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RCAM Technologies' Comments for Offshore Wind EPIC 4 Investment Plan (docket #20-EPIC-01)

Please find attached RCAM Technologies' Comments for Offshore Wind EPIC 4 Investment Plan (docket #20-EPIC-01)

Additional submitted attachment is included below.

Comments on
Electric Program Investment Charge 2021-2025 Investment Plan Scoping - Offshore Wind Energy R&D Opportunities for EPIC 4

Research Idea Exchange, Docket [Docket Log (20-EPIC-01)]

Prepared by:
RCAM Technologies, Inc.
2840 S Mansfield Ave
Los Angeles, CA 90016

General Comments

RCAM Technologies, Inc. (RCAM) is a growing renewable energy and energy storage technology company with offices in California, Colorado, and Scotland. We offer the following public comments regarding the workshop panel questions about (1) Research and Development Opportunities for Floating Offshore Wind (FOSW) and (2) Facilitating Early FOSW Deployments in California.

RCAM strongly supports the Electric Program Investment Charge (EPIC's) plan for research, development, and acceleration of Floating Offshore Wind deployment in California and the Investment Plan themes of Decarbonization, Resilience and Reliability, Entrepreneurship, Affordability, and Equity. The Investment Plan and themes are appropriate priorities for maximizing the benefits of clean energy R&D in California.

RCAM believes that the CEC's previous and proposed investment plans are critical to:

1) Increasing the cost competitiveness, performance, reliability, and knowledge of the environmental and wildlife impacts of FOSW in California.

2) Ensuring economic benefits and manufacturing of FOSW components benefit California ratepayers and disadvantaged residents.

3) Creating and sustaining an ecosystem of California small entrepreneurial businesses, educational institutions, supply chain members, and investors required to innovate, develop, and manufacture FOSW in California.

Responses to Panel Discussion Questions

Topic 1: Research and Development Opportunities for Floating Offshore Wind (FOSW)

What technical developments are most critical to early deployment (next 5 to 10 years) of FOSW in California? And what specific research needs, or promising innovations, would help address cost reductions?

RCAM agrees with the comments of the panel members that technical developments in mooring and anchoring technologies are critical to early deployment of FOSW in California, primarily for the two reasons below.

1. The manufacturing and installation costs of present FOSW anchors systems are very high. At an installed cost of approximately $1M per anchor, anchors represent the third largest portion (~15%) of the manufacturing costs for floating wind plants. According to the Energy Innovation Needs Assessment (EINA) report for Offshore Wind[1], "reliable and cost-effective moorings are becoming essential for deployment increases to occur. For example, in a 1 GW floating wind plant using 67 15-MW turbines, each with three conventional suction anchors, the steel suction anchors will cost approximately $200M.
2. California has relatively unique FOSW technical resources that will require new mooring and anchoring technologies suitable for (1) very deep water installations (100m to 2000m), (2) seismic events, and (3) reduce the mooring watch circle size. EPIC support is critical to developing and demonstrating these new mooring and anchoring technologies, such as a new low cost 3d Printed suction Anchor for single and multi-line mooring that RCAM and its partners are developing called 3dp-A.

Our response provides the following description of RCAM's 3d concrete printed suction anchor (3dp-A) as an example promising mooring technology that requires EPIC R&D funding for commercialization in California. 3dp-A is a new mooring technology invented in 2019 that stemmed from prior 3d concrete printing R&D for onshore wind turbine funded by EPIC in 2017. In 2020, a team co-led by RCAM Technologies proved the viability of 3dp-A in a project sponsored by the Floating Wind Joint Industry Project (JIP) which is a collaboration between the Carbon Trust and 15 developers with funding from the Scottish Government. In the project, RCAM and its partners completed the preliminary 3dp-A design and performed proof-of-concept manufacturing of 3dp-A sections.[2]

The project found that the 3dp-A is a viable solution for floating offshore wind. 3dp-A is ideal for single and multi-line mooring of nearly all floating platform designs and mooring configurations (catenary, semi-taut and taut) because it accepts omnidirectional loading, locates with high accuracy, and can be installed and removed with little environmental disturbance in a variety of depths and seabed conditions (i.e., sand and clay) typical off California coastlines.

3dp-A is projected to cut installed suction anchor costs by 67% compared to steel suction anchors or drag anchors in a conventional single-line mooring configuration. When combined with multi-line mooring (shared anchor), 3dp-A is projected to reduce installed anchor cost by 90% (for 3-point mooring) and 95% (for 6-point mooring) compared to drag anchors which are limited to one load direction. In addition, 3dp-A's ability to resist vertical loads facilitates vertical mooring line configurations such as tension leg platform designs with taut or semi-taut mooring that have a smaller footprint and shorter mooring lines reducing conflicts with other marine uses and marine life.

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[1] "Energy Innovation Needs Assessment - Sub-theme report: Offshore wind," Department for Business, Energy, & Industrial Strategy, London, Oct. 2019. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/845662/energy-innovation-needs-assessment-offshore-wind.pdf

[2] "3D Printed Concrete Suction Anchor (3DSA)," Floating Wind Technology Accelerator Competition, Scotland 2021. [Online]. Available: https://prod-drupal-files.storage.googleapis.com/documents/resource/public/FWTC_3DSA.pdf

Several technical aspects of 3dp-A need to be further developed and validated through additional design, analysis, testing, and demonstration. RCAM is continuing to seek public and private funding to continue development of 3dp-A; however, interviews with private investors, potential customers and advisors, such as offshore wind developers, indicate that the early stage technology (approximately TRL 4/5) needs further development to mitigate risks before private investment can be secured. Most notably, the most critical next development steps in developing and de-risking 3dp-A are:

- Fabricating a complete anchor at large scale
- Testing the embedment and extraction processes and verifying numerical geotechnical models
- Demonstrating deployment, installation, and recovery operations at sea.

As a small pre-revenue company, RCAM alone does not have the internal R&D resources, facilities, or cross-cutting experience necessary to undertake large scale fabrication, testing, and demonstration of the anchor alone. EPIC support is critical to performing site specific designs, testing, and demonstration of anchors and mooring systems for California conditions such as RCAM's. RCAM's route to market uses non-dilutive grant funding to support earlier-stage development and prototype demonstrations to cost-effectively de-risk the technology for larger private investments for full-scale demonstration and commercial deployments. RCAM's commercialization plan includes designing, fabricating, and demonstrating 3dp-A at half scale in 2023, full-scale in 2025, and commercial deployments beginning in 2027. Specific steps in the 3dp-A development path include:

1) Design of newly invented next generation 3dp-A features and concrete materials that further reduce cost and mass, handle seismic loads, and increase durability
2) Sub-scale and large scale manufacturing of a complete anchor up to approximately 12-m in diameter and 10m tall depending on the targeted seabed conditions and floating platform technology
3) Structural and durability tests of the mooring line and reinforcement systems
4) Function tests in a port and/or simulated (laboratory) seabed environment
5) Embedment and extraction test in an operational environment (open water)
6) Pull-out proof testing in the ocean for single and multi-line mooring
7) Design of alternative installation and retrieval equipment and procedures
8) Design certification activities
9) Demonstration of a 3dp-A connected to a floating wind turbine platform or other structure.

Additional grant funding from EPIC on the order of $3M to $5M is critical to performing these development steps before attracting larger private investments needed to scale up for production.

What target performance metrics, other than levelized cost of energy, would you recommend to measure success of floating offshore wind systems?

In addition to cost and greenhouse gas metrics, RCAM suggests metrics that reflect the themes of the 2021-2025 Investment Plan including:

1. Economic value or mass of components manufactured in California
2. Job and educational opportunities for residents in disadvantaged zones
3. Amount of project funding spent by California small businesses
4. Measures or steps to develop and grow California's FOSW supply chain
5. GHG emission reductions

Topic 2: Facilitating Early FOSW Deployments in California

What are some research opportunities for advancing floating offshore wind energy to accelerate the transition to clean energy? What innovations would help the offshore wind industry capitalize on its complementary generation profile with solar? What does the grid of the future look like and what are key challenges to grid integration and transmission that can be addressed through research?

RCAM would like to emphasize the unique and timely opportunity California has for combining FOSW and ocean based long duration energy storage such as Marine Pumped HydroElectric Storage (M-PHES). California has vast deep water ocean resources extending more than 800 miles along its coastlines that are ideal for both FOSW and M-PHES. The integration of these two technologies in a hybrid wind/storage energy system would have synergistic benefits for both FOSW and M-PHES that could accelerate deployment, reduce the cost, and increase the value and benefits of both technologies. RCAM suggests the CEC consider two new technical reports by NREL and London Imperial College that describe the benefits of hybrid energy systems such as wind energy with long duration mechanical energy storage. [3,4]

A 1st generation M-PHES has been proven independently by MIT and the Fraunhofer Institute. RCAM's next generation M-PHES concept is a lower cost, longer duration energy storage technology that can be used with renewable energy technologies along America's coastlines and in lakes to provide up to 100% clean electricity and strengthen grid resiliency for over 127 million people. M-PHES has all the benefits of conventional (onshore) Pumped HydroElectric Storage (PHES) but solves the problems PHES has with long development timelines, water availability, financing, capital costs, and limited geographic availability. RCAM project M-PHES will cut project development time by 75%, capital costs by 50%, and increases the available storage technical resource capacity 200X compared to PHES.

RCAM is developing a patent pending, multiple-sphere M-PHES configuration that improves the cost effectiveness and storage capacity that can be manufactured using low cost 3D concrete printing (3DCP) methods. The 3DCP additive manufacturing approach facilitates fast production of M-PHES systems of various sizes and capacities in California ports using regionally available concrete materials and concrete supply chains, providing quality jobs and localized economic benefits.

M-PHES uses the static pressure of the water column in lakes, seas, and oceans to store and release electrical energy when needed in a process similar to conventional (onshore) pumped hydro power plants. To use this potential energy, a large hollow concrete sphere is installed under water in oceans and lakes in depths between 150 m and 2000 m. A motor/pump connected to the hollow spheres stores electrical energy by pumping water out of the sphere against the surrounding hydrostatic pressure. The process is reversed to generate electricity using a turbine/generator (Figure 1).

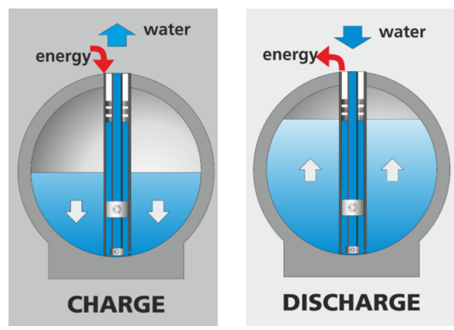

Figure 1: M-PHES charges by pumping water out of a sphere (left) and is discharged by allowing the water to return through a turbine (right). Image source is the Fraunhofer Institute.

The amount of M-PHES energy storage depends primarily on the water depth and volume of water stored. RCAM's higher capacity design efficiently couples multiple spheres to a single pump-turbine assembly to cost effectively increase the storage volume and capacity in all water depths, which is especially important in shallower waters with less pressure head. 3DCP cuts manufacturing costs in half and enables RCAM to vary the number of spheres, depth, and diameters without fabricating new formwork. Nominally, a grid-scale M-PHES with three 30-m diameter

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[3] "Whole-System Value of Long-Duration Energy Storage in a Net-Zero Emission Energy System for Great Britain," *Imperial College London*. http://www.imperial.ac.uk/energy-futures-lab/reports/whole-system-value-of-long-duration-energy-storage-in-a-net-zero-emission-energy-system-for-great-britain/ (accessed Jul. 24, 2021)

[4] "Are Hybrid Systems Truly the Future of the Grid? NREL's Magic 8-Ball Says: 'Concentrate and Ask Again.'" https://www.nrel.gov/news/features/2021/are-hybrid-systems-truly-the-future-of-the-grid.html (accessed Jul. 24, 2021).

spheres installed in 700-m water and a 5-MW pump/turbine module has a storage capacity of 60 MWh providing 12 hours of energy storage at rated power. Increasing the spheres to 8 per pump/turbine provides 32 hours (1.3 days) or 160 MWh of energy storage. The modularity of M-PHES allows deployment of additional systems to meet growing capacity needs.

The daily and seasonal mismatch of variable renewable energy sources (such as wind and solar) and load demand requires long duration storage from hours to days to achieve very high levels of renewable energy in the power sector. The National Renewable Energy Laboratory (NREL) projects the U.S. needs to install approximately 350 GW of long duration energy (4 - 12 hours) and multiday seasonal storage to reach 80% to 90% penetrations of renewable energy.[5] Conventional pumped hydroelectric energy storage has been the preferred long duration storage technology due to its high efficiency (80%), low cost, vast storage capacities, quick response time, ultra-long plant life (100 years with refurbishment), and technological maturity. In 2019 PHES contributed 93% of U.S. grid storage power capacity (22 GW) and 99% of electrical energy storage (553 GWh). **However no new pumped hydropower plants have started operations in the U.S. in over 25 years due primarily to long regulatory and construction timelines for development of new projects (up to 10 years), financing challenges, and limited availability of suitable terrain and water**. Environmental concerns with competing land and water uses, and financing challenges with huge, high cost PHES projects have hindered successful development of new PHES projects.

RCAM's innovative M-PHES system solves the geographic limitations of conventional pumped hydro by increasing the deployable technical resource capacity by 200X, cuts capital costs, increases drought resistance, and reduces development time by avoiding fresh-water use-conflicts and land-use permitting challenges. M-PHES has potential to reduce regulatory and development time from 10 years to 3 years by avoiding contentious land and water use conflicts and adapting marine permitting processes in or soon-to-be in-development for California offshore wind and wave energy deployments. M-PHES is deployed out-of-sight on the seafloor without obstructing marine traffic above. M-PHES can be planned, permitted, and installed with future U.S. fixed and floating offshore wind, wave, and solar plants or be installed independently ensuring that California has long duration energy storage it needs for deployment of renewable energy sources such as FOSW. EPIC programs that encourage or support technology integration such as a hybrid FOSW / M-PHES systems will be critical to developing this unique and timely California opportunity.

Thank you for your consideration of these comments.

Jason Cotrell
Founder and CEO
RCAM Technologies, Inc.

[5] P. Denholm, *et al.*, "Storage Futures Study: The Four Phases of Storage Deployment: A Framework for the Expanding Role of Storage in the U.S. Power System," NREL, Jan. 2021.