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RCAM and FWTC Comments on R&D Opportunities for Floating Offshore Wind Energy Draft

Additional submitted attachment is included below.

Comments on the CEC Staff Workshop, Research and Development Opportunities for Floating Offshore Wind Energy In California

Research Idea Exchange, Docket Number 19-ERDD-01

Prepared by:

RCAM Technologies
2372 Morse Avenue, Ste. 358, Irvine, CA 92614

The Floating Wind Technology Company (FWTC)
18960 W. 92nd Drive, Arvada, CO 80007

RCAM Technologies (RCAM) and the Floating Wind Technology Company (FWTC) offer the following public comments regarding Navigant's March 2020 draft Consultant Report *Research and Development Opportunities for Offshore Wind Energy in California* on the following questions posed by the CEC.

(1) Do the identified **recommendations** capture high priority research, development, and deployment (RD&D) opportunities specific to the California market?

RCAM and FWTC believe the recommendations do, in general, capture the high priority RD&D opportunities specific to California; however, RCAM and FWTC request addition technologies be included in Recommendation 1. RCAM and FWTC especially support the following recommendations:

- Recommendation 1: Advance technologies for mooring and cabling, including inter-array cabling webs and dynamic cabling. However, this support is contingent on anchors and semi-taut and taut mooring systems and floating foundations being added as described in our response (2) below.
- Recommendation 3: Develop technical solutions to integrate offshore wind to the grid, including facilitating technologies like advanced hydrogen and subsea storage. However, RCAM believes subsea storage has been much less studied than hydrogen systems making a California emphasis on subsea storage potentially more impactful than additional hydrogen studies.
- Recommendation 4: Develop approaches to use and optimize existing supply chain and manufacturing or assembly solutions in California.
- Recommendation 5: Study the seismic vulnerability of floating platform mooring systems.
- Recommendation 6: Conduct a comprehensive study on port infrastructure in California and develop technical solutions to identified gaps.

(2) What **innovative technical solutions** can facilitate the increased cost-competitiveness of offshore wind projects in CA?

RCAM and FWTC request that the **Recommendation 1 be expanded to specifically include low-cost anchor designs, manufacturing methods, and installation methods.** Conventional anchors are more expensive than the mooring lines; anchors (which are typically considered part of the broader mooring system) are the 3rd largest capital cost item in a floating wind system behind the turbine and platform. Furthermore, anchors, mooring lines, floating wind turbine platforms, and installation systems work together and must be co-designed as a system and therefore should be explicitly identified in this recommendation to achieve the most possible cost reductions. RCAM and FWTC have provided more detail regarding the need and opportunity for an innovative RCAM / FWTC concept for a low cost suction anchor in Attachment 1 to illustrate the innovation and cost reduction potential in anchor systems.

RCAM and FWTC also recommend the report include semi-taut and taut mooring systems and floating platform configurations as an 11th recommendation. For example, Tension Leg Platforms (TLPs) which use semi-taut and/or taut mooring systems are widely acknowledged to be one of the most stable floating wind platform configurations making them especially well suited to California's extreme wind and waves and deep waters. Furthermore, the anchor foot print is the smallest of any platform potentially mitigating defense navigation challenges, wildlife and environmental concerns. To date, RCAM is not aware of any existing prototype deployments that use taut or semi-taut mooring configurations resulting in a need opportunity for California to further support the assessment and development of the technologies.

3) How can energy RD&D funds support the demonstration and validation of floating platforms in California?

See response 2. In addition, **a particular challenge RCAM faces is finding both laboratory and ocean testing facilities for its cost reducing anchor and energy storage concepts in California** or the broader United States**.** RCAM's commercialization path for its anchors and energy storage systems require both laboratory and ocean testing and demonstrations of its anchor technologies in the ocean. RCAM anticipates that this challenge is also barrier for deploying floating platforms. Obtaining the necessary permissions and permits for this testing is time-consuming and expensive. In particular, any proposals that include ocean testing or deployment will likely trigger CEQA reviews, discretionary permits or determinations by California's Environmental Quality Act (CEQA) making such EPIC proposals challenging to prepare in a timely manner thereby creating a potential barrier for both mooring system and floating foundation proposals. Possible mitigation methods for this challenge might include (1) special EPIC solicitation provisions that provide sufficient time and funding to help meet CEQA requirements, (2) creation of a designated 'pre-permitted' deep-water installation and test site, (3) support collaboration and use of Oregon's PacWave ocean testing facilities for these purposes, and (4) other creative measures to address this challenge.

Attachment 1

The Need and Opportunity for Low Cost 3D Concrete Printed Suction Anchor

(An excerpt from an RCAM / FWTC proposal)

Approximately 60% of the U.S. offshore wind resource area is in water depths greater than 60m - too deep for conventional fixed-bottom substructures. Floating wind turbines, however, face several challenges, especially with regard to station keeping and mooring, e.g: high anchor fabrication and installation costs, installation location precision, installation time, installation in high wind, wave, and current conditions, mooring sea-keeping performance, and structural reliability. The most recent U.S. R&D Roadmap calls for innovative anchors and storage for shallow and deep installations (see reference National Offshore Wind Research & Development Consortium following Attachment 1).

In shallower floating sites (up to 100 m), mooring is particularly demanding because of the need to avoid line snap-loads that are promoted by both challenging wave regimes and reduced mooring hydrodynamic stiffness--especially with catenary systems. This is accompanied by increased line and anchor loads, especially cyclic vertical loads that cannot be easily handled by conventional embedment anchors. In these cases, seabed stresses caused by wave induced loading propagate into the subsoil and increase pore water pressure leading to a potential for liquefaction. In deeper waters (250-1000 m), mooring lines are long, heavy, and expensive. Furthermore, especially in the case of steel catenary mooring, heavy lines increase demands on the floating foundation and have a wide footprint that impacts fishing operations. Along the U.S. Pacific Coast and offshore of the Hawaiian Islands, (water depths ~500-1000 m), an additional hurdle (especially in California) to the mooring is presented by seismicity, which can also lead to soil liquefaction failure.

Typical drag embedment anchors are problematic because of the time and high cost for installation, the difficulty in precisely controlling final position, and small vertical load capacity. The typical drag anchor requires larger installation vessels and are reported to cost up to $500k per unit to install. Other anchor designs, such as gravity anchors, are too large for cost effective mooring of floating turbines. Driven pile anchors are also problematic due to high material and installation costs.

Suction buckets are a preferred floating turbine solution, as they can be installed in nearly all water depths, withstand omnidirectional loading, and can be installed with high location accuracy. However, conventional rolled steel suction-bucket anchors are very expensive to manufacture and install. In addition, many countries import steel anchors because they do not have the existing supply chain efficiencies to manufacture suction buckets domestically.

The manufacturing cost of components for a floating wind plant is nearly 70% of the lifecycle cost (Figure 1). Next to the turbine and substructure, the anchors are the most expensive components to manufacture and deploy. Three conventional suction anchors for a 10-MW floating spar turbine were estimated to cost ~$4.3M (Lifes50+[2016]). Thus, the anchors for a 500 MW floating wind plant are nearly $220M when using conventional technologies.

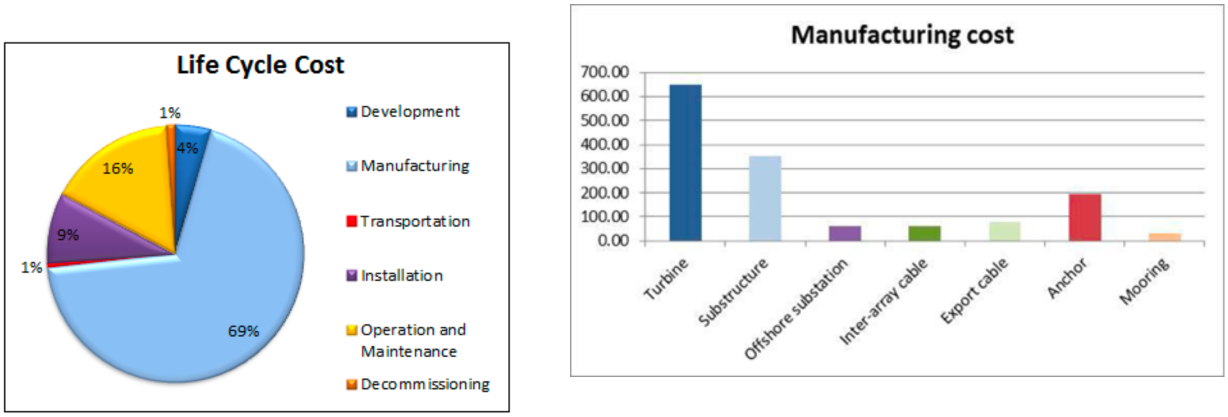

Figure 1. Projected manufacturing costs would be the largest portion of life cycle cost for a 500 MW floating wind plant comprised of spar foundations and 10-MW turbines off the Coast of Maine (left). Conventional anchors represent the third largest portion of the manufacturing cost for the wind plant (right). (Lifes50+ [2016]).

The high cost of conventional steel suction buckets and the environmental impact and poor positioning accuracy of drag embedment anchors, create a significant opportunity for new foundation designs and manufacturing technologies that reduce cost and overcome U.S. offshore wind deployment barriers.

The Commercial Opportunity: The United States has tremendous potential for generating more than 4,000 GW of electricity via offshore wind, which is about 4 times the nation's total electric-generating capacity. 60% of the U.S. offshore wind resource is in water depths between 60 m and 1000 m that are cost prohibitive for fixed-bottom substructures.

The typical drag anchor requires large installation vessels and is reported to cost up to $500k per unit to install. Suction buckets are a preferred floating turbine solution, as they can be installed in shallow and deep water, withstand virtually omnidirectional loading, and can be installed with high location accuracy. However, conventional rolled steel suction-bucket anchors are very expensive to manufacture and install creating a significant opportunity for new foundation designs and manufacturing technologies. The manufacturing cost of components for a floating wind plant is nearly 70% of the lifecycle cost (Figure 1). Next to the turbine and substructure, the anchors are the most expensive components to manufacture and deploy at nearly 200 million euros for a 50 MW floating wind plant. Three conventional suction anchors for a 10-MW turbine were estimated to cost $4.3M (Lifes50+[2016]).

It is projected that the global market for anchors will reach some $400B associated with some 150GW of installed capacity [derived from IRENA (2016) and Renewable UK & Scottish Renewables (2019)]. We calculate that the anchor market size in the U.S. will reach $5B by 2040 in the U.S. Pacific region.

However, cost challenges must be overcome for these projections to materialize. 3D-concrete-printed (3DCP) suction anchors (3DSAs) promise to be cost-disruptive, by cutting installed costs of anchors by up to 80%. The primary *customers* for the 3DSA are offshore floating wind plant developers on the East and West Coast. RCAM and FWTC have performed phone and in-person interviews to discuss 3DSA's potential. All interviews expressed interest in the concept, indicated it may be feasible and warrants further exploration.

The Innovation: Our proposed 3DSA concept (see Figure 2 and Figure 3) draws upon and combines the advantages offered by anchoring solutions already existing in the industry, into an innovative, cost-disruptive design. The 3DSA uses low-cost 3D concrete printing technologies, with domestically available concrete materials to manufacture low-cost suction anchors that can be floated to the installation site with inexpensive, readily-available tugs (Figure 3).

Figure 2. The 3DSA is designed to take advantage of the positive aspects of other anchoring concepts (low-cost, accurate positioning, quiet installation and omnidirectional load capacity) whilst mitigating high-cost items (logistics and installation) and reducing installed CapEx by 80%.

Our preliminary estimates indicate that 3DCP suction anchors could reduce the installed costs by up to 80% compared to conventional suction buckets fabricated by rolling steel plates and installed via specialized and costly anchor-handling vessels. Furthermore, the 3DCP anchors can be manufactured using existing concrete supply chains located in nearly every region of the country.

Suction bucket anchors have potential for use in all water depths greater than 60 m, with virtually any floating substructure configuration (e.g., semi-submersible, barge, spar, and tension leg), and any mooring layout (e.g., catenary, semi-taut, and taut). Suction anchors offer faster installation speeds, resist multi-directional loading, reduce mooring footprint, improve installation position precision, and work well with shared mooring and synthetic mooring lines. However, they have been associated with high costs, partly due to the large steel quantities and extensive labor, and partly because of the specialized anchor handling vessels used for deployment.

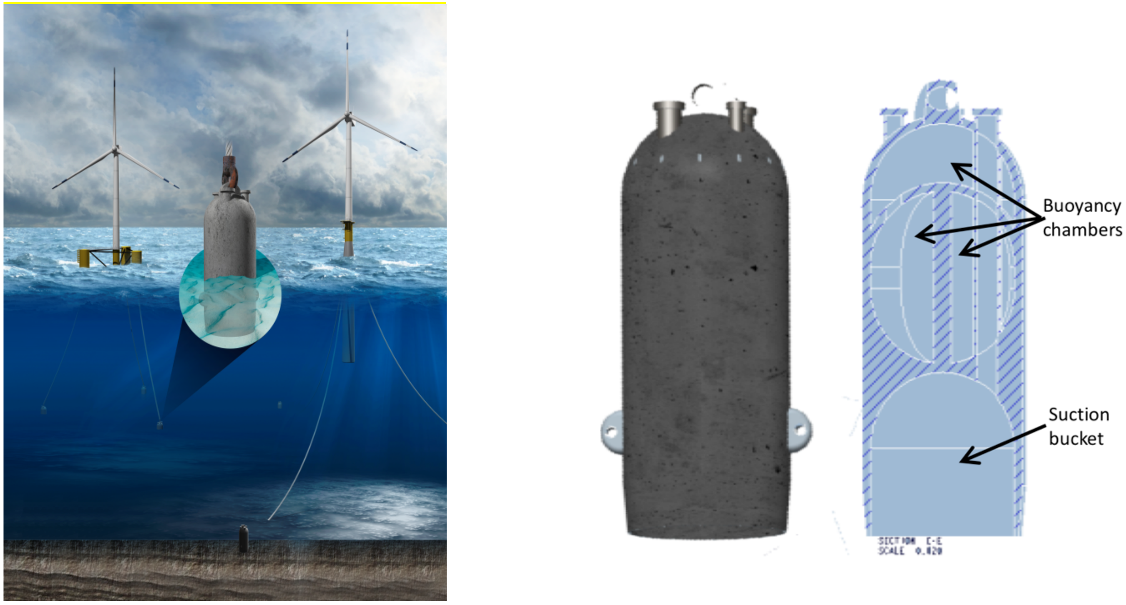

Figure 3. Left: Artistic rendering of the 3DSA installed for different types of floater and mooring configurations. Right: cross-section and front view of 3DSA.

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