they are constantly changing speed and direction which requires a large amount of torque and power from a dynamometer during testing. To address this need, a hydraulic geared motor, which can be used by many different applications, was designed, built, and tested in collaboration with NREL.
- Reduced ecological impacts – Currently, expensive vessels that can produce significant amount of GHGs are used for delivering, retrieving, charging, and communicating with marine assets. Example: over a year's time, the support vessel for a remotely operated vehicle can produce 25,000 mte of CO_2 and can cost up to $100,000 per day . A SeaRAY AOPS can drastically reduce the cost and carbon footprint of the current state-of-the-art.

Project Objectives: Approach

Approach:

- A market-discovery process at the beginning of the project identified required attributes for an AOPS and showed large improvements to the current state of art were possible through a novel WEC design.
- Utilizing C-Power's extensive expertise in utility scale WEC design, the low power SeaRAY WEC was designed to cost-effectively meet the market's needs, importantly improving the power-to-weight ratio and deployability of the device, while reducing technical and project risk for a novel prototype design, build and test.
- Acceleration of commercialization was accomplished through a co-development model in which prospective customers and channel partners were invited to influence the design and to demonstrate their data-gathering systems alongside the AOPS.
- An easily transportable and rapidly deployable system design approach was taken. Market feedback indicated cost reductions and reduction in complexity in these areas would prove to be a large improvement over the state of the art. This approach led to assembled structural components that could be shipped in shipping containers and to a single point mooring that contains station-keeping and bi-directional power and data transfer components.



Low power WEC (bottom) influenced from utility scale WEC (top)

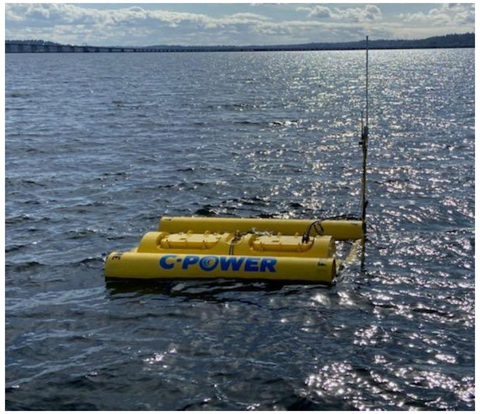
Project Objectives: Expected Outputs and Intended Outcomes

Outputs:

- SeaRAY AOPS product with an immediate market demand
- Papers and presentations at conferences
- New hydraulic dynamometer and test fixture at NREL
- Evolution of NREL's Mobile Data Acquisition (MODAQ) software
- Electrical, Optical, and Mechanical single point mooring
- Configurable seafloor base unit

Outcomes:

- Customers can use a SeaRAY AOPS to power and communicate with their devices remotely in new ways
- C-Power will use collected data to improve modeling to engineer a more efficient device
- Built and tested a smaller version of SeaRAY (TigerRAY) for the University of Washington - Applied Physics Lab



TigerRAY deployment in Puget Sound 2022

Project Timeline

FY 2019

Customer surveys

Concepting

Contractor selections

Project Management Plan

FY 2020

Risk assessment

Preliminary design

GNG – given the "go"

FY 2021

Final design

Construction and assembly of subassemblies

Verification and Validation

FY 2022

Final assembly

Permits acquired - NMFS concurrence, USACE permit, CATEX

Seafloor Base Unit manufacturing (FY21)

EOM Mooring testing (FY21)

PTO and Power Electronic Dyno Testing (FY21-22)

Project Budget

Total Project Budget – Award Information		
DOE	**Cost-share**	**Total**
$3,241K	$1,209K	$4,450K

FY19	FY20	FY21	Total Actual Costs FY19–FY21
Costed	**Costed**	**Costed**	**Total Costed**
$236K	$1,573K	$1,944K	$3,753K

- Increased scope and budget ($1,236k increase) for improvements and upgrades:
  - Mechanical-only mooring to mechanical, plus electrical and optical data transfer
  - Gravity anchor upgraded to seafloor base unit with energy storage and multiple electrical and data interfaces for assets
  - Original scope was to burn produced power, increased scope required power electronics capable of transforming power to meet asset demands
  - MODAQ scope increase to accommodate system changes
  - Inclusion of seafloor asset demonstrations

End-User Engagement and Dissemination

- Customer engagement strategy
  - SeaRAY AOPS aims to reduce costs, complexity, and carbon footprint for existing and future marine energy applications
  - Customer interactions and surveys focused on manufacturers, customers, and end-users of asset classes that an AOPS is intended to support: uncrewed marine vehicles and vessels, data gathering systems, and operating equipment
  - Beyond design inputs, co-development and integration partners were recruited to participate directly or indirectly in Project
  - Project asset demonstrations secured from: Biosonics for environmental monitoring package, Fugro for seafloor sensor, Franatech for hydrocarbon emissions sensor, and Saab for Sabertooth hybrid autonomous underwater vehicle (AUV)
  - Over a dozen channel partners and potential customers are now engaged with C-Power
  - Development of configuration model for techno-economic optimization of specific customer sales opportunities
- Project dissemination and technology transfer
  - Papers and Presentations – Offshore Technology Conference 2020,2021,2022; Subsea Tieback 2022; North Sea Decarbonization Conference 2021, and others
  - Podcasts – “Through the Noise” and others
  - Development of vendor products – MODAQ, Halo, mooring, power electronics
  - Participant in US Navy Coastal Trident port and maritime security demonstration program

Performance: Accomplishments and Progress

- Technical accomplishments
  - Design and build of novel, purpose-built wave-energy-powered AOPS
  - Designed, built, and tested a method for converting dirty, cyclic power into a usable form for various electrical requirements
  - Designed and built single point mooring with fiber optic lines and twisted copper pairs embedded for bi-directional data and energy flow
  - Created a method for importing design loads from hydrodynamic models into a spreadsheet to use DNV standards to create a preliminary design for wall thicknesses and stiffeners
  - Developed method for passively returning a float to normal operating position using novel hydrodynamic design
  - Exceeding technoeconomic metrics for Levelized Cost of Energy (LCOE), Annual Energy Production (AEP), and Power to Weight Ratio (PWR). Final metric analysis will be performed after the deployment.

Performance: Accomplishments and Progress (cont.)

- Results from project
  - Selected for multiple conference papers and presentations
  - US Patent Application No. 17/528,705
  - APL selected C-Power to design and deliver a smaller version of the WEC designed in this project that was used for multiple day trips in Lake Washington and the Puget Sound
  - Established co-development relationships with multiple potential customers and partners

Future Work

- Final power electronics and PTO V&V at NREL – C-Power is utilizing the new hydraulic dynamometer at NREL to test the WEC in a controlled environment. A Regatron unit is also be used to simulate the seafloor base unit by mimicking the load of the batteries, as well as pushing power to the WEC. This testing is nearing completion.
- Full system assembly and checkout in Hawaii – After all components are onsite in Hawaii, they will be assembled and tested mechanically and electrically. To date, many of these interfaces have been simulated, but this test will be the first time all components are put together.
- Deployment – After full system checks, the full system and the BioSonics asset will be deployed at WETS for 6 months. During that deployment, additional assets will be deployed alongside the AOPS.

Q&A