National Offshore Wind Research and Development Consortium

Notice of Upcoming Technical Challenges

First Research Pillar: Offshore Wind Plant Technology Assessment | Initial Release Version 1.0 | November 2018

CARBON TRUST

NEW YORK STATE OF OPPORTUNITY. | NYSERDA

U.S. DEPARTMENT OF ENERGY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

rcg Renewables Consulting Group

Cover Image: Getty Images

Abstract

This Notice of Upcoming Technical Challenges identifies priority topics for U.S. offshore wind research and development in advance of solicitations to be issued by the National Offshore Wind Research and Development Consortium (“the Consortium”) in 2019. Four Challenge Areas are identified to support the Consortium’s first Research Pillar, Offshore Wind Plant Technology Advancement. These challenge areas are: (1) Array Performance and Control Optimization, (2) Cost-Reducing Turbine Support Structures for the U.S. Market, (3) Floating Structure Mooring Concepts for Shallow and Deep Waters, and (4) Power System Design and Innovation. Technical descriptions of each Challenge Area have been developed as a guide for prospective research project proposers, as well as some examples of the types of projects that could address these challenges. Guidelines for quantifying the benefits of proposed projects to the U.S. offshore wind industry are also provided.

Key Words

offshore wind, OSW, offshore wind plant, wind technology, wind power, turbines, array performance, mooring concepts, clean energy

Acknowledgements

This Notice of Upcoming Technical Challenges was produced by the National Offshore Wind Research and Development Consortium's internal technical team comprised of offshore wind experts from the New York State Energy Research and Development Authority (NYSERDA), the U.S. Department of Energy (DOE), the Renewables Consulting Group (RCG), the National Renewable Energy Laboratory (NREL), and the Carbon Trust (CT). In addition, offshore wind developers serving on the Consortium's Board of Directors provided extensive input. The primary authors were Walter Musial (NREL), Richard Bourgeois (NYSERDA), Gary Norton (DOE), Alana Duerr (DOE), Jan Matthiesen (CT), Michael Stephenson (CT), Emilie Reeve (RCG), and Doug Pfeister (RCG).

Table of Contents

1 Introduction

In June 2018, the U.S. Department of Energy (DOE) announced the selection of the New York State Energy Research and Development Authority (NYSERDA), the Renewables Consulting Group (RCG), the Carbon Trust, and the Advanced Energy Research and Technology Center (AERTC) at Stony Brook University to lead a nationwide research and development consortium for the offshore wind industry. The National Offshore Wind Research and Development Consortium ("the Consortium") is a nationally focused, independent, not-for-profit organization led by key offshore wind industry stakeholders and research institutions. The Consortium is dedicated to managing industry-focused research and development of offshore wind to maximize economic benefits for the United States. The U.S. DOE award is for $20.5 million, at least $2 million of which will directly fund U.S. federally funded research and development centers (FFRDCs). This award will be matched by NYSERDA.

The Consortium seeks to fulfill, in part, a long-term vision for offshore wind in the United States that is supported by current policy for an all-inclusive energy strategy. To achieve this vision, the Consortium supports a strategy of identifying the technology innovations needed to address challenges and lower costs in each of the five U.S. offshore regions, allowing offshore wind to compete in all regional electricity markets without subsidies. The necessary cost reductions can be realized in part through targeted research and development (R&D) that removes or reduces technological and supply chain barriers to deployment and lowers development risk to investors. The Consortium envisions conducting this research as desktop studies, design development, and computer analysis, as well as hardware development with supporting demonstration and validation activities.

2 Research and Development Solicitations

In November 2018, the Consortium released its initial Research and Development Roadmap (Roadmap) to advance offshore wind technology, drive wind innovation, and combat climate change. Established in response to industry-led feedback, the Roadmap establishes a long-term vision for innovative offshore wind technology development in the United States and identifies key priorities for establishing the industry as a leading national clean energy sector.

Focusing on the research and development priorities identified in the Roadmap, the Consortium intends to distribute available research funds through a series of competitive solicitations over the next four years. These competitive solicitations will mirror the three research pillars described in the original DOE funding opportunity announcement (DOE FOA 1767):

- Pillar #1: Offshore Wind Plant Technology Advancement
- Pillar #2: Offshore Wind Power Resource and Physical Site Characterization
- Pillar #3: Installation, Operations and Maintenance, and Supply Chain

The Consortium plans to open a solicitation for each of these three pillars in 2019, beginning with Pillar #1 in the first quarter of that year. No specific allocation has been made with respect to the distribution of research funds across the three pillars.

3 Notice of Upcoming Technical Challenges

This document is a Notice of Upcoming Technical Challenges prior to the competitive solicitation for Research Pillar #1, Offshore Wind Plant Technology Advancement. Per the Roadmap, Pillar #1 includes:

> Technology advancements that drive significant reductions to offshore wind energy levelized cost of energy (LCOE) in the United States, which can be extended to global offshore wind markets. Accelerated innovation can reduce capital costs and expand annual energy production, targeting long-term LCOE reductions for fixed-bottom and floating offshore wind systems of 40% and 60%, respectively. Research and development (R&D) under this pillar should also address the domestic market challenges in wind turbine and wind plant technology (e.g., deep water, extreme conditions, hurricanes).

A formal solicitation for R&D project proposals in Pillar #1 will be issued at a later date, targeted for early February 2019. The Consortium expects to announce its first awards under this solicitation as soon as March 2019; however, the solicitation will remain open and continue to accept proposals after this date. Solicitations for R&D project proposals in Pillar #2 and Pillar #3 are expected in the months immediately following the initial Pillar #1 solicitation. These formal solicitations will include specific requirements regarding proposal content, scoring criteria, program policy factors, and terms and conditions, as well as instructions for submittal. No proposals received prior to issuance of the formal solicitation will be considered. The purpose of this notice is to give project proposers additional time prior to the release of the solicitation to form teaming relationships and develop technical content.

The following technical descriptions have been developed as a guide for prospective proposers. This includes a summary of some of the highest priority technical challenges the Consortium identified from the Pillar #1 topics identified in the Roadmap as well as some examples of the types of projects that could address these challenges. Guidelines for quantifying the benefits of proposed projects to the U.S. offshore wind industry are also provided.

4 Highest Priority Technical Challenges for Pillar #1

4.1 Challenge Area 1: Array Performance and Control Optimization

Challenge Statement

To date, efforts to improve annual energy production and increase reliability focused more on individual wind turbine refinement than on the challenges and rewards of operating multi-turbine arrays to perform most efficiently as fully integrated wind plants. As offshore turbines and projects grow larger, new plant-wide design approaches and control strategies are needed to optimize energy capture, minimize turbine downtime, and reduce overall cost, based on an enhanced understanding of wake characteristics, wind profiles, and other atmospheric conditions at U.S. offshore wind sites.

Objective

The main objective of this challenge is to enable wind plant performance optimization through development of new methods, tools, and designs based on technology innovation and computer modeling of advanced plant controls.

Background

Recent studies such as the FP7 Cluster Design project; ECN Far and Large Offshore Wind Farm program: Wind Farm Wake Modeling, Fatigue Loads and Control; the DOE's Atmosphere to Electrons (A2e) program; and Carbon Trust Wind Farm Control Trials; indicate array performance and control optimization can improve lifetime economic performance through increased power production and reduced O&M costs as well as extend the lifetime of the asset. Moreover, the pitch and yaw-based control strategy estimates could result in a combined 0.5-3.5% increase in energy yield, and therefore, impact levelized cost of energy reduction. Also, employing array optimization strategies could enable load reductions of up to 50% for certain wind turbine components, which will reduce fatigue and turbine maintenance and O&M costs (Carbon Trust, 2017).

Several studies have been undertaken to understand the atmospheric conditions, wake characteristics, and their effects on energy production at European offshore wind sites and on U.S. land-based wind sites through the DOE's A2e program. However, there is a need to better understand the atmospheric conditions at all U.S. wind energy areas (Atlantic, Pacific, Gulf of Mexico, and Great Lakes), taking into account differences in the wind conditions between U.S. and European sites. Understanding these differences is important as it will lead to improving the atmospheric models used to predict offshore wind plant loads and performance in the U.S. and help better inform how wind plant performance could be affected. As the number and size of offshore wind plants built in U.S. waters increases, methods and tools are needed to improve the wind plant annual energy production, increase reliability, and reduce O&M costs.

Proposals in this area are expected to demonstrate innovations that can lead to higher wind plant output and/or lower plant operating costs in a comprehensive cost model that accounts for improvements. Indirect effects on the market and U.S. supply chain should also be described.

Example Project Types

The following list provides example project types that could address this challenge. This list is meant as a reference and is not intended to be exclusive. All project proposals will be considered provided they contribute to the objectives of addressing this Challenge Area.

- Model the performance and assess the physical behavior of ultra-large rotors (200+ meters) in a large-scale array, including examining possible behavioral deviations from current understandings (e.g., wake expansion ground/surface effects).
- Assess how best to optimize whole wind plant control systems to maximize energy capture for varying wind directions and atmospheric conditions found in U.S. wind energy areas.
- Assess the best approach to wake steering strategies to reduce intra-array turbulence and power losses within existing and future U.S. wind energy areas. For reference, the A2e program conducted similar studies for onshore wind plants (DOE, 2016).
- Enhance optimization methods by developing offshore wind models for ascertaining least-cost plant layouts, considering real-world site conditions such as siting restrictions due to fishing etc.
- Near-term solutions to refine layout planning.

Proposers are encouraged to seek inputs from, or partner with, equipment manufacturers and other members of the supply chain in order to maximize applicability to commercial offshore wind plants, as well as to provide insight on commercialization pathways for new technologies.

Additionally, to avoid duplication of effort and build on the overall state-of-the-art, proposals should seek opportunities to build on prior research efforts and leverage existing programs in wind plant optimization. One example relevant to this challenge area is the A2e program supported by the DOE, which seeks to reduce the cost of both land-based and offshore wind energy through an improved understanding of the complex physics governing electricity generation by wind plants.

4.2 Challenge Area 2: Cost-Reducing Turbine Support Structures for the U.S. Market

Challenge Statement

Fixed-bottom turbine support structure designs developed for Europe may not be optimal for the U.S. market due to differences in seabed characteristics, extreme weather conditions, environmental and regulatory constraints, available installation vessels, and maturity of the domestic supply chain. Technology solutions are needed to optimize monopiles, jackets, gravity-base, suction buckets, transition pieces and/or other types of foundation designs in order to lower overall cost and ensure suitability under the specific conditions of U.S. offshore wind regions.

Objective

The main objective for this challenge is to develop fixed-bottom support structure design options (including transition piece designs) more suitable for U.S. site conditions and that facilitate the advancement of U.S. manufacturing capabilities relative to existing baseline designs. Design modifications will be proposed and evaluated, and new support structures designs will be identified to suit site conditions or enable support structure manufacturing within the U.S.

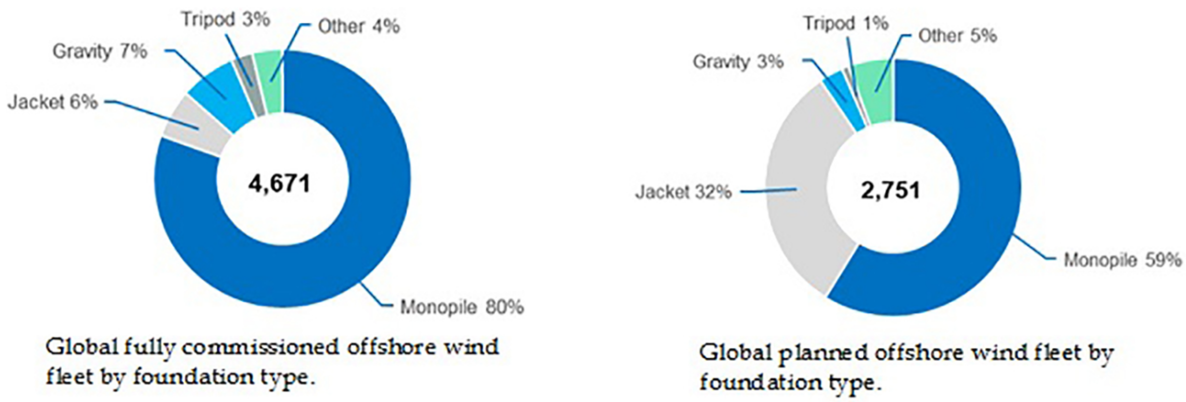
Background

Most offshore wind turbines installed to date are mounted on fixed-bottom substructures embedded into the seabed. This is largely due to the easy transferability of skills and knowledge from the oil and gas industry, as well as the relatively shallow water depths available for siting projects. With more than 40% of the U.S. offshore wind resource located in water depths of 60 meters or less, the use of fixed-bottom substructures is feasible in many U.S. offshore locations (DOE, 2017) and offer the best near-term solution for the initial U.S. offshore wind projects.

To date, monopiles make up the majority of installed offshore wind substructures in Europe. However, their dominance in the industry is decreasing as other substructures are better suited for some sites due to varying site conditions. In addition, alternative substructures may offer greater cost reductions in U.S. waters and may be more easily fabricated by the domestic supply chain. Block Island is one example where a jacket substructure was chosen in order to utilize U.S. fabricators in the Gulf of Mexico, reducing the overall cost of the wind plant.

Figure 1. Global Offshore Wind Fleet

Source: GRIP, The Renewables Consulting Group, 2018



Though there are several different substructure designs available, the market is predominantly dominated by three existing available designs: monopiles, jackets, and gravity-base—all designed and developed based on European offshore site conditions. Assessments of the suitability of existing available support structures targeted for U.S. specific conditions are needed. These assessments are encouraged to quantify, but are not limited to, the following variables:

- Support structure mass and cost scaling
- Domestic installation capabilities
- The development of calculation methods suitable for U.S. soils and seabed conditions
- Domestic supply chain opportunities
- Alternative installation methods to mitigate possible environmental impacts
- Alternative installation methods to avoid negative cost impacts due to Jones Act restrictions
- Extreme wind and wave resiliency
- Water depth

In addition to assessing the suitability of existing designs for U.S. site conditions, there are a number of opportunities to develop innovative products or solutions that are more suited to U.S. conditions, supply chain and vessel availability. Such as:

- Innovative substructure designs or design modifications to existing substructures
- Innovative materials used as an alternative to steel, such as advances in composite concrete, that are more cost effective, provide necessary strength, and supplied by U.S. manufacturers (Wind Power Engineering, 2018)
- Substructure solutions that reduce the dependency on foreign flagged or expensive heavy lift vessels
- An innovative or optimized approach to fabricating substructures (e.g., increasing the modularity of a substructure) that will increase the efficiency of quayside fabrication
- Options that extend the lifetime of the substructure, delaying the need to decommission and reducing the overall levelized cost of energy

As the offshore wind industry continues to develop, there is a great opportunity to innovate, modify, and optimize offshore substructures to match U.S. offshore conditions, manufactured and installed by U.S.-based companies.

Substructures and foundations account for 13.9% of the capital expenditure for a fixed-bottom offshore wind plant (NREL, 2016), and this percentage can vary significantly with water depth, bottom conditions, and the capability of the local supply chain. There is the potential for these projects to have a marked impact on reducing the capital expenditure for substructures and enable development at some sites where existing substructure technology is not feasible. However, large levelized cost of energy reductions may not be possible unless the innovation affects multiple areas of the cost breakdown structure such as installation and construction.

These projects will enable potential U.S. substructure suppliers to design and develop substructures that are better fit for purpose, without having to take on the entire design and development cost themselves, which could be prohibitive. These projects may also identify gaps in the supply chain that can help inform and focus wider domestic supply chain enabling activities such as use of existing facilities and indigenous materials.

Example Project Types

The following list provides example project types that could address this challenge. This list is meant as a reference and not intended to be exclusive. All project proposals will be considered provided they contribute to the objectives of addressing this Challenge Area. For the purpose of this challenge, the term “existing fixed-bottom substructures” refers to the transition piece, monopiles, jackets, gravity-base, suction buckets, tripods, and tri-pile support structures only.

- Technical assessment of existing fixed-bottom support structures for suitability in U.S. offshore site conditions
- Technical assessment of the types of modifications required to make existing support structures more suited to U.S. site conditions:
    - Likely overall cost implications of any modifications
    - Ability to be installed without the use of a heavy-lift vessel
    - Capability of U.S. supply chain to deliver modifications
    - Demonstrated ability to mitigate a technology barrier (e.g., difficult soils types) to deployment in the U.S.
- Supply chain gap analysis for manufacturing current fixed-bottom support structures
- Innovative substructure designs or design modifications to existing substructures delivered by the U.S. supply chain
- Innovative materials that can be used as an alternative to steel, such as advances in composite concrete, that are more cost effective, provide the necessary strength, and supplied by U.S. manufacturers

- An innovative or optimized approach to fabricating substructures (e.g., increasing the modularity of a substructure) that will increase the efficiency of quay side fabrication
- Options that extend the lifetime of the substructure, delaying the need to decommission and reducing the overall levelized cost of energy

All prospective proposals for this challenge are encouraged to seek inputs from, or partner with an offshore wind developer, a U.S. offshore wind substructure supplier or include an advisory group comprising of developers and/or substructure suppliers to ensure the direction of the project and outcomes can be commercially applied. Additionally, proposals should identify research and/or partners who have been working on this challenge to demonstrate research will further the overall state-of-the-art.

4.3 Challenge Area 3: Floating Structure Mooring Concepts for Shallow and Deep Waters

Challenge Statement

Anchoring floating offshore wind systems in both shallow water depths (between 60 and 100m found off the U.S. Atlantic coast) and depths of 500 meters or more (Pacific Coast), poses design, installation, and cost challenges. Innovative mooring and anchoring technologies and methods are needed to manage loads on the substructure and anchors, incorporate alternative materials, optimize safety factors, and lower cost. Such innovations should consider potential impacts of increasing line spread, potential environmental and navigation impacts, and long-term performance. Based on factors such as varying water depth, seabed conditions, extreme wind and wave conditions, and seismic activity, the technology needs for floating wind mooring and anchoring systems will vary by region.

Objective

The main objective of this challenge is to identify new shallow and/or deep-water mooring concepts that are effective, easy to install, and lower technical risk. The impact of these projects will be to enable a greater number of potential development sites, as deployment at very deep or very shallow sites is presently perceived as expensive or high risk.

Background

Shallow Water Mooring Concepts

Current mooring systems (especially catenary mooring types) become more expensive at shallower water depths due to the need to avoid snap loading and anchor uplift forces; constrained watch circles; and the need to balance stiffer motion frequencies with wave excitation. Large platform motions in storms can cause localized tension spikes (snap loads) in mooring lines when a line re-engages after momentarily going slack (Hsu, 2017). Shallow water depths may also increase anchor loads and introduce unfavorable load vectors, requiring local seabed condition optimization. Alternative design configurations and mooring solutions are needed to address shallow water issues, including load management solutions, optimized safety factors and new materials, without adding cost at sites representative of U.S. seabed conditions.

Deep Water Mooring Concepts

A steep drop of the continental shelf off the Pacific coast, combined with minimizing visual impact by locating projects far from shore, will likely lead to Pacific floating wind projects regularly being sited in water exceeding 500 m depth. Technology concepts are sought to demonstrate mooring and anchors system designs that assess the following:

- Practical floating wind system depth limits
- Potential to exceed assumed practical limits (e.g., 1000 m maximum depth) for the Pacific coast and Hawaii
- Mooring line spread requirements—how they scale with depth for the California and Hawaii BOEM wind energy call areas, and how they can be optimized
- Optimized anchor designs and methods for installation in deep water and at sites prone to seismically induced soil liquefaction

Whether optimized for shallow regions or deep-water conditions, new mooring concepts should demonstrate feasibility using dynamic mooring analysis for major International Electrotechnical Commission (IEC) design load cases and system cost models. Concepts should also comply with upcoming recommended design, installation, and operations practices for floating systems in U.S. waters. Consideration will also be given to design concepts for any depth that minimize conflicts with existing offshore commercial and recreational activities and stakeholders, such as commercial fishing groups.

Mooring systems may include catenary spread moorings, tension leg moorings, or taut mooring systems, suitable for expected soil conditions or hybrid solutions. Proposed designs for optimized mooring systems may use novel line materials and configurations, potentially including components such as buoys, clump weights, and buoyant towers, with emphasis on components and installation methods that utilize U.S. suppliers and installers.

The global floating offshore wind supply chain is currently in its infancy; however, with the considerable expertise the U.S. already has through the oil and gas (O&G) sector, there is the opportunity for O&G suppliers to diversify to floating wind and become global offshore wind supply chain leaders. Furthermore, many of the proposed projects for this challenge will likely require some form of technical innovation. These projects will support the growth of the U.S. floating offshore wind supply chain by enabling domestic supply chain companies to benefit from these innovative mooring systems.

Example Project Types

The following list provides example project types that could address this challenge. This list is meant as a reference and not intended to be exclusive. All project proposals will be considered provided they contribute to the objectives of addressing this Challenge Area. All prospective proposals for this challenge are encouraged to seek inputs from, or partner with, a U.S. offshore wind substructure supplier or include an advisory group comprising of developers and/or substructure suppliers to ensure the direction of the project and outcomes can be commercially applied. Additionally, proposals should identify research and/or partners who have been working on this challenge to demonstrate that the research will further the overall state-of-the-art.

- New mooring designs to minimize cost and maximize performance for various platform types:
  - Designs optimized for use in shallow water
  - Designs and methods to automate/expedite anchor and mooring line installation, including hook up, as well as solutions for lowering O&M costs by facilitating easy disconnect and reconnect of the platform from the mooring system
  - Development and qualification of synthetic materials for applications specific to mooring systems
  - Tethering solutions incorporating springs, elastomers, and other specialized components for improved dynamic response within mooring systems
- Anchor designs for challenging seabed conditions (e.g., rock)
- Technical studies of fatigue mechanisms in floating wind mooring systems for improved understanding of conditions leading to failure and facilitation of future system optimization
- Development of loading, redundancy, and Operations & Maintenance (O&M) inspection concepts, strategies, and guidelines, appropriate to the offshore wind industry
- Assess the potential for fluid soil/structure interaction dynamics to impact the stability limits (including seismic conditions)
- Assessment of the potential impact of mooring lines and electric array cables on fishing activity
  - Possible mooring line and array cable design configurations that could reduce any identified potential impacts to fishing activity

4.4 Challenge Area 4: Power System Design and Innovation

Challenge Statement

Rapid deployment of offshore wind in the U.S. will create significant technical challenges for utilities, developers, regulators, and policymakers seeking to introduce offshore wind with minimal grid disruption at the lowest possible cost. Power system technology solutions are needed to lower individual project cost, reduce transmission losses, and enable aggregation strategies that address potential integration problems.

Objective

The main objective for this challenge is to reduce the cost and/or risk of bringing electricity to land from an offshore wind plant and distributing it to the grid. Uncertainty around interconnection can raise contingencies and finance costs as well as make the array cabling more expensive.

Background

Transmission infrastructure typically accounts for 10–20% of offshore wind capital expenditure, of which 8–12% typically accounts for the cost of cable supply and installation. Lessons learned from European offshore wind plants have shown that cable related incidents account for 80% of insurance claims and approximately 60% relate directly to cable damage during construction (Carbon Trust, 2018). Typically, the design of the offshore wind transmission infrastructure is influenced by several factors (NREL, 2014):

- Site characteristics; for example, distance to shore, water depths, and seabed geology
- Number and type of wind turbines and related construction and maintenance operations/ requirements
- Turbine spacing and cable configuration
- Reliability (dependent on many factors)
- Electrical line losses
- Location of substation platform(s)

The significant cost savings estimate of 5-6% of overall project cost can be achieved through advancements in transmission system design (NREL, 2014). These advancements may include the following:

- Innovative power system simulation software tools that can be used for electrical/cabling system design for both offshore and onshore applications
- Layout optimization assessment to minimize electrical losses
- Innovative or modified inter-array cable designs that are more cost efficient
- Innovative or modified export cable designs that are lighter and more cost efficient
- Medium Voltage Direct Current (MVDC) wind turbines that eliminate the need for turbine mounted transformers

The criticality of the transmission infrastructure in connecting the offshore wind plant to the land-based grid means there is great motivation for continued improvement and optimization to limit risks, reduce the levelized cost of energy and increase reliability.

It is considered that power system projects will financially enable the U.S. supply chain to develop innovative electrical infrastructure that would have otherwise been cost-prohibitive for them to design on their own. Projects will also provide a clear vision on where the industry is focusing its efforts, and therefore, what technical trends the supply chain and regulators should focus on for future offshore wind electrical system advancement. As most of the equipment is currently imported to the U.S., there is a considerable opportunity for tier 1 suppliers to develop U.S. supply lines.

Example Project Types

The following list provides example project types that could address this challenge. This list is meant as a reference and not intended to be exclusive. All project proposals will be considered provided they contribute to the objectives of addressing this Challenge Area. All prospective proposals for this challenge are encouraged to seek inputs from, or partner with an offshore wind developer or include an advisory group comprising of developers to ensure the direction of the project and outcomes can be commercially applied. Additionally, proposals should identify research and/or partners who have been working on this challenge to demonstrate that the research will further the overall state-of-the-art.

- Technical assessment of the most critical power system infrastructure barriers or enablers to developing offshore wind
- Innovative power system technologies/designs/architectures that lower individual project cost, reduce risks, reduce losses, or enable longer distance transmission through the application of new power conversion systems, cable technology, or array power system technology that are fully tested and compliant with U.S. standards.
    - Medium Voltage Direct Current (MVDC) dynamic cables
    - MVDC breakers
    - High-voltage array cables
- Technology solutions to reduce cost through the elimination of the offshore substation
- Technology advances that lower cost and increase U.S. market availability of both turbine-to-turbine array cables and array-to-shore export cables
- Assessment of existing onshore grid systems, future requirements, and the potential upgrades needed to ensure uptake of large amounts of offshore wind power.

5 Project Benefit Quantification

5.1 The Potential Impact on Levelized Cost of Energy

All proposals should provide an explanation of how the proposed project will impact the levelized cost of energy or component level cost reduction. Explanations should consider the overall positive effect on the cost of energy rather than focus on any one component of levelized cost of energy to the detriment of others. For example, a proposal that reduces capital cost may increase risk and negatively impact the ability to finance offshore wind development projects. Projects that seek to reduce the cost of energy by reducing health and safety risks should clearly describe and wherever possible quantify the direct and indirect positive effects of the project. A high-level levelized cost of energy methodology will be provided as part of the solicitation to standardize calculations.

5.2 How Can This Project Positively Impact the Supply Chain?

All proposals will be required to provide an explanation on how the proposed project could have a positive impact on advancing the U.S. offshore wind supply chain. It is understood that some projects may not have a direct impact on the U.S. supply chain, in this case a description of indirect impacts resulting from the proposed project is encouraged.

5.3 Commercialization Strategy

All proposals will be required to include an explanation (including a high-level plan) of foreseeable follow-on efforts that will be required to enable the commercial use of the results obtained from that project in offshore wind plants in the U.S. All proposals for an innovative or modified technology/ methodology are required to provide a commercialization plan that details the expected path to commercialization or how the innovation will enable commercialization, and the necessary milestones in achieving this. Although an award may support certain stages of commercialization, there should not be an expectation that consortium funding will support all stages required to reach commercialization. Any proposal for innovative designs, methods, or advanced systems must ensure they are compliant with U.S. regulations and best practices and may require further engineering effort and possibly tank testing, structural component tests, or offshore demonstrations to refine the concepts.

It is recognized that for some projects, considerable stakeholder engagement may be required to achieve the desired dissemination and utilization of results. Proposals will be encouraged to highlight where industry buy-in is needed, who the key stakeholders are, and provide a brief summary of how this industry integration could be achieved.

5.4 Timeframe for Applying the Results/Technology

All proposals will be encouraged to provide a Gantt Chart indicating the expected time frame to complete the project under consortium funding, and where relevant, the expected time frame to reach technology commercialization. This should include a high-level breakdown of the time required to undertake follow-on tasks to reach commercialization. It is recognized that the time frame to apply the results from a project depend on the type of project being proposed; however, the Consortium encourages proposals that maximize project outputs in a highly efficient timeframe, with the aim of achieving results that can be used by the U.S. offshore wind industry as quickly as possible.

6 References

Carbon Trust, Floating Wind Joint Industry Project, May 2018. Phase I Summary Report [ONLINE] Available at: https://www.carbontrust.com/media/675868/flw-jip-summaryreport-phase1.pdf. [Accessed 15 November 2018]

Carbon Trust, June 2015. Floating Offshore Wind: Market and Technology Review [ONLINE] Available at: https://www.carbontrust.com/media/670664/floating-offshore-wind-market-technology-review.pdf. [Accessed 15 November 2018]

Carbon Trust, Offshore Wind Accelerator, 2018. Cable Installation. [ONLINE] Available at: https://www.carbontrust.com/offshore-wind/owa/cables/. [Accessed 15 November 2018]

Carbon Trust, Offshore Wind Accelerator, 2018. Electrical Systems. [ONLINE] Available at: https://www.carbontrust.com/offshore-wind/owa/electrical/. [Accessed 15 November 2018]

Carbon Trust, 2017. Wind Farm Control Trials. [ONLINE] Available at: https://www.carbontrust.com/offshore-wind/owa/demonstration/wfct/. [Accessed 11 November 2018]

Department of Energy, Atmosphere to Electrons [ONLINE] Available at https://a2e.energy.gov/. [Accessed 29 November 2018]

Department of Energy, Atmosphere to Electrons, 2016. Wake Steering Experiment. [ONLINE] Available at https://a2e.energy.gov/projects/wake. [Accessed 22 November 2018]

ECN, Far and Large Offshore Wind (FLOW) program, 2014. Wind Farm Wake Modelling, Fatigue Loads and Control. [ONLINE] Available at: http://www.flow-offshore.nl/page/wind-farm-wake-modelling-fatigue-loads-and-control. [Accessed 11 November 2018]

European Commission, FP7 Cluster Design, 2017. A tool box for offshore wind farm cluster designs. [ONLINE] Available at: https://cordis.europa.eu/result/rcn/189357_en.html. Accessed 11 November 2018]

Golightly, Chris, Future Offshore Foundations (conference paper), November 2017, Anchoring & Mooring for Floating Offshore Wind. [ONLINE] Available at: https://www.researchgate.net/profile/Chris_Golightly/publication/321011241_Anchoring_Mooring_for_Floating_Offshore_Wind_Brussels_8th_November_2017/links/5a072405aca272ed279e52e5/Anchoring-Mooring-for-Floating-Offshore-Wind-Brussels-8th-November-2017.pdf. [Accessed 15 November 2018]

Hsu, Wei-ting, et al, Marine Structures, Vol. 55, Sep 2017. [ONLINE] Available at: https://www.sciencedirect.com/science/article/pii/S0951833917300886?via%3Dihub. [Accessed 15 November 2018]

National Offshore Wind Research and Development Consortium, 2018. Research and Development Roadmap, Initial Release Version 1.0. [ONLINE] Available at: nyserda.ny.gov/osw-consortium-roadmap. [Accessed 30 November 2018]

National Renewable Energy Laboratory, 2015. Software Models Performance of Wind Plants. [ONLINE] Available at: https://www.nrel.gov/docs/fy15osti/63378.pdf. [Accessed 11 November 2018]

National Renewable Energy Laboratory, 2017. Enabling the SMART Wind Power Plant of the Future Through Science-Based Innovation [ONLINE] Available at: https://www.nrel.gov/docs/fy17osti/68123.pdf. [Accessed 22 November 2018]

National Renewable Energy Laboratory, 2014. Offshore Wind Plant Electrical Systems. [ONLINE] Available at: https://www.boem.gov/NREL-Offshore-Wind-Plant-Electrical-Systems/ [Accessed 15 November 2018]

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, 2017. U.S. Conditions Drive Innovation in Offshore Wind Foundations. [ONLINE] Available at: https://www.energy.gov/eere/articles/us-conditions-drive-innovation-offshore-wind-foundations. [Accessed 12 November 2018]

Wind Power Engineering & Development, 2018. U.S. offshore wind industry needs improved foundations. [ONLINE] Available at: https://www.windpowerengineering.com/projects/offshore-wind/u-s-offshore-wind-industry-needs-improved-foundations/. [Accessed 12 November 2018]