## Offshore Wind Planning in the New York Bight:

# Technology Assessment and Cost Considerations Study


NEW YORK STATE

NYSERDA
New York State Energy Research and Development Authority

NYSERDA Report 25-13
February 2025

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# Offshore Wind Planning in the New York Bight: Technology Assessment and Cost Considerations Study

***Final Report***

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# Notice



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# Abstract

This study assesses the technology readiness and cost landscape for deepwater offshore wind (OSW) from 60 to 3,000-meter water depths in the Area of Analysis (AoA) across the New York Bight. As water depths increase, OSW projects will require a different set of foundation and electrical system designs. These step changes in technology track the evolution of the OSW industry globally, with deeper water technologies requiring additional industry innovation and local infrastructure. This conclusion is highlighted by the jump from the upper limits of fixed-bottom foundations to floating OSW, the market for which is less mature and typically places greater demands on port infrastructure, such as, deeper berths, higher bridge clearances, and greater water draughts. These new infrastructure requirements present an opportunity for local investment. But the technology and local infrastructure for the upper limits of fixed-bottom is more advanced overall, which may favor this approach. This study also presents a cost comparison of three representative cost cases across the AoA, linked to the step-changes in technology as water depth increases. The results of this cost analysis show a 15 to 30 percent increase in capital expenditure, operations expenditures, and levelized cost of energy from the initial fixed bottom cost case to the two floating projects, one at modest depths 100 to 200 meters deep and another in ultra-deep waters over 2,000 meters deep. For each cost metric, at the upper limits of fixed-bottom OSW emerges as the most cost-effective technology due to its shallower depths and shorter port and transmission distances as compared with the other two cases in much deeper water and significantly further out to sea.

# Keywords

Floating offshore wind, offshore wind turbines, capital expenditure (CapEx), operations expenditures (OpEx), fixed bottom offshore wind, steel jacket foundations, offshore wind supply chain, steel floating semi-submersible foundations, anchors and moorings, array and export cables, dynamic cables, offshore wind port infrastructure, area of analysis (AoA), outer continental shelf, technology readiness, marine construction vessels

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# Acronyms and Abbreviations

| | |
|---|---|
| AHTSV | Anchor Handling Tug Supply Vessel |
| AoA | Area of Analysis |
| BOEM | Bureau of Ocean Energy Management |
| CapEx | Capital Expenditure |
| COD | Commercial Operation Date |
| CTV | Crew Transfer Vessel |
| DevEx | Development Expenditure |
| FOSW | Floating Offshore Wind |
| GIS | Geographic Information System |
| GW | Gigawatt(s) |
| ha | hectare |
| HVAC | High-Voltage Alternating Current |
| HVDC | High-Voltage Direct Current |
| IAC | Inter-Array Cable |
| IP | Intellectual Property |
| IRA | Inflation Reduction Act |
| IRS | Internal Revenue Service |
| ITC | Investment Tax Credit |
| km | kilometer(s) |
| kV | kilovolt(s) |

| | |
|---|---|
| LCOE | Levelized Cost of Energy |
| LiDAR | Light Detection and Ranging |
| Master Plan | New York State Offshore Wind Master Plan |
| MW | Megawatt(s) |
| nm | nautical mile(s) |
| NYSERDA | New York State Energy Research and Development Authority |
| O&G | Oil and Gas |
| O&M | Operations and Maintenance |
| OCS | Outer Continental Shelf |
| OCSLA | Outer Continental Shelf Lands Act |
| OCV | Offshore Construction Vessel |
| OEM | Original Equipment Manufacturer |
| OpEx | Operations Expenditure |
| OSW | Offshore Wind |
| POI | Point of Interconnection |
| PSV | Platform Supply Vessel |
| R&D | Research and Development |
| RCG | The Renewables Consulting Group |
| SOV | Service Operation Vessel |
| $t/m^2$ | tons per square meter |
| TRL | Technology Readiness Level |
| TWG | Technical Working Group |
| U.S. | United States |
| WEA | Wind Energy Area |
| WTG | Wind Turbine Generator |
| WTIV | Wind Turbine Installation Vessel |

# Summary

## S.1 Scope of Work

The scope of work for this study is divided into two tasks, a market overview and a cost assessment.

## S.2 Market Overview

In this section of the study, The Renewables Consulting Group (RCG) provides an overview of the deepwater wind market, inclusive of installation and construction techniques. Specific topics include:

- Assessment of the technological readiness of each deepwater offshore wind (OSW) component. This effort focuses on components with unique supply chain considerations for deepwater OSW and notes which equipment can directly leverage technology and supply chains from the current fixed-bottom market.
- Outline of the physical and logistic requirements or constraints for assembly and marshalling facilities. This includes a high-level summary of the range of project design and construction strategies for floating wind and the implications for onshore infrastructure needs.
- Highlighting the key component localization gaps to identify what infrastructure is required from the local regional supply chain. This high-level analysis assesses the key needs and opportunities for different deepwater wind technologies. It does not assess the specific capabilities of New York State facilities to support deepwater, fixed-bottom, or floating offshore wind (FOSW).

### S.2.1 Cost Assessment

RCG has conducted a high-level cost assessment to stress-test the sensitivity of project costs to water depth and distance to shore. To do so, RCG and New York State Energy Research and Development Authority (NYSERDA) have agreed on three representative project cost cases (listed in Table S-1) to capture the spectrum of project designs and locations possible across the Area of Analysis (AoA).

This assessment provides a baseline cost forecast to assess these three cost cases. Numerical results are supplemented with discussion of the key cost drivers, including an outline of whether the primary concern for each OSW component is distance or depth, and commentary on the drivers of cost premiums as depth and distance increase.

This report assesses the technology readiness and cost landscape for deepwater OSW from 60 to 3,000-meter water depths across the New York Bight.

**Table S-1. Market Overview Summary**

| | Key Additional Needs from Current Fixed-Bottom Market | |
|---|---|---|
| | **Required Technology and Market Developments** | **Gaps in Essential Local Infrastructure** |
| **Upper Limits of Fixed-Bottom** | • Jacket foundation supply chain | • NA |
| **Sub-500-meter Floating Wind** | • Dynamic cables<br>• Floating substructure design and construction<br>• Major component operations and maintenance (O&M)<br>• For sites with floating substation foundations: floating substations | • Floating wind marshalling and O&M port |
| **Ultra-deep Floating Wind** | • Dynamic cables<br>• Floating substructure design and construction<br>• Floating substations<br>• Major component O&M<br>• Cost-effective marine operations | • Floating wind marshalling and O&M port |

This study assesses some of the key market considerations for deepwater OSW, in order to highlight the key challenges and opportunities of OSW development from 60 to 3,000 meters. As water depths increase, OSW projects will require a different set of foundation and electrical system designs.

These step-changes in technology track the evolution of the OSW industry globally, with deepwater technologies requiring additional industry innovation and local infrastructure. This conclusion is highlighted by the jump from the upper limits of fixed-bottom foundations to FOSW. FOSW is a less mature market and typically requires higher specifications for port infrastructure (e.g., bridge clearance, water draughts).

The additional innovation and local infrastructure requirements, above the current fixed-bottom market, presents an opportunity for local investment. But the technology and local infrastructure for the upper limits of fixed-bottom OSW is more advanced overall.

**Table S-2. Cost Summary**

| | Cost Case 1: Upper Limits of Fixed-Bottom | Cost Case 2: Sub-500 meter Floating Wind | Cost Case 3: Ultra-deep Floating Wind |
|---|---|---|---|
| **Cost Rank (1 =lowest cost)** | 1 | 2 | 3 |
| **Nameplate Capacity (megawatts [MW])** | 1,360 | 1,360 | 1,360 |
| **Commercial Operation Date Year** | 2035 | 2035 | 2035 |
| **Export Route Length (kilometers [km])** | 198 | 210 | 290 |
| **Site Depth (meters)** | 60—70 | 100—200 | ~2000 |
| **Estimated Capital Expenditure** | $4.10 m/MW | $4.90 m/MW | $5.59 m/MW |
| **Annual Avg Technical Operations Expenditures** | $0.043 m/MW | $0.049 m/MW | $0.051 m/MW |

This study presents a cost comparison of three representative project [1]cost cases across the AoA, linked to the step-changes in technology as depth increases. These results are meant to compare the three cost cases on an all-else-equal basis. Cost cases assume a more specific depth range than the technology concepts in order to best capture the range found across an actual project site, and due to the greater specificity needed to build up a cost model. To accomplish this, the nameplate capacity, wind turbine generator (WTG) size, and Commercial Operation Date (COD) year are kept constant.

The results of this cost analysis (see Table S-2) show a 15 to 30% increase in capital expenditure (CapEx), operations expenditures (OpEx), and levelized cost of energy (LCOE) from cost case 1 to ost case 3. For each cost metric, cost case 1 emerges as the most cost-effective technology due to its shallower depths and shorter port and transmission distances. Overall, there is a similar order of magnitude increase in costs from case 1 to case 2 and from case 2 to case 3.

Notably, these results are pre-Inflation Reduction Act (IRA) subsidies and exclude some potential cost considerations such as port upgrades, supply chain development, interconnection costs, and United States Bureau of Ocean Energy Management (BOEM) auction payments.

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[1] The selection of these representative cases is solely for illustrative purposes and should not be construed as preference for these cases over other *possible* alternatives.

# 1 Introduction

In 2019, New York's historic Climate Leadership and Community Protection Act (Climate Act) was signed into law, requiring the State to achieve 100% zero-emission electricity by 2040 and to reduce greenhouse gas emissions 85% below 1990 levels by 2050. The law specifically mandates the development of 9,000 megawatts (MW) of offshore wind energy by 2035, building upon its previous goal of 2,400 MW of offshore wind energy by 2030. The New York State Energy Research and Development Authority (NYSERDA) is charged with advancing these goals.

For more than a decade, New York State has been conducting research, analysis, and outreach to evaluate the potential for offshore wind (OSW) energy. The New York State Energy and Research Development Authority (NYSERDA) led the development of the New York State Offshore Wind Master Plan (Master Plan), a comprehensive roadmap and suite of more than 20 studies for the first 2,400 megawatts (MW) of OSW energy. The Master Plan encourages the development of OSW in a manner that is sensitive to environmental, maritime, economic, and social issues, while addressing market barriers and aiming to lower costs. The Master Plan included spatial studies to inform siting of offshore wind energy areas. Now, NYSERDA is undertaking new spatial studies to review the feasible potential for deepwater OSW, at or exceeding depths of 60 meters in the New York Bight.

Planning processes considering the development of offshore wind in the deepwater areas examined in each of NYSERDA's spatial studies must consider these studies in the context of one another. Decision making must additionally consider different stakeholders and uses and will require further adjusted approaches and offshore wind technologies to ensure the best outcome. Globally, deepwater wind technology is less mature and primarily concentrated on floating designs at the depth ranges being assessed through these spatial studies, while deepwater fixed-bottom foundations are at their upper technical limit within the Area of Analysis (AoA). Therefore, floating designs were predominantly considered since most, if not all, of the AoA would likely feature floating offshore wind (FOSW). NYSERDA, along with other state and federal agencies, is developing research and analysis necessary to take advantage of opportunities afforded by deepwater OSW energy by assessing available and emerging technologies and characterizing the cost drivers, benefits, and risks of FOSW. Findings from these studies and available datasets will be used to support the identification of areas that present the greatest opportunities and least risk for siting deepwater OSW projects.

## 1.1 Benefits and Cost-Reduction Pathways

The Master Plan analysis concluded that OSW development will enhance the State's job market, supply chain, and economy; reduce the use of fossil fuels; and provide other public health, environmental, and societal benefits. While the State plans to continue procuring offshore wind projects within the existing lease areas, the timing is right to build a better understanding of the opportunities and challenges of projects farther offshore. Cost is a critical consideration for the State in the development of offshore wind. Discussions of costs and cost-reducing strategies focusing on State options for contracting related to deepwater OSW, job-training programs, and infrastructure investments will also be developed as part of future planning efforts.

Offshore wind energy development is being introduced into a highly dynamic and human-influenced system. These reports seek to better understand the potential interaction of offshore wind development and marine wildlife and habitats; however, it is important to consider these within the broader context of climate change and existing land-based and marine activities. The State will continue to conduct research through its established Technical Working Groups (TWGs) concerning the key subjects of fishing, maritime commerce, the environment, environmental justice, jobs, and the supply chain. These TWGs were designed to inject expert views and the most recent information into decision making.

Taken together, the information assembled in these spatial studies will provide an unparalleled level of data collection, analysis, public input, and strategic forethought that will empower New York State and its partners to take the informed steps needed to capitalize on the unique opportunity presented by OSW energy.

### 1.1.1 Spatial Studies to Inform Lease Siting

- Benthic Habitat Study
- Birds and Bats Study
- Deepwater Wind Technologies – Technical Concepts Study
- Environmental Sensitivity Analysis
- Fish and Fisheries Data Aggregation Study
- Marine Mammals and Sea Turtles Study
- Maritime Assessment – Commercial and Recreational Uses Study
- Offshore Wind Resource Assessment Study Zones 1 and 3
- Technology Assessment and Cost Considerations Study

Each of the studies was prepared in support of a larger planning effort and shared with relevant experts and stakeholders for feedback. The State addressed comments and incorporated feedback received into the studies. Feedback from these diverse groups helps to strengthen the studies and also helps ensure that these work products will have broader applicability and a comprehensive view.

Please note that assumptions have been made to estimate OSW potential and impacts in various methodologies across the studies. NYSERDA does not necessarily endorse any underlying assumptions in the studies regarding technology and geography, including but not limited to turbine location, turbine layout, project capacity, foundation type, and point of interconnection (POI).

The Energy Policy Act of 2005 amended Section 8 of the Outer Continental Shelf Lands Act (OCSLA) to give BOEM the authority to identify OSW development sites within the Outer Continental Shelf (OCS) and to issue leases on the OCS for activities that are not otherwise authorized by the OCSLA, including wind development. The State recognizes that all development in the OCS is subject to review processes and decision-making by BOEM and other federal and State agencies. This collection of spatial studies is not intended to replace the BOEM WEA identification process and does not commit the State or any other agency or entity to any specific course of action with respect to OSW energy development. Rather, the State's intent is to facilitate the principled planning of future offshore development off the New York coast, provide a resource for the various stakeholders, and encourage the achievement of the State's OSW energy goals.

### 1.1.2 Scope of Study

The spatial studies will evaluate potential areas for deepwater OSW development within a specific geographic AoA of approximately 35,670 square miles of ocean area extending from the coast of Cape Cod south to the southern end of New Jersey. It includes three zones extending outward from the 60-meter depth contour, which ranges between 15 and 50 nautical miles (nm) from shore to the 3,000-meter contour, which ranges from 140 to 160 nm from shore. See Figure 1.

The eastern edge of the AoA avoids Nantucket Shoals and portions of Georges Bank, since those areas are well known to be biologically and ecologically important for fish and wildlife, fisheries, and maritime activity. The AoA does include areas such as the Hudson Canyon, which is under consideration to be designated as a National Marine Sanctuary and thus unlikely to be suitable for BOEM site leases.

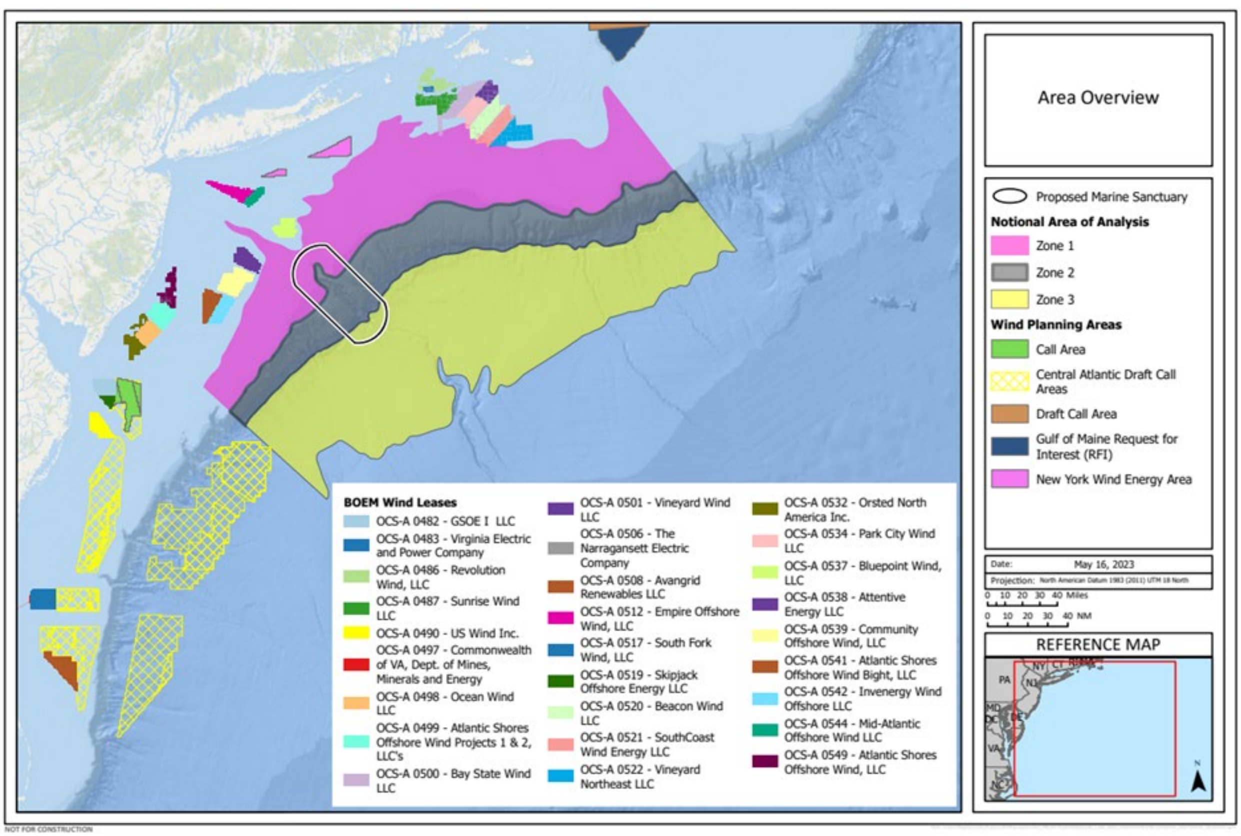
While OSW infrastructure will not be built across the entire AoA, the spatial studies analyze this broad expanse to provide a regional context for these resources and ocean uses.

- Zone 1 is closest to shore and includes a portion of the OCS. It extends from the 60-meter contour out to the continental shelf break [60 meters (197 feet) to 150 meters (492 feet) deep]. Zone 1 is approximately 12,040 square miles.
- Zone 2 spans the steeply sloped continental shelf break, with unique canyon geology and habitats [150 meters (492 feet) to 2,000 meters (6,561 feet) deep]. Zone 2 is approximately 6,830 square miles.
- Zone 3 extends from the continental shelf break out to 3,000 meters (9,842 feet) depth. Zone 3 is approximately 16,800 square miles.

Zone 2, stretching across the steeply sloped continental shelf break with its distinctive canyon geology and unique habitats, is unlikely to host OSW turbines, but is still likely to be impacted by OSW development activities through maritime traffic and/or cabling and was therefore included in this study.

**Figure 1. Northeast Offshore Wind Projects, Planning Areas, and Area of Analysis Considered**

*Source: NYSERDA*



# 2 Technology Assessment and Cost Consideration Introduction

## 2.1 Technology Tranches

This section provides information on the three technology cases used to frame the market overview. The three cost cases introduced in the Executive Summary and assessed later in the report are representative projects informed by the three technology tranches detailed below.

### 2.1.1 Overview

For the Market Overview section of this report (Section 3), the AoA has been subdivided into three technology tranches ("concepts") to provide commentary on the technology readiness of OSW across the range of depth zones. Information on these concepts is provided in Table 1.

By nature, these three concepts can occur in overlapping depth ranges. For the sake of clarity, these concepts have been specified into distinct ranges, but the exact cutoff points and overlaps between technologies will depend on location-specific site conditions, the evolution of the market, and development preferences and priorities.

**Table 1. Technology Tranches**

| | Concept 1: Upper Limits of Fixed-Bottom | Concept 2: Sub-500-meter Floating Wind | Concept 3: Ultra-deep Floating Wind |
|---|---|---|---|
| **Depth Range (m)** | 60—70 | 70—500 | 500+ |
| **AoA Zone** | Zone 1 | Part of Zone 1 and Part of Zone 2 | Part of Zone 2 and Part of Zone 3 |
| **Foundation Concept** | Fixed-bottom | Floating | Floating |
| **Substation Foundation** | Fixed-bottom | Fixed-bottom up to ~150 meters | Floating |
| **Array Cables** | Traditional static | Partially dynamic | Fully dynamic (no bottom contact) |

### 2.1.2 Base-Case Definitions for Cost Analysis

A set of key inputs is required to begin the cost analysis and frame the market commentary.

- For the Cost Assessment Section of this report (section 4), the three concepts have been further refined into three specific cost cases as shown in Table 2.
- This refinement is necessary to specify the precise project-design basis assumed for the cost analysis (e.g., fixed-bottom versus floating substation foundations). These cost cases therefore serve as representative project cases for each technology tranche for comparison of the cost implications of depth and distance to shore. Further explanation of the three cost cases is included in section 4.1.
- These baseline modeling assumptions are considered reasonable, early-stage assumptions; physical characteristics of the site such as depth and distance are derived from the AoA zone, while technological characteristics such as project size and foundation concept are derived from global industry trends and technical conditions at the target depth ranges. However, further site assessment, planning, and engineering studies are required in order to finalize what design choices and site locations are most feasible and cost-effective across the AoA.

**Table 2. Key Suggested Inputs: Cost Model Assumptions**

| | Cost Case 1 | Cost Case 2 | Cost Case 3 |
|---|---|---|---|
| **Turbine Size** | 20 MW, 275-meter rotor diameter | | |
| **Project Size** | 68 WTGs, 1,360 MW total | | |
| **Commercial Operation Date (COD) Year** | COD 2035 | | |
| **Marshalling Port Distance (nm)** | 100 | 110 | 150 |
| **Export Cable Route Offshore/Onshore (km)** | 185/15 | 200/15 | 280/15 |
| **Depth Range (meters)** | 60–70 | 100–200 | ~2000 |
| **AoA Zone** | Zone 1 | Zone 1/Zone 2 | Zone 3 |
| **Foundation Concept** | Steel jackets with pin-piles | Steel floating semi-sub | Steel floating semi-sub |
| **Substation Foundation** | Fixed-bottom | Fixed-bottom | Floating |
| **Array Cables** | Traditional static | Partially dynamic | Fully dynamic |
| **Mooring Spread** | NA | 6x Catenary | 6x Semi-taut |
| **Anchor Concept** | NA | Drag-embedded | Suction buckets |

# 3 Market Overview

## 3.1 Technology Readiness

### 3.1.1 Introduction

Three technology concepts, discussed in section 2.1, frame the market commentary provided below.

#### *3.1.1.1 Overview*

The purpose of this section is to assess the readiness of the OSW market to build out the various depth grades found across the AoA; therefore, the AoA has been subdivided into three technology concepts (see Table 1) to help structure the market overview section of this report.

#### *3.1.1.2 Defining "Readiness"*

All readiness scores are rated relative to standard fixed-bottom OSW (e.g., current active developments on the East Coast).

A green rating means that there are minimal additional readiness risks relative to current fixed-bottom development—not that there are no risks overall. While general risks exist, no significant new risks are identified that would impede the readiness of the technology. This is typically associated with factors that are well understood and can be managed using established practices. For example, onshore infrastructure will be the same, so there are no added readiness risks to identify even though challenges with interconnection may remain a key consideration.

In addition to a green rating, there are yellow and red ratings indicating moderate to high risks. A yellow rating reflects a moderate risk level, pointing to some additional readiness risks that are more substantial than those associated with a green rating but not as critical as a red rating. These risks may require careful planning, additional resources, or specific expertise to manage, but they do not fundamentally threaten the feasibility of the technology. They represent challenges that can be mitigated with appropriate measures.

A red rating is assigned to high-risk levels, signifying that there are significant additional readiness risks that pose a serious challenge to the development. These are often complex, high-impact issues that may lack straightforward solutions and could significantly delay or increase the cost of the technology. Red ratings demand extensive attention and resources to address and often involve uncertainties that are difficult to quantify or mitigate.

### 3.1.2 Floating versus Fixed-Bottom Offshore Wind

#### *3.1.2.1 Similarities with Existing Industries*

**Leveraging Fixed-Bottom OSW**

Floating wind leverages the fixed-bottom OSW industry for most elements of the wind farm, such as the wind turbine generators (WTGs), most of the electrical equipment, some sections of the array and export cables, all onshore infrastructure, and the scheduled maintenance equipment. Desk-based assessments undertaken by engineering and environmental professionals are also relatively similar, with wind resource, wave climate assessment, and soil investigations roughly matching what developers currently perform for fixed-bottom project development.

Some floating foundation concepts also present commonalities with current bottom fixed-bottom foundation design, such as circular columns or tubular bracings. If not exactly similar, these components can often be manufactured by the same supply chain.

Floating wind structures primarily differ from fixed-bottom in the substructure and foundation. While fixed-bottom foundation turbines use monopiles or jacket foundations driven into the seabed, floating turbines have floating or hull substructures attached to mooring lines that are anchored to the seabed. Furthermore, while fixed-bottom OSW farms can use static array cables that are fixed to the seabed, floating farms must use dynamic cables to accommodate the movements of the turbine in the ocean. This also means that installation processes are different; while fixed-bottom foundations are typically prefabricated, lowered to the seabed with a crane, and then installed, floating foundations are typically constructed at the port and towed to the site before being connected to mooring lines.

**Building on Floating Oil and Gas**

The floating nature of floating wind technology leverages the extensive experience from the oil and gas (O&G) industry, with more than 390 floating installations currently in service globally[2] (as of 2022), as well as knowledge from the marine sector for the design and fabrication of the floating substructures.

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[2] Floating Production Systems Report and Online Database, 2018.

O&G industry experience is key for anchor, mooring, and substructure design, although the need to serialize design, production, installation, and the thinner margins of the electricity market lead to different design priorities for floating wind.

#### *3.1.2.2 Key Technical Differences from Fixed-Bottom Foundations*

**Mobile Substructures**

Floating structures are decoupled from the seabed, meaning that the turbine-foundation structure moves together according to its combined characteristics. This requires a more complex design environment whereby the complete unit WTG, tower, substructure, mooring and anchors, power cables) must be modelled using an integrated approach.

The differences in foundation design also results in major changes to the supply and fabrication of these elements. While floating foundations may see extensive serial fabrication, the size and technical specifications (e.g., quay size) of the facilities required to deploy commercial-scale floating projects is often a limiting factor.

Decoupling from the seabed allows floating projects to be less dependent on seabed conditions, given that anchors for mooring systems require smaller loads than fixed-bottom foundations. That said, the multiple anchor points per foundation mean that added costs for challenging conditions are multiplied across three to six times the number of installations per WTG for floating wind.

**Dynamic Cables**

Cable designs for FOSW must allow for foundation movements (particularly heave and vertical movement), and they will be exposed to the wave and current loading without being protected by J-tubes or cable burial below the seabed. Depending on-site depth, dynamic cables may be needed for some or all array cable lengths. Only the last few kilometers (km) of export cables connecting to the substation are anticipated to need dynamic capabilities.

Dynamic cabling has been deployed at array-voltage on floating projects. There are currently no dynamically rated export cables available commercially, though they are under development. This introduces uncertainties in transmission design for the first commercial-scale projects, particularly given that the expected market for such cables may be relatively small (because only the last section of each transmission cable will be dynamic).

**Unique Marine Operations**

Floating installation differs substantially from fixed-bottom OSW. Floating wind allows and requires many operations to be run at port or in sheltered areas, usually without expensive installation vessels. This, in turn, requires the transportation of the complete assembly (including the WTG) and the mooring and array cables to be in place before the floating foundation is transported offshore. Accordingly, turbine and other costs may fall earlier in the capital expenditure (CapEx) schedule, given that they are needed earlier in the construction regime.

Burial operations in deep waters are not expected to cause increased challenges compared to current burial methods used in fixed-bottom OSW. Minor upgrades to existing tools are likely required. Still, the history of interconnectors installed up to 1,600 meters deep in Europe provides confidence that depth is unlikely to be a significant risk to floating wind deployment.

Finally, heavy component maintenance strategies are yet to be fully developed since the current approach for fixed-bottom foundations—repairs and component exchanges using jack-up vessels—is not an option for floating wind projects.

### 3.1.3 Floating Foundations: Floating Concept Development Stages

The arc for technology readiness level (TRL) is used to describe the status of different FOSW foundation designs as shown in Table 3 and Figure 2. Only a handful of foundation designs are on a path toward gigawatt-scale commercial readiness by 2030.

#### *3.1.3.1 Defining Technology Readiness Level*

TRL scoring is a method for estimating technology maturity as it progresses from research and development (R&D) to commercial maturity. The Renewables Consulting Group (RCG) has refined its own TRL scoring framework to evaluate the commercial readiness of the 100+ floating wind foundation designs globally.

Each foundation concept is scored based on its most advanced deployment to date. For example, a foundation design that has been proven with a deployed project of five 6 MW WTGs (30 MW total) would achieve a TRL 8 score based on the criteria above. Only designs at a TRL 9 score are ready for deployment on a gigawatt-scale wind farm. Two designs have achieved a TRL 9 to date, with five others developing projects to reach this milestone this decade.

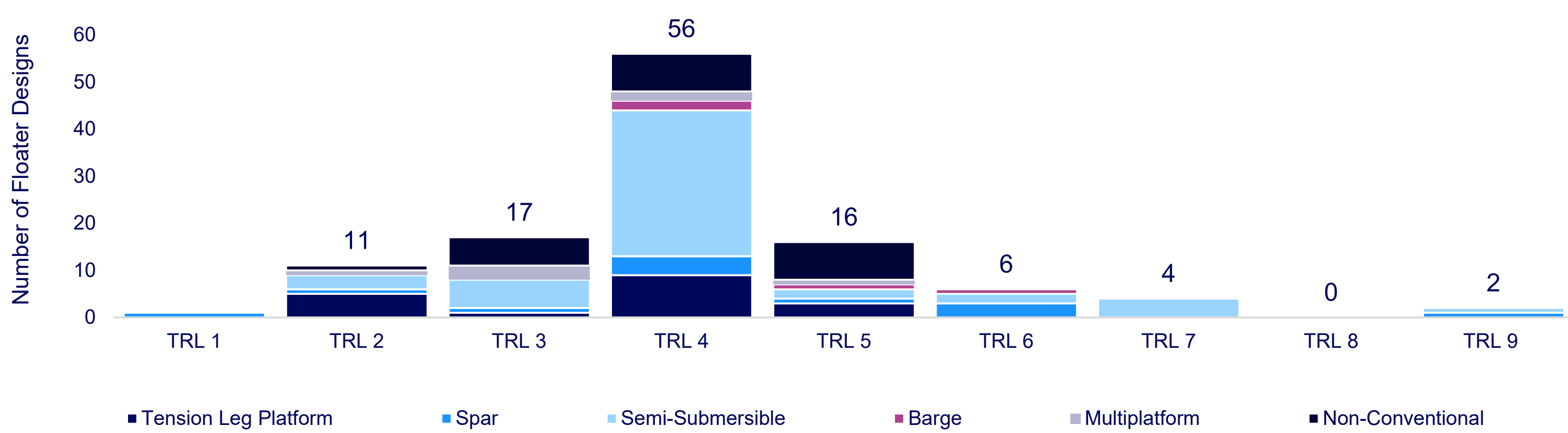
**Table 3. Defining Technology Readiness Level for Floating Wind.**

| TRL | TRL 1 | TRL 2 | TRL 3 | TRL 4 | TRL 5 | TRL 6 | TRL 7 | TRL 8 | TRL 9 |
|---|---|---|---|---|---|---|---|---|---|
| Generic Definition[1] | Basic research | | Applied Research & Development | | | Demonstration | | Pre-commercial deployment | |
| | Basic Research | Applied Research | Critical Function or Proof of Concept Established | Laboratory Testing/ Validation of Component(s) / Process(es) | Integrated/ Semi-Integrated System Testing in Realistic Environment | Prototype System Verified | Integrated Pilot System Demonstrated | System Incorporated in Commercial Design | System Proven and Ready for Full Commercial Deployment |
| Floating Wind Interpretation[2] | Initial concept | Proof of concept | Numerical modeling | Tank testing | Scaled testing | 1-5 MW Demo | >5 MW Demo | Pilot array (<50 MW) | Pre-commercial (50-200 MW) |

[1] UK Government definitions (2021) Floating Offshore Wind Demonstration Programme guidance notes.

[2] RCG's definition used to support foundation concept evaluation and selection.

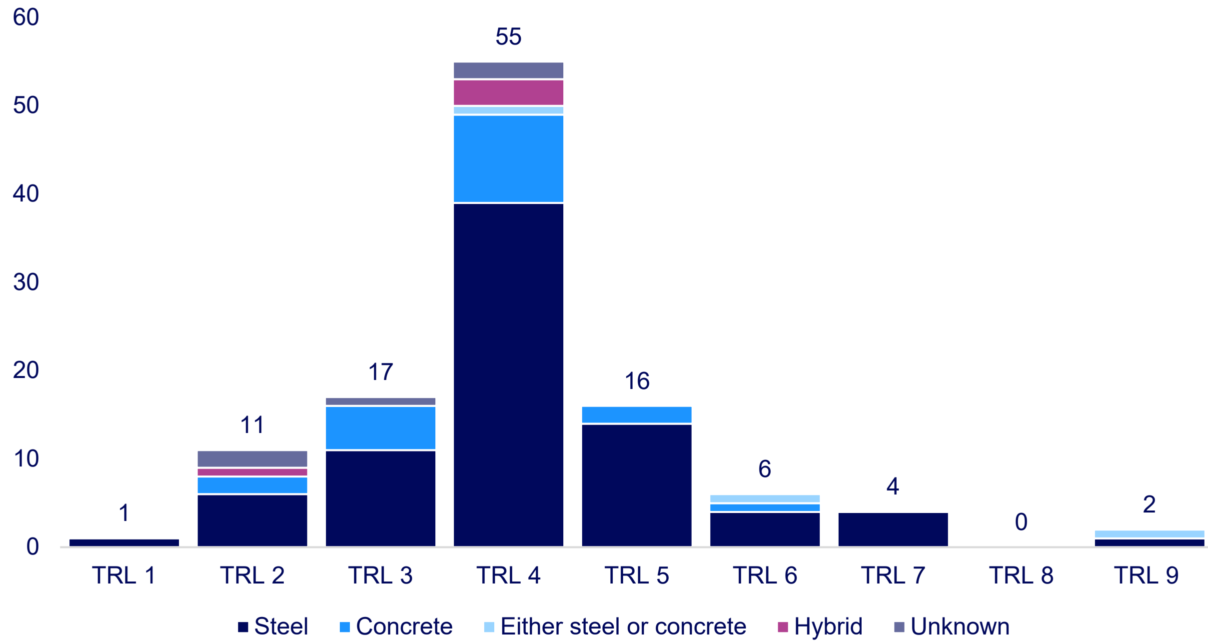
**Figure 2. Floater Concepts by Current Technology Readiness Level**



### 3.1.4 Floating Concept Development Stages

Floating wind foundation concepts are still not ready for commercial scale, with only two deployed in pre-commercial projects to date as shown in Figure 3.

**Figure 3. Floater Concepts by Foundation Material**




#### *3.1.4.1 Conclusions*

- Floating wind foundation concepts as a whole are still working toward commercial readiness. Only two have been deployed at pre-commercial scale to date, with ten additional designs deployed at demonstration-scale. This results in 12 total design options at a TRL-6 or higher.
- As shown in the Figure 3, most floater designs in development use steel as their primary material. Three of the 12 TRL-6 or higher concepts can be constructed with concrete, but steel foundations are considered the most typical for the market today.
- Steel foundation concepts tend to offer greater modularity and a wider range of design options, as well as more transferrable skills from existing wind manufacturing (both offshore and onshore). Concrete foundation concepts are typically larger structures that can be difficult to transport. Concrete can be advantageous in regions with strong existing marine concrete infrastructure, but elsewhere steel is typically preferred due to the high cost of concrete construction and transportation outside of those regions.

- Not all of the concepts under development are designed to be a good fit for New York State's geography. For example, some spar concepts may require deep drafts at port (e.g., 100+ meters) that can only be found in regions with fjords or other deep protected waters. Four of the 12 total concepts that have reached demo scale use a spar concept, but innovation in spar design and construction may unlock this technology for a wider range of geographies.

### 3.1.5 Wind Turbine Generators

The floating wind market can draw directly from fixed-bottom turbine technology, but growing demand and challenging contractual interfaces put upward pressure on turbine supply costs for floating wind projects. Technology readiness of WTGs for the three concepts described in section 2.1 is provided in Figure 4.

#### *3.1.5.1 Technology Readiness*

- Turbine technology will remain fundamentally similar to fixed-bottom OSW. However, floating structures are decoupled from the seabed, meaning that the turbine-foundation structure moves together according to its combined characteristics.
- Floating foundations require a more complex design environment whereby the coupled unit (WTG, tower, substructure, mooring and anchors, power cables) must be modeled using an integrated approach—an Integrated Load Analysis. Software packages are commercially available to run this design work; however, WTG suppliers are not normally willing to provide controller details, due to sensitivity of sharing sensitive intellectual property (IP). The lack of IP sharing (notably the controller) drives complexities in the coupled engineering design and requires significant effort in the interface management between contractual parties. The coupled design also requires more effort from turbine suppliers at an earlier stage in the development.
- Given these motions, floating turbines are expected to require some small modifications such as stiffer towers and modifications to control systems. To monitor the performance of the wind turbine, WTG original equipment manufacturers (OEMs) and developers are aiming to use Light Detection and Ranging (LiDAR) systems installed at the nacelle to measure wind conditions more extensively. RCG understands that this is the best practice deployed in previous floating wind pilot projects allowing developers to secure funds.
- Given what is expected to be a low-cost impact and high degree of engineering complexity, RCG has not differentiated costs between foundation concepts or between the lease areas' site conditions. Some cost differences are expected, although these are anticipated to have minimal impact on LCOE.

**Figure 4. Technology Readiness for Wind Turbine Generators**

| | Concept 1 | Concept 2 | Concept 3 |
|---|---|---|---|
| | Upper Limits of Fixed Bottom | Sub-500 meter Floating Wind | Ultra-deep Floating Wind |
| Technology Readiness | *Analogous to current fixed bottom market* | *Coupled design and contracting interfaces; O&M challenges* | *Coupled design and contracting interfaces; O&M challenges* |

### *3.1.5.2 Supply Chain Readiness*

- Although a mature industry, turbines are less proven in floating applications. Global floating deployment levels at project procurement will drive design improvements and demand volumes and thus determine costs for a project.
- Recently, Vestas and Siemens Gamesa are the two European OEMs that have supplied turbines to pre-commercial floating wind projects.
- Supply chain bottlenecks, the emergence of Chinese suppliers and OEMs, and rapidly rising demand for offshore turbines will all shape the turbine market through procurement. Furthermore, operations and maintenance (O&M) for deepwater floating turbines requires innovation both at an individual and array level due to the current difficulties in maintaining this infrastructure. These drivers are outlined in greater detail in the following sections.

### 3.1.6 Concrete Floating Foundations

Concrete floating foundations have yet to reach commercial scale. No foundations with a concept compatible with New York State geography have surpassed the readiness level of a demo project. Technology readiness of concrete floating foundations for the three concepts described in section 2.1 is provided in Figure 5.

### *3.1.6.1 Technology Readiness*

- Several foundation concepts using concrete have reached or plan to reach pilot array scale, meaning demonstration in a project of up to 50 MW.
- The most advanced concrete projects use either barge foundations, in which the turbine is attached to a free-surface stabilized structure with a large water plane area and relatively small draught; or spar foundations, in which the turbine is attached to a weight-buoyancy stabilized structure with a relatively large draught.

- Equinor’s Hywind concept is the most successful of these and can use either steel or concrete. The concept is operational in the 30 MW Hywind Scotland pilot, first active in 2016, and is used in the 88 MW Hywind Tampen site in Norway (end of construction planned for this year). However, it uses a spar concept that requires deep drafts only found in regions with deep protected waters.
- BW Ideol’s Damping Pool foundation concept also uses either concrete or steel. Its initial demo, the 2 MW Floatgen, used a lightweight self-placing concrete to build the foundation; however, subsequent demo project Hibiki and the upcoming 30 MW Eolmed project use steel due to the high expense of concrete construction without strong existing concrete infrastructure.
- Saitec’s SATH concept uses concrete; a 2 MW demo project is under construction for this year, while two pre-commercial pilot projects are planned in Spain for 2025.

**Figure 5. Technology Readiness for Concrete Floating Foundations**

| | Concept 1 | Concept 2 | Concept 3 |
|---|---|---|---|
| | Upper Limits of Fixed Bottom | Sub-500 meter Floating Wind | Ultra-deep Floating Wind |
| Technology Readiness | *N/A* | *No commercial-scale projects active* | *No commercial-scale projects active* |

### *3.1.6.2 Supply Chain Readiness*

- The weight and labor-intensive manufacturing process of concrete foundations creates unique cost and supply chain constraints compared to those of steel. Concrete supply chains must be drawn from the local region of a project rather than internationally; furthermore, labor is a significant cost driver for these foundations.
- Concrete foundations are suited to local manufacture and can be either cast onsite or assembled from off-site components; both the fabrication site and the assembly port must be located within about 500 nm of the project. This range, often considered a practical limit for economical and timely shipping of heavy materials and components by sea, also ensures efficient transportation logistics. It minimizes both costs and environmental impact associated with the shipping of heavy construction materials over long distances.
- Concrete foundations also have more strenuous port requirements than steel foundations—they require a greater laydown area, a higher ground bearing capacity, a larger quayside, a deeper channel, and a port closer to the site, all of which adds difficulties in supply chain procurement.

### 3.1.7 Steel Floating Foundations

Steel floating foundations have yet to reach full commercial readiness but are in use in pre-commercial projects. Technology readiness of steel floating foundations for the three concepts described in section 2.1 is provided in Figure 6.

#### *3.1.7.1 Technology Readiness*

- There are several operational pre-commercial FOSW projects that use steel as a foundation. The foundation concept types are not only barges and spars, but also tension leg platforms, in which the turbine is attached to a vertically anchored floating structure whose station keeping system consists of tethers or tendons anchored at the seabed; and semi-submersible foundations, in which the structure is buoyant and free surface stabilized with a relatively shallow draught.
- The largest scale foundation concepts that use steel are Principle Power's WindFloat and Equinor's Hywind. WindFloat uses a semi-submersible foundation concept and is active on the 50 MW Kincardine farm off the coast of Scotland; it is projected to be used on the 100 MW Erebus project in the Celtic Sea. Although Equinor's upcoming 88 MW Hywind Tampen project will use concrete, the foundation concept works for both concrete and steel.
- Other notable foundation concepts include the Stiesdal TetraSub and TetraSpar; TetraSub will be used in Scotland's 100 MW Pentland FOSW farm, planned for 2026.
- The majority of foundation concepts under development use steel; however, there are only two concepts that have even reached the pre-commercial phase.

**Figure 6. Technology Readiness for Steel Floating Foundations**

| | Concept 1 | Concept 2 | Concept 3 |
|---|---|---|---|
| | Upper Limits of Fixed Bottom | Sub-500 meter Floating Wind | Ultra-deep Floating Wind |
| Technology Readiness | *N/A* | *No commercial-scale projects active* | *No commercial-scale projects active* |

#### *3.1.7.2 Supply Chain Readiness*

- Steel foundation requirements are comparatively less difficult than those of concrete. They may be sourced domestically or imported. However, the federal Investment Tax Credit (ITC), is only available for domestically manufactured foundations.
- Steel substructures can be made from structures suited to shipyard construction or large tubulars suited to manufacture in tower or monopile factories. Local supply for this type of manufacture is limited, so overseas markets may be important in fulfilling demand.

- Although steel foundations generally do not require ports as large as concrete, they do require a wider port entrance to be able to accommodate the foundation width.
- Many steel foundation concepts, including Stiesdal's TetraSub/TetraSpar and Principle Power's Windfloat, feature either modular or dismountable designs that enable them to take advantage of existing supply chains.

### 3.1.8 Deepwater Jacket Foundations

Deepwater jacket foundations have grown increasingly popular as the OSW industry moves to deep waters, becoming the preferred option for water depths between 40 and 60 meters. Technology readiness of deepwater jacket foundations for the three concepts described in section 2.1 is provided in Figure 7.

#### *3.1.8.1 Technology Readiness*

- A jacket is a steel lattice structure that is used as a foundation structure for offshore WTGs. It consists of a series of welded steel tubes that form a lattice pattern between typically three or four wider diameter steel legs. The legs are then secured to the seabed using pin piles or in some cases suction caissons. Jacket structures for offshore wind are similar in design to those traditionally used for offshore O&G platforms.
- Jackets are typically installed using pre-piling, in which a pile driving hammer and a template are used to ensure pin piles are placed correctly before the jacket is secured to the piles using grout.
- Jacket foundations are popular for OSW projects in waters too deep for monopiles, or where soil conditions favor jackets.
- Currently, jackets have been used for projects up to 60 meters in water depth and for WTGs with rotor diameters up to 174 meters.
- There are currently over 1,000 individual jacket foundations that either have been installed or are planned to be installed around the world.
- From a technology standpoint alone, jackets can be deployed in depths of well over 100 meters. The question of the upper limit for offshore wind is an economics and supply chain optimization, not a technical limitation. The number of units required to supply a gigawatt-scale offshore wind farm far exceeds that of the O&G industry, meaning that efficient fabrication, shipping, and installation are key to the viability of jackets in deep waters.

**Figure 7. Technology Readiness for Deepwater Jacket Foundations**

* Notice 2023-38; IRS Domestic Content Bonus Credit Guidance

| | Concept 1 | Concept 2 | Concept 3 |
|---|---|---|---|
| | Upper Limits of Fixed Bottom | Sub-500 meter Floating Wind | Ultra-deep Floating Wind |
| Technology Readiness | *Supply chain and T&I economics* | *N/A* | *N/A* |

### *3.1.8.2 Supply Chain Readiness*

- Jackets are more complex to fabricate than conventional fixed-bottom monopiles due to both their size and complexity of manufacture. This makes cost a notable constraint compared to fixed-bottom OSW.
- The size of jackets mean they often require significant crane capacity for installation vessels only possessed by a handful of heavy lift vessels globally.
- Jacket foundations' similar design to those used in O&G structures enables the OSW industry to leverage existing supply chains. However, existing fabricators have sometimes struggled due the cyclical nature of O&G orders, and many of these established fabricators have had difficulty moving to mass manufacturing rather than the small unit, bespoke manufacturing common in O&G.
- Notably jacket foundations must be 100% sourced from the U.S. in order for a project to qualify for the IRA's 10% adder for domestic content. This is because jackets are designated as "Iron and Steel" components under the Internal Revenue Service's (IRS) latest guidance (Notice 2023-38; IRS Domestic Content Bonus Credit Guidance).

## 3.1.9 Dynamic Array Cables

An immature dynamic cable market and growing demand for array cables put upward pressure on floating wind array cable costs. Technology readiness of dynamic array cables for the three concepts described in section 2.1 is provided in Figure 8.

- Technology Readiness.
- Dynamic cables require protections and allowances for foundation movements (particularly heave and vertical movement), casing wave and current loading. Unlike static cables, which are buried in the seabed, dynamic cables are subject to the stresses of platform movements, water depths, and ocean currents.
- Dynamic cables at array cable voltage have been deployed for O&G platforms, but only limited experience exists for floating wind applications.

- For deepwater sites, utilizing fully dynamic array cables will likely be the most cost-effective, with no sections buried in the seabed. This cutoff will depend primarily on depth, and cable design, dynamic cable costs, wind farm layout, and site conditions.
- The most effective array cables for ultra-deep sites would be fully dynamic with buoyancy modules to keep them buoyant in the water column. Although this principle has been effective in the O&G industry, the dynamic behavior of FOSW adds technical risk.
- Systems are under development for "plug-and-play" connections to turbines. These are currently not cost effective, although further advances may lead to additional investment (paid for with operations expenditure (OpEx) savings and reduced downtime).

**Figure 8. Technology Readiness for Dynamic Array Cables**

| | Concept 1 | Concept 2 | Concept 3 |
|---|---|---|---|
| | Upper Limits of Fixed Bottom | Sub-500 meter Floating Wind | Ultra-deep Floating Wind |
| Technology Readiness | *N/A* | *Technology under development for commercial use* | *Technology under development for commercial use* |

#### *3.1.9.1 Supply Chain Readiness*

A limited supply chain for dynamic cables exists today from O&G, though growth is expected over the coming decade. The level of global FOSW deployment through project procurement will drive design improvements and demand volumes and thus determine costs for a project.

- Nexans, JDR and Prysmian are among the contractors that have provided inter-array cables (IACs) to small-scale pilot-array projects so far. Other potential suppliers include NKT and Hellenic Cables, and both suppliers participate in the EU's IAC R&D projects.
- Given the current project pipeline and visibility of available manufacturing facilities, there will be an under-supply for IACs across the overall OSW market through 2030. Along with developing the dynamic cable industry, cable suppliers will need to invest in expansion to their manufacturing capabilities to keep pace with demand.

### 3.1.10 Dynamic Export Cables

An immature dynamic cable market and still-developing technology for high-voltage dynamic cables currently limit the overall output of potential FOSW farms. Technology readiness of dynamic export cables for the three concepts described in section 2.1 is provided in Figure 9.

### 3.1.10.1 Technology Readiness

- Dynamic cables require protections and allowances for foundation movements (particularly heave and vertical movement), casing wave, and current loading. Unlike static cables, which are buried in the seabed, dynamic cables are subject to the stresses of platform movements, water depths, and ocean currents.
- For deepwater sites, dynamic export cables will only be needed for the first few miles to link the offshore substation to the static export cable. However, this technology does not currently exist for voltages above 66 kilovolts (kV), and not for High-Voltage Direct Current (HVDC) technology, meaning that there are currently no options for deepwater floating wind to export power without using significantly more cable.
- Although higher-voltage dynamic export cables are under development, their unfinished status limits the turbine size and overall output of potential FOSW farms.

**Figure 9. Technology Readiness for Dynamic Export Cables**

| | Concept 1 | Concept 2 | Concept 3 |
|---|---|---|---|
| | Upper Limits of Fixed Bottom | Sub-500 meter Floating Wind | Ultra-deep Floating Wind |
| Technology Readiness | *N/A* | *Technology not developed for commercial use* | *Technology not developed for commercial use* |

### 3.1.10.2 Supply Chain Readiness

- Although a limited supply chain for dynamic cables exists today from O&G, the technology does not currently exist for higher voltages, with cables of 100 kV or more still under development. The industry will therefore need to further mature in order to accommodate commercial-scale projects.
- Given the current project pipeline and visibility of available manufacturing facilities, there will be an under-supply for dynamic export cables across the overall OSW market through 2030. Along with developing the dynamic cable industry, cable suppliers will need to invest in the expansion of their manufacturing capabilities to keep pace with demand.
- The supply chain may struggle further to manufacture dynamic export cables, as the expected market may be relatively small, since it is only the last section of each export cable that needs to be dynamic.

### 3.1.11 Mooring Systems

Mooring systems can be adapted from floating O&G, but the industry has yet to determine their optimal design and performance standards. Technology readiness of mooring systems for the three concepts described in section 2.1 is provided in Figure 10.

#### *3.1.11.1 Technology Readiness*

- There are a variety of different mooring solutions that have been developed in the O&G industry and are suitable for FOSW projects. Different designs are suited to different water depths, metocean conditions, foundation weights/types, and anchors. Mooring system design must consider the overall system dynamics of the WTG, floating foundation, dynamic cable, and moorings.
- Catenary and semi-taut mooring systems have the simplest design, with taut moorings often more challenging to design and install due to higher loads and soil requirements.
- For concept 2, when soil conditions allow, catenary and semi-taut mooring systems tend to be the least expensive to manufacture and install.
- Catenary systems are not typically well-suited for concept 3 as they do not scale well in deep waters due to cost. More taut mooring systems are better suited for deep water, but their complexity (ground loads, installation requirements, etc.) can add project risk. Overall, deep waters add mooring system risk due to more challenging installation, O&M, and the expensive system design required.
- Mooring system design and selection is ultimately a project-specific cost and risk optimization, with many viable design options for any given site.
- As floating wind is still growing to commercial scale, the industry has yet to determine the best design solutions and performance standards, especially in deep waters where no pilot project nor demo project has been installed.

**Figure 10. Technology Readiness for Mooring Systems**

| | Concept 1 | Concept 2 | Concept 3 |
|---|---|---|---|
| | Upper Limits of Fixed Bottom | Sub-500 meter Floating Wind | Ultra-deep Floating Wind |
| Technology Readiness | *N/A* | *Design novelty and reliability concerns* | *Design novelty and reliability concerns* |

#### 3.1.11.2 Supply Chain Readiness

- Floating OSW mooring technology draws directly from the O&G industry, meaning that there is already design and supply chain experience. However, the volume of demand expected from FOSW might exceed the existing supply chain of mooring components.
- Cost-effective design is much more important for OSW farms due to the increased volume of moorings needed for a project. While O&G moorings are overbuilt due to the lower impact of added cost, OSW has up to 50 times the number of moorings to be manufactured, handled, and installed; developers therefore must balance performance with economics.
- OSW moorings also have different loadings compared with O&G, meaning designs must be adapted due to different stress patterns. In particular, since the pull-in loads for moorings are very high, especially for non-redundant systems, it can stress the supply chain due to a necessary adaptation of new designs.

### 3.1.12 Floating Substations

Although much of the technical aspects of floating substations can be adapted from existing industries, the technology is still unproven and would require adaptation for mooring and high-voltage equipment. Technology readiness of floating substations for the three concepts described in section 2.1 is provided in Figure 11.

#### 3.1.12.1 Technology Readiness

- Floating substations are a current source of risk due to their low-technical readiness. Although floating substation technology may not be the greatest challenge to FOSW, it is still unproven and there are currently no commercial-scale floating substations.
- The first floating substation was installed in 2013 as part of the Fukushima Offshore Demo; however, it only exported power at 66 kV, not feasible for a commercial-scale wind farm. Furthermore, the project itself was decommissioned in 2021.
- Although this technology will not be necessary for fixed-bottom sites or even the shallowest floating sites, fixed-bottom substations are unfeasible in ultra-deep water. Floating substations will therefore have to be developed to commercial readiness along with dynamic export cables, adding risk to future ultra-deep projects.
- The innovation requirements are heightened for the New York Bight area due to the need for HVDC transmission given the distance from shore. HVDC platforms are typically larger and heavier than High-Voltage Alternating Current (HVAC) substations.
- Although a depth of 150 meters is considered a good cost parity cutoff point for early project planning, the comparatively low readiness of floating substations means that fixed-bottom jacket foundations are still worth considering at depths up to 250 to 300 meters, in line with the upper-limits of jacket foundations in O&G applications.

**Figure 11. Technology Readiness for Floating Substations**

| | Concept 1 | Concept 2 | | Concept 3 |
|---|---|---|---|---|
| | Upper Limits of Fixed Bottom | Sub-500 meter Floating Wind | | Ultra-deep Floating Wind |
| Technology Readiness | *N/A* | *Shallower – Jackets* | *Deeper – Floating* | *No commercial-scale projects active* |

### *3.1.12.2 Supply Chain Readiness*

- Most components of a floating substation can be adapted from the O&G, maritime, and existing OSW industries. However, the substation's high-voltage equipment must be adapted for the additional accelerations experienced as part of a floating substation. This would require a new design for these components, particularly the main power transformer and gas-insulated switchgear, that has not been built on a commercial scale.
- The required change in design means existing elements of the offshore substation supply chain may not be applicable for high-voltage components; furthermore, potential projects would require testing of these components which may cause delays.
- Floating substations also require mooring designs separate from those of the turbines. Substations are both heavier and have a lower center of gravity than turbines. Because they are the single point of failure for the wind farm, the mooring system must have a different design form to those of the turbines that is implemented with a high level of redundancy. A key area of focus during floating construction/assembly will be maintaining a load-out rate aligned with the shipping/production rate to avoid costly delays. This will require careful planning, training, and the use of weather windows and/or dedicated storage.

## 3.1.13 Marine Operations

The existing marine construction industry is well-suited to serve the floating wind market. Technology readiness of marine operations for the three concepts described in section 2.1 is provided in Figure 12.

### *3.1.13.1 Technology Readiness*

- Marine operations for floating OSW are characterized by generally low-supply chain risk, with techniques allowing for a direct re-purpose from floating O&G infrastructure, fixed-bottom OSW planning, and other marine construction industries.

- Floating wind allows and requires many operations to be run at port or in sheltered areas, usually without expensive installation vessels. This requires the transportation of the complete assembly, and for mooring and array cables to be in place before the turbine is transported offshore. This means that turbine and mooring costs may fall earlier in a project's CapEx schedule, as they are needed earlier in a project's life cycle.
- Burial operations in deep waters are not expected to cause increased challenges compared to fixed-bottom burial operations.
- A key point of technology readiness risk in marine operations is strategy for heavy component maintenance, as the current approach for fixed-bottom, which uses jack up vessels, is not an option for floating projects. Alternative strategies to towing the floaters to shore are yet to be fully developed.
- Health and safety hazards are distinct from those of fixed-bottom projects. A key area of focus is personnel transfer between two dynamic platforms (i.e., an installation vessel and a floating platform).

**Figure 12. Technology Readiness for Marine Operations**

| | Concept 1 | Concept 2 | Concept 3 |
|---|---|---|---|
| | Upper Limits of Fixed Bottom | Sub-500 meter Floating Wind | Ultra-deep Floating Wind |
| Technology Readiness | *Constraints on heavy-lift installation vessels* | *Some logistical novelty but can leverage existing supply chains* | *Experience from O&G. Only challenging from a cost perspective (installing anchors)* |

### *3.1.13.2 Supply Chain Readiness*

Floating projects will typically require the following vessels/cranes:

- WTG assembly crane.
- For towing and support services: a primary tow-tug supported by 2–3 auxiliary tugs.
- For projects shipping finished foundations long distances (500+ nm), potentially two or more large, semi-submersible heavy transport vessels.
- For non-drag embedment anchors: An offshore construction vessel (OCV), with support equipment (e.g., remotely operated deepwater vehicle, vacuum pump, or hammer).
- For mooring installation and anchor-feeding for the OCV: An anchor handling tug supply vessel (AHTSV) or platform supply vessel (PSV).

All vessels are available from other industries, with those transiting to and from port needing to be Jones Act Compliant (e.g., AHTSV, PSV, support tugs). RCG predicts that OCVs and heavy transport vessels are most likely to experience bottlenecks and will therefore be important to secure early. Jackets installation vessels are the biggest bottleneck overall. This installation requires use of one of few heavy-lift vessels globally that are in high demand.

### 3.1.14 Technical Readiness Summary

Much of the required infrastructure for floating wind is available from existing fixed-bottom technology or O&G; however, innovation is required for dynamic cables, O&M, marine operations, and floating foundations. Technology readiness for the three concepts described in section 2.1 is summarized in Table 4.

**Table 4. Technology Summary**

| Concept | High Readiness Available today with minimal modifications | Medium Readiness Available to draw from existing designs and supply chains with some modifications | Low Readiness Substantial technology and supply chain innovation required |
|---|---|---|---|
| Concept 1: Upper Limits of Fixed-Bottom | • Wind Turbines<br>• Static Array Cables<br>• Static Export Cables<br>• Fixed-Bottom Offshore Substation<br>• Onshore Substation | • Deepwater Jacket Foundations<br>• Marine Operations | • None Identified |
| Concept 2: Sub-500-meter Floating Wind | • Static Array Cables<br>• Static Export Cables<br>• Onshore Substation<br>• For sites with fixed-bottom substation foundations: Offshore Substation | • Wind Turbines<br>• Dynamic Array Cables<br>• Mooring System Design<br>• Cost-effective marine operations program<br>• Marine Operations | • Floating Foundation Design and Fabrication<br>• Major Component O&M<br>• For sites with floating substation foundations: Floating Substations and Dynamic Export Cables |
| Concept 3: Ultra-deep Floating Wind | • Wind Turbines<br>• Static Array Cables<br>• Static Export Cables<br>• Onshore Substation | • Wind Turbines<br>• Dynamic Array Cables<br>• Mooring System Design | • Floating Foundation Design and Fabrication<br>• Floating Substations<br>• Dynamic Export Cables<br>• Major Component O&M<br>• Cost-effective deepwater marine operations. |

This readiness assessment is based on the current state of the market and known developments in the global pipeline. Readiness for a Commercial Operation Date (COD) 2035 project will ultimately depend on the successful deployment of planned stepping-stone projects (particularly for floating wind) and which are operational or under construction by the early 2030s. This report highlights the technical considerations that will require the greatest evolution this decade to enable a presumed 2035 deployment in the AoA, considering the state of the industry today and current known deployment plans.

## 3.2 Construction Methods and Local Infrastructure

### 3.2.1 Introduction

This section provides a broad look at the necessary infrastructure and localization opportunities associated with FOSW development.

#### *3.2.1.1 Objectives*

This section aims to outline the supporting infrastructure associated with successful FOSW development. This section reviews:

- Infrastructure localization needs and minimum requirements.
- The high-level construction process of FOSW and where different methodologies may be employed.
- The importance of ports and ballpark minimum port requirements for FOSW development.
- A high-level review of an FOSW port in development in the U.S.

This report does not aim to assess the compatibility and gaps in current existing infrastructure, such as ports or manufacturing facilities in the region.

#### *3.2.1.2 Definitions of Scoring Criteria*

**Minimum Requirement:** For project feasibility, the assessed component/activity must, at the very least, occur within the noted location. This is mainly driven by logistical constraints.

**Added Benefit:** Highlights opportunities where a component or activity may see risk or cost improvements from siting/sourcing at the noted location.

**Can Leverage Fixed Supply Chain:** Highlights opportunities where a component or activity can draw directly from existing fixed-bottom supply chains with minimal upgrades or modifications required.

### 3.2.2 Localization Summary

Table 5 summarizes what activities and components benefit from in-state, regional, or domestic siting/sourcing.

#### *3.2.2.1 Commentary*

Table 6 provides detail on which activities and components benefit from in-state, regional, or domestic siting/sourcing.

**Table 5. Summary Scores of the Need and Opportunities for Localization**

* Floating wind technology only.

| Component/Activity | NY Region (within ~250 nm of site) | East Coast Region (within ~500 nm of site) | Domestic | Global |
|---|---|---|---|---|
| | Criteria | | | |
| Turbines | Can Leverage Fixed Supply Chain | | Added Benefit (ITC) | Minimum Requirement |
| Steel Foundation Fabrication | Can Leverage Fixed Supply Chain | | Added Benefit (ITC) | Minimum Requirement |
| Steel Foundation Assembly Port* | — | Added Benefit (Shipping) | Added Benefit (Shipping, ITC) | Minimum Requirement |
| Concrete Foundation Fabrication* | Added Benefit (Shipping) | Minimum Requirement | — | — |
| Concrete Foundation Assembly Port* | Added Benefit (Shipping) | Minimum Requirement | — | — |
| Construction Marshalling Port* | Minimum Requirement | — | — | — |
| O&M Port | Minimum Requirement | — | — | — |
| Marine Operations–Vessel Source | — | Added Benefit (Mobilization) | Minimum Requirement (Jones Act operations) | Minimum Requirement (non-Jones Act operations) |
| Mooring and Anchor Supply | — | — | Added Benefit (ITC) | Minimum Requirement |
| Array Cables | Can Leverage Fixed Supply Chain | | Added Benefit (ITC) | Minimum Requirement |
| Export Cables | Can Leverage Fixed Supply Chain | | Added Benefit (ITC) | Minimum Requirement |
| Offshore Substations | — | — | Added Benefit (ITC) | Minimum Requirement |
| Onshore Substations | Minimum Requirement | — | — | — |

**Table 6. Summary of the Need and Opportunities for Localization**

| Component/ Activity | NY Region (within ~250 nm of site) | East Coast Region (within ~500 nm of site) | Domestic | Global |
|---|---|---|---|---|
| Turbines | Projects can draw from regional supply chains established for fixed-bottom turbines. Reduced shipping costs can lead to small additional savings. | | 10% ITC Domestic Content adder. Turbines (nacelles, blades, rotor hub, power converter) count as a “manufactured product” and must meet the minimum percentage of domestic investment to qualify. The tower is an “Iron and Steel” component, so it must be 100% domestic to qualify. | Global procurement is standard and leverages the integrated international supply chain network. |
| Steel Foundation Fabrication | Projects may be able to draw from regional supply chains established for existing fixed-bottom projects’ foundations, but facilities will need to be carefully screened and adapted to be able to manufacture the foundation types required for deepwater projects. Reduced shipping costs can lead to small additional savings. | | Domestic fabrication facilitates qualification for 10% ITC Domestic Content adder. Domestic manufacturing is known to be especially important for jackets as they count as “Iron and Steel” components, so must be 100% domestic for project to qualify. | Global fabrication taking advantage of international supply chains is typical, but system design and construction must account for international component or sub-component shipping. |
| Steel Foundation Assembly Port (Floating Only) | Assembling steel foundations locally is an option. However, assembling elsewhere in the east coast region and wet-towing to a local marshalling harbor is likely cost-effective. | Assembling locally can reduce shipping costs, depending on labor costs between potential assembly locations. | Assembling domestically facilitates ITC adder eligibility and mitigates shipping costs. | At a minimum, foundations can be assembled abroad and shipped on heavy transport vessels or wet-towed for shorter distances. |
| Concrete Foundation Fabrication (Floating Only) | Fabrication within the immediate New York State region would further limit transport distances and associated shipping costs (which can be significant due to the weight of concrete foundations). | The weight of concrete foundations makes it important to fabricate foundations within the same region, while balancing shipping versus local labor costs. | Due to the weight of concrete foundations and associated cost and logistical challenges, it is typically not feasible to fabricate a concrete floating foundation outside of the east coast region. | |

**Table 6 continued**

| Component/ Activity | NY Region (within ~250 nm of site) | East Coast Region (within ~500 nm of site) | Domestic | |
|---|---|---|---|---|
| Concrete Foundation Assembly Port (Floating Only) | Final foundation assembly within the immediate New York State region would further limit transport distances and associated shipping costs. | The weight of concrete foundations make it necessary to perform final foundation assembly within the same region. | Not feasible due to concrete foundation weight and associated cost and logistical challenges. | |
| Construction Marshalling Port | A marshalling port within a three-day tow of the project site significantly limits costs and construction risks. | Not feasible. The marshaling port must be closer to the installation site. | | |
| O&M Port | O&M ports must be close to the project site. This allows for routine project maintenance and emergency activities. | Not feasible. O&M port must be closer to the project site for routine project maintenance and emergency activities. | | |
| Marine Operations Vessel Source | Sourcing vessels from the immediate region may minimally reduce mobilization costs and team experience, but the added potential benefit is small. | Where vessels are available locally, sourcing from the region reduces mobilization costs and improves construction team experience with local conditions. | Domestic vessels are required for Jones Act Compliance when carrying equipment between U.S. ports or from a U.S. port to the project site. | For non-Jones Act compliance activities, globally sourced vessels are typical, especially where specialized equipment is required. |
| Mooring and Anchor Supply | Limited additional benefit. | | Domestic fabrication facilitates qualification for 10% ITC Domestic Content adder. | It is typical to source mooring and anchor equipment competitively from the global supply chain. |
| Array Cables | Projects can draw from regional supply chains for fixed-bottom turbines if existent in the immediate region. | Projects can draw from regional supply chains established for fixed-bottom turbines. Key possible difference in technology is the addition of dynamic cables. | Domestic fabrication facilitates qualification for 10% ITC Domestic Content adder. | It is typical to source cable supply and installation contracts competitively from the global supply chain. |

**Table 6 continued**

<table>
<tr><th>Component/ Activity</th><th>NY Region (within ~250 nm of site)</th><th>East Coast Region (within ~500 nm of site)</th><th>Domestic</th><th>Global</th></tr>
<tr><td>Export Cables</td><td>Projects can draw from regional supply chains for fixed-bottom turbines if existent in the immediate region.</td><td>Projects can draw from regional supply chains established for fixed-bottom turbines. Key possible difference in technology is the addition of dynamic cables.</td><td>Domestic fabrication facilitates qualification for 10% ITC Domestic Content adder.</td><td>It is typical to source cable supply and installation contracts competitively from the global supply chain.</td></tr>
<tr><td>Offshore Substation</td><td colspan="2">Limited additional benefit and requires specialized fabrication yards. Potential small savings on transportation costs.</td><td>Domestic fabrication facilitates qualification for 10% ITC Domestic Content adder, jacket foundations must be sourced domestically to qualify.</td><td>Substations require large fabrication yards, especially for HVDC, and are typically competitively sourced and outfit globally to ship to the project site.</td></tr>
<tr><td>Onshore Substation</td><td>Onshore substations must be constructed locally to interconnect with the local grid.</td><td colspan="3">Not feasible</td></tr>
</table>

### 3.2.3 Port Capabilities

This section describes the required port characteristics for the manufacturing and construction required for FOSW.

#### *3.2.3.1 Manufacturing and Construction Process*

**Floating Foundation Fabrication**

- An image of steel substructures storage is presented in Figure 13. Typically, steel substructures can be made from structures suited to shipyard construction or large tubulars suited to manufacture in tower or monopile factories (limited local supply at current, possibly dependent on overseas markets).
- Concrete structures, more reliant on local manufacturing infrastructure, can be cast in-site or assembled from components brought in from off site.

**Figure 13. Fabrication of Structures in a Warehouse**

### Foundation Assembly/Launch

1. There are multiple methodologies for foundation assembly and load-out. Foundation assembly may occur at the initial fabrication port or at a staging port proximal to the project site, as shown in Figure 14. A floating foundation is typically launched in one of four ways:
   - Heavy lift (large onshore crane to lift foundation into the water).
   - Semi-submersible barge (roll or skid/jack the foundation onto a barge which then submerges and floats the foundation off).
   - Slip launch (using a large, sloped ramp).
   - Assembly in a dry dock, where the dock can be flooded to float the structure.

**Figure 14. Foundation Assembly and Load-Out at a Port**


### WTG Integration

- Typically, a marshalling area of around 16 to 30 hectares (ha) is required to store turbine nacelles, blades, and towers, having been manufactured off site.
- A strengthened launching quay 100 to 150 meters in length will be needed to transfer most structures from shore to a submersible barge for floating off into the water. Given that the turbines that sit on top of these floating structures will have rotor diameters of 200 meters plus, an assembly quay of up to 300 meters long will be required. If a spar buoy is selected, a sheltered slip-forming berth with up to 100-meters water depth is required.

### 3.2.4 Floating Foundation Construction Options—Fabrication and Assembly

Different techniques discussed in this section, are utilized in the fabrication, assembly, and load out of FOSW foundations. These methods are dependent on project-specific characteristics and will likely differ across projects.

#### *3.2.4.1 Foundation Fabrication*

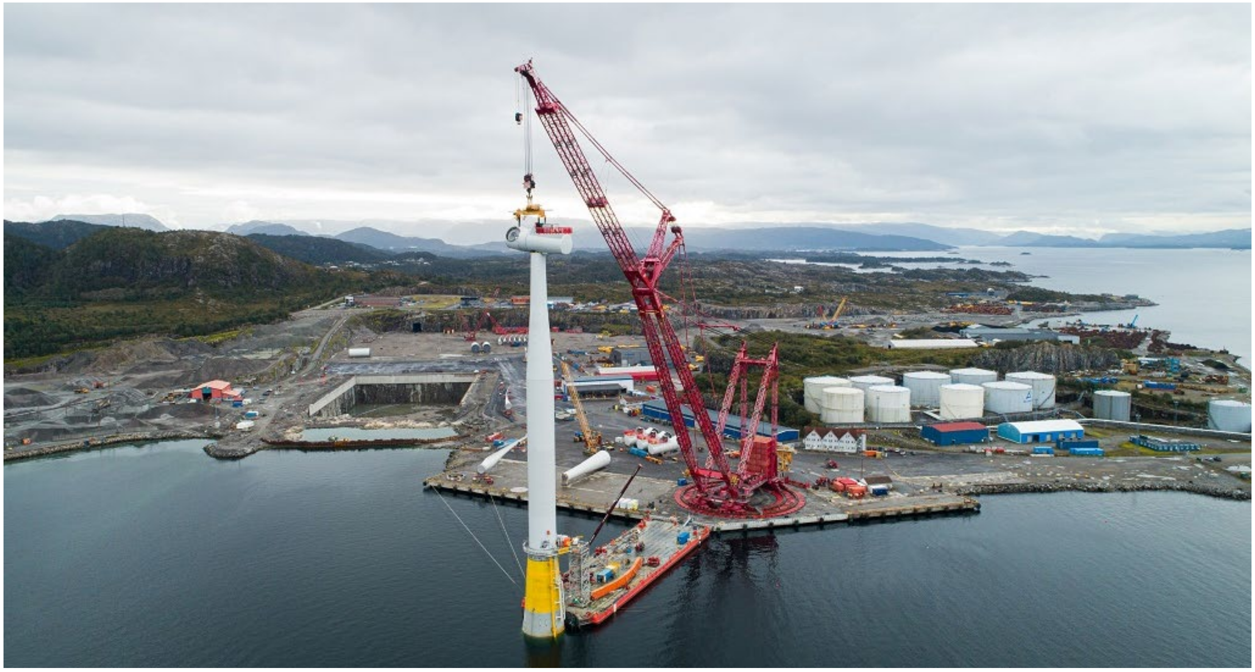
The first step in the construction of floating foundations is the fabrication of the foundation components. The components are highly dependent on the foundation technologies and materials used. As previously described, steel and concrete are the two materials utilized across all foundation designs.

Across most floating foundation designs, numerous large components need to be combined to create the structure. There are three main construction methods used in this fabrication.

1. The entire floating foundation is fabricated and assembled at one location. The foundations are subsequently towed to the main port located near the project site with a heavy transport vessel (dry tow) or with heavy tugboats (wet tow).
2. The floating foundation sub-assemblies (components) are fabricated at one site and shipped to a port facility proximal to the project site. With this method, components are more efficiently shipped as the sub-sections take up less space (can potentially be flat-packed) prior to foundation assembly.
3. The floating foundation components are fabricated, assembled, and turbines are installed at the same facility. This method requires significantly more space and port/harbor capabilities. This facility must be located near the project site.

**Figure 15. Construction of Floating Offshore Wind**

*Source: Wergeland*



### *3.2.4.2 Assembly of Sub-Components into Finished Foundation*

The process of assembling floating foundations from a set of components is completed with different connection methods. As previously discussed, this process may occur at a facility/port proximal to the project site or at a facility farther away and subsequently wet or dry towed to staging port closer to the project site. Figure 15 presents this process at a port proximal to the project site.

The most common connection techniques for converting steel sub-assemblies into finished foundations are:

- **Bolted/Pinned Connections:** This is significantly quicker than welding, since components can be supplied in a fully finished condition (i.e., painted), with just alignment and bolt tensioning/grouting required at the rate-limiting final assembly station.
- **Grouted Connections:** Grouted connections are widely used in support structures for OSW turbines.
- **Welded Connections:** Structural welding is a complex and quality-driven process and final assembly welds are typically completed manually by experienced welders.

### 3.2.5 Floating Foundation Construction Options—Turbine Assembly and Installation

The turbine installation process for FOSW typically occurs portside and the completed structure is subsequently towed to site, as shown in Figure 16. This process is described below.

**Figure 16. Floating Offshore Wind Tow-Out**

*Source: Boskalis*

#### *3.2.5.1 Turbine Assembly and Installation Overview*

FOSW turbines are usually installed on the foundation at port. This is a key difference between the installation process of fixed-bottom and FOSW. An example of this is shown in Figure 17.

Portside installation activities may be limited by the availability of cranes, lifting capacity, space, and draught. The exact process will differ depending on concept design, port, and site location, available infrastructure, and environmental conditions. Specifically, barge and semi-submersible foundation designs have a shallower draught and more stability which makes them more suitable for onshore/quayside assembly. The most common turbine installation process is as follows:

- Major turbine components are moved to the quayside, some pre-assembly work is c ompleted, and the components are stored.
- The floating foundation is brought out of wet storage and moved to the quayside.
- The major turbine components are then installed onto the foundation using a landside crane. Depending on lift capacities, the turbine is installed one section at a time or pre-assembled and installed at once.
- Pre-commissioning at port and wet storage before tow-out of assembled FOSW turbines (WTG foundation units).

In unique circumstances, the turbine may be installed with a wind turbine installation vessel (WTIV) in protected waters or offshore. This presents logistics and cost challenges and would only occur if there is no marshaling port within 250 nm of the project site.

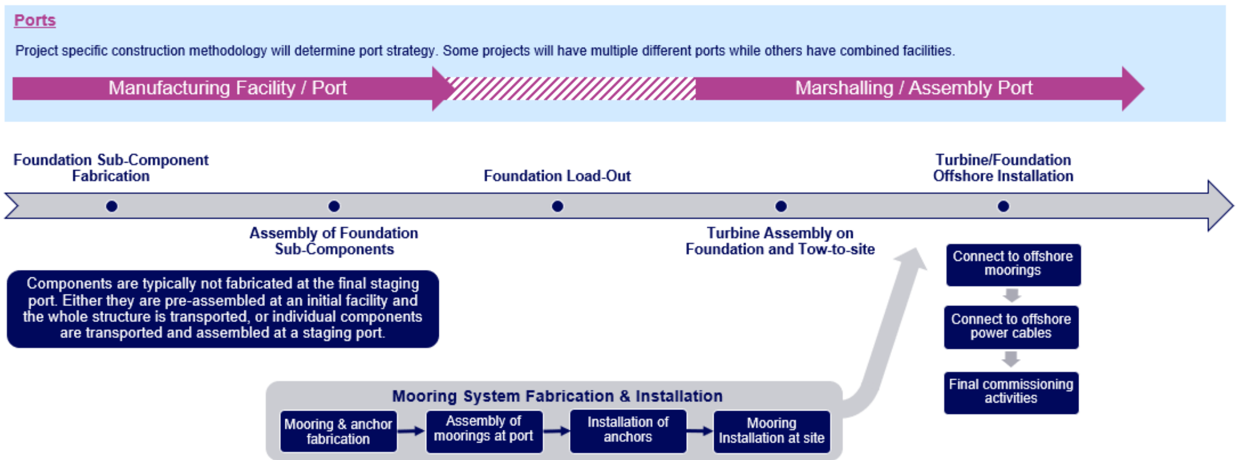
**Figure 17. Turbine Installation at Port**

*Source: Equinor*

### 3.2.6 Overview of Floating Foundation Construction Process

The construction process for FOSW is complex and the specifics are dependent on local manufacturing, infrastructure, and port capabilities. This construction process is outlined in Figure 18.

**Figure 18. Floating Foundation Construction Process**




### 3.2.7 Port Characteristics

Ports are a critical component of OSW development and play a particularly large role in FOSW construction due to extensive onshore assembly activities.

#### *3.2.7.1 The Role of Ports*

Ports are a key component in nearly all aspects of FOSW. Considering OSW components are larger than onshore wind components, the fabrication, assembly, storage, and general handling of such large components requires specialized port capabilities. These components are typically too large for rail or road transportation and hence rely on sea transportation.

Ports are the backbone of FOSW projects and play an important role in the fabrication and assembly of components, the storage of components and foundations, pre-installation and commissioning activities, and the accommodation of personnel and vessels.

Manufacturing, marshalling, and operation and maintenance ports are the three main types of ports used in the development of FOSW. In most cases, no single port will provide all the capabilities needed.

Ports also realize one of the key advantages of FOSW—minimized offshore work. Floating foundations are assembled in port and then towed to the project site with tugs as opposed to the required heavy-lift vessels for fixed-bottom foundation installation. With more onshore operations, FOSW assembly and installation is less susceptible to weather delays limiting extended delay periods that may increase project costs.

**Defining "Minimum Requirements"**

For the purpose of this section of the report, the minimum requirement of a specific port parameter, as opposed to infrastructure localization needs for a given component, refers to the threshold at which there is significant risk to the development of a generic project with the specified characteristics (steel versus concrete or fixed-bottom versus floating turbines).

Most ports exceed these standards and values at or below these levels induce a high-feasibility risk.

**Parameters with Hard Constraints**

The values portrayed in the following tables are generalized across designs and methodologies. However, when making project decisions, specific parameters must align with the exact design and approach selected for the development. The following parameters have hard constraints related to specific component designs and construction methodologies:

- quayside depth
- entrance width
- channel depth
- air draught
- laydown areas

### 3.2.8 Minimum Port Requirements: Floating Offshore Wind Construction

Ground loading, laydown areas, and quayside depths are key requirements for the fabrication of FOSW foundations. The minimum requirements are described below.

#### *3.2.8.1 Commentary*

Construction/manufacturing ports must be optimized for the fabrication of FOSW foundations.
The specific requirements are dependent on the foundation design.

Currently, floating foundations designs are made from steel or concrete. The steel requirements listed in the middle column of Table 7 assume the construction port is for the fabrication and assembly of a steel foundation. Concrete requirements in Table 7 assume concrete foundations are made at the construction port and then towed to the marshalling port.

The two main criteria in determining construction port feasibility are the laydown area and ground loading. Concrete foundations are heavier than steel foundations and have higher ground loading requirements as a result.

Large laydown areas are required for the fabrication process of both steel and concrete foundations.

Additionally, quayside depths are important for both steel and concrete foundations. After fabrication and assembly, the foundations are launched from quayside into the water. The specific depth requirements will be dependent on the foundation design and weight.

**Table 7. Minimum Construction Port Requirements (Steel and Concrete Foundations)**

| Parameter | Steel | Concrete |
|---|---|---|
| Laydown Area | 15 ha | 30 ha |
| Ground Loading—Floating Foundation | 15 t/m2 | 25 t/m2 |
| Quayside Depth | 12 m | 14 m |
| Quayside Length | 200 m | 450 m |
| Entrance Width | 225 m | 115 m |
| Channel Depth | 13 m | 15 m |
| Air Draught | NA | NA |
| Distance to Site | No hard constraint for fabrication<br><500 nm assembly | <500 nm fabrication<br><250 nm assembly |

### 3.2.9 Minimum Port Requirements: Floating versus Fixed-Bottom Marshalling Port

Marshalling ports require large laydown areas for key components, and quayside depths suitable for turbine assembly using a heavy lift crane. An overview of these requirements are described in this section.

#### 3.2.9.1 Commentary

Marshalling ports, commonly known as staging or deployment ports, are used to assemble the wind turbine onto the foundation at the quayside before they are deployed to site. A combination of quayside laydown and wet storage can be used for foundation staging.

Fixed-bottom and FOSW farms use different turbine installation methods leading to different port requirements. Turbine installation on floating foundations typically occurs quayside while turbine installation for fixed-bottom OSW farms occurs at the project site. The minimum requirements shown in the center column of Table 8 assume only one turbine installation spot for FOSW (an optimized workflow may include two spots and an extended quay length).

#### 3.2.9.2 Floating

- Quayside storage is essential as building the turbine is a weather-sensitive process. All components must be staged for quick deployment.
- Height limits must be enforced for the navigation route between the marshalling port and the site due to the height of the turbine and blades for tow-out to site.

#### 3.2.9.3 Fixed-Bottom

- The port requirements for a marshalling port are significantly reduced as the foundations do not need to be stored.
- Jack-up vessel requirements drive the main port requirements.
- Air-draught restrictions are based on the size of the jack-up vessel legs that must be raised for transfer from port to site.

**Table 8. Minimum Marshalling Port Requirements**

| Parameter | Floating | Fixed-Bottom |
|---|---|---|
| Laydown Area | 16 ha (land) 30 ha (wet storage*) | 16 ha (land) |
| Ground Loading—Foundation | 15 t/m2 | 10 t/m2 |
| Quayside Depth | 12 m | 9 m |
| Quayside Length | 175 m | 200 m |
| Entrance Width | 225 m | 80 m |
| Channel Depth | 13 m | 10 m |
| Air Draught | 400 m | 80 m |
| Distance to Site | 3 days (~200 nm) | 250 nm |

* Dependent on specification of the assembly yard. Wet storage needs at marshalling could be reduced if assembly yard has wet storage available and/or a large production capacity.

### 3.2.10 Minimum Port Requirements: Floating versus Fixed-Bottom Operations and Maintenance Port

O&M ports are active throughout the lifetime of an OSW farm. Minimum requirements, described in the section below, depend on vessel strategies and maintenance procedures.

#### *3.2.10.1 Commentary*

For both floating and fixed-bottom OSW, the port requirements are highly dependent on the applied vessel/transport strategy.

To access the wind farm, there are three main transport methods used:

- **Crew transfer vessel (CTV):** Vessels that are 15 to 30 meters long, used for shore transfers of personnel to the WTG, but not equipped for complex maintenance operations.
- **Service operation vessel (SOV):** Vessels over 50 meters that are equipped to stay offshore for longer periods of time (typically 2- to 3-week periods) to carry out routine maintenance.
- **Helicopter landing officer:** Comprises helicopters and gear that can transfer a technician and gear required to the WTG platform.

Routine maintenance can be carried out at site, although for major component repair/replacement, the turbine may need to be towed back to port for repair, typically back to the original construction marshalling port. The requirements shown in Table 9 assume a project does not use the O&M port for tow-to-shore repair activities; therefore, requirements for fixed and floating foundations are the same. Although helicopter access can form part of the O&M strategy through the incorporation of a helicopter landing officer, due to the cost it is generally not used for daily needs and can be limited by weather conditions. Efforts are underway to find innovative repair techniques that do not require towing foundations to port for major repairs, but RCG's base-case assumption remains that tow-to-shore repairs will be required for certain repairs where a jack-up repair vessel would be used for fixed-bottom foundation projects.

Some projects may opt for an O&M port with greater capabilities to handle major repairs, depending on local port capabilities and operating strategy.

**Table 9. Minimum Operations and Maintenance Port Requirements**

| Parameter | Fixed-Bottom / Floating |
|---|---|
| Laydown Area | 2 ha |
| Ground Loading—Foundation | NA (CTV)<br>5 t/m2 (SOV) |
| Quayside Depth | 3 m (CTV)<br>6.5 m (SOV) |
| Quayside Length | 30 m (CTV)<br>100 m (SOV) |
| Entrance Width | 15 m (CTV)<br>30 m (SOV) |
| Channel Depth | 4 m (CTV)<br>7 m (SOV) |
| Air Draught | NA (CTV)<br>30 m (SOV) |
| Distance to Site | > 50 km (CTV)<br>2 days<br>(200 km) (SOV) |

### 3.2.11 Ports Case Study: Humboldt

In 2022, the California Energy Commission approved a $10.5 million grant for upgrades at the Port of Humboldt Bay in support of FOSW activities. This section provides an overview of this project.

#### *3.2.11.1 Summary*

With the approved renovation, the new Humboldt Bay Offshore Wind Heavy Lift Marine Terminal will be capable of handling large heavy cargo vessels, OSW floating platform development, integration, and decommissioning, and other maritime activities. The terminal will initially support up to 1.6 gigawatts (GW) of FOSW in the Humboldt lease areas.

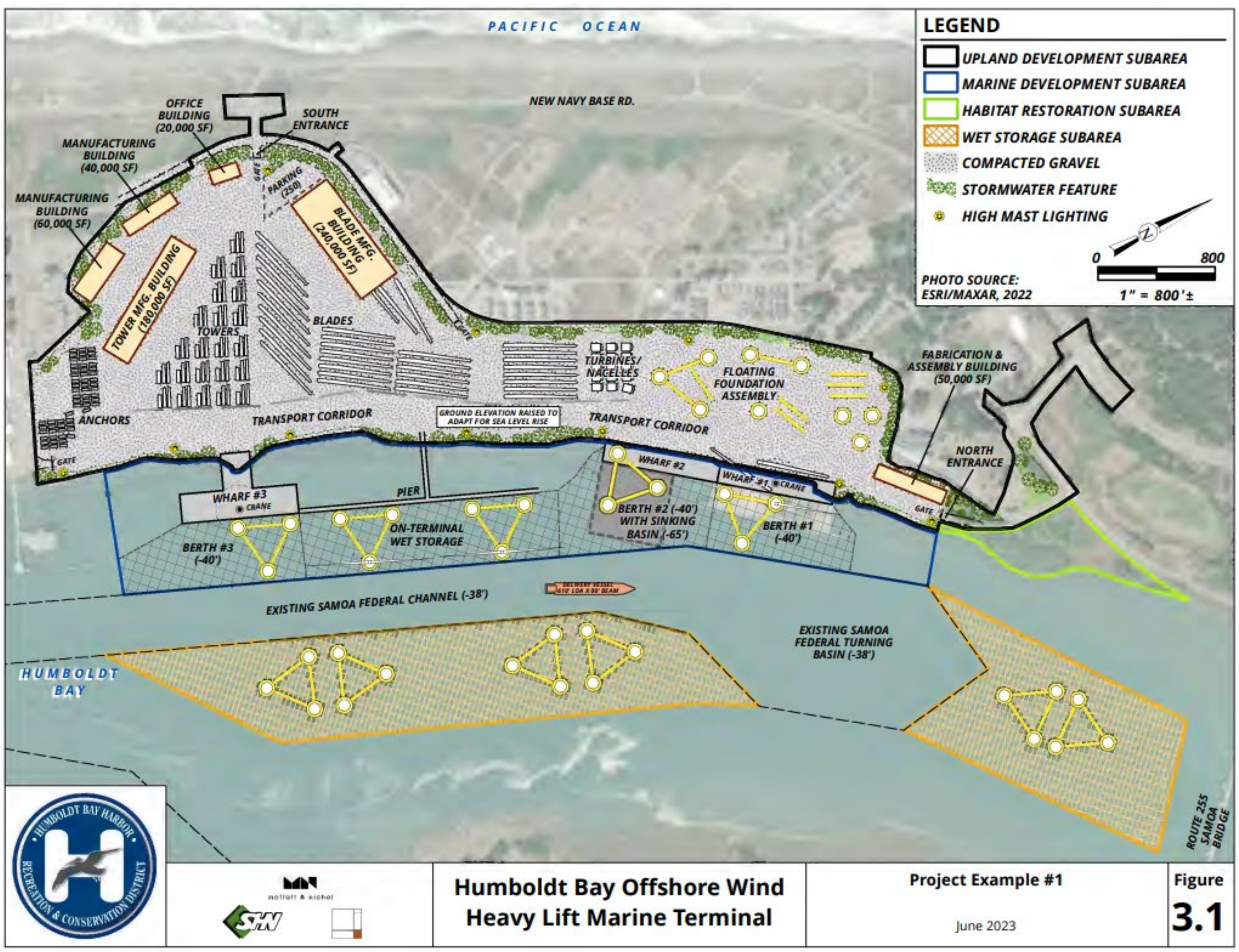
Crowley has entered into an agreement to exclusively become the developer and operator of the port. The company hopes to start construction on the terminal in late 2024. The first phase, and major focus, of the project is a 98-acre plot to serve as a laydown yard for turbine components. The terminal will include onsite manufacturing and fabrication facilities that receive raw materials, create larger components, and provide ample space for storage.

Project design is still ongoing and three conceptual plans demonstrating how the site may be developed have been presented. Project example no. 1 is shown in Figure 19. All conceptual plans so far indicate an extensive laydown area, wet storage area (dredged to about 40 feet mean lower low water), the construction of up to three wharfs totaling a maximum of approximately 2,500 feet along the shoreline, and multiple operation and fabrication buildings.

Significant facility upgrades are required at the port including quayside strength, crane capacity, and berth dredging. According to a study done by the Schatz Energy Research Center, CapEx costs for port upgrades at Humboldt to support commercial scale OSW project assembly and O&M will range between $130 and $310 million and floating substructure fabrication would range between $50 and $100 million. However, Crowley has stated it is too early to provide cost estimates for the project.

**Figure 19. Project Example No. 1 (June 2023)**

*Source: Notice of Preparation of Draft Environmental Impact Report*



# 4 Cost Assessment Purpose and Methodology

## 4.1 Introduction

### 4.1.1 Base-Case Definition for Cost Analysis

**Three Representative Cost Cases**

This section presents a cost comparison of three representative projects from the three technology concepts outlined previously in this report.

Rather than the broad technology concepts, the focus here is on three specific cost cases outlined in Table 10, meant to reflect specific example sites drawn from the broader technology zones. These cost cases discussed in section 2.1.2 assume a more specific depth range than the technology concepts in order to best capture the range found across an actual project site, and due to the greater specificity needed to build up a cost model.

These three cost cases are meant to capture the key project design elements that lead to step-changes in costs as site depth increases.

Costs between the cases are differentiated by:

- **Depth:** WTG foundation design, substation foundation design, mooring system design, array cable design, and export cable design.
- **Distance from shore:** Offshore export cable distance, port transit distance for installation, and O&M activities.

The Marshalling Port and Export Cable used for this study are high-level measurements made by RCG's Geographic Information System (GIS) Team. Based on input from NYSERDA, the port distance is a representative measurement to the New York Harbor region, while the export cable distances are representative measurements to an average point of interconnection (POI) taken from the average of Zones J & K, the load zones of New York City and Long Island.

**Table 10. Cost Modeling Assumptions**

| | Cost Case 1 | Cost Case 2 | Cost Case 3 |
|---|---|---|---|
| **Turbine Size** | 20 MW, 275 m rotor diameter | | |
| **Project Size** | 68 WTGs, 1,360 MW total | | |
| **COD Year** | COD 2035 | | |
| **Marshalling Port Distance (nm)** | 100 | 110 | 150 |
| **Export Cable Route Offshore/Onshore (km)** | 185/15 | 200/15 | 280/15 |
| **Depth Range (m)** | 60—70 | 100—200 | ~2000 |
| **AoA Zone** | Zone 1 | Zone 1/Zone 2 | Zone 3 |
| **Foundation Concept** | Steel jackets with pin-piles | Steel floating semi-sub | Steel floating semi-sub |
| **Substation Foundation** | Fixed-bottom | Fixed-bottom | Floating |
| **Array Cables** | Traditional static | Partially dynamic | Fully dynamic |
| **Mooring Spread** | NA | 6x Catenary | 6x Semi-taut |
| **Anchor Concept** | NA | Drag-embedded | Suction buckets |

* The cost scenarios utilize steel over concrete due to its industry-wide use in existing floating projects. Concrete's logistic and regional supply constraints make it less feasible. The reasoning for the use of steel over concrete for the cost modeling scenarios is summarized in section 3.1.4.

## 4.1.2 Approach and Purpose

The approach and key sources used for cost forecasting as well as the purpose of the exercise is described below.

### *4.1.2.1 Approach*

RCG has utilized its understanding of the current U.S. OSW market which, combined with a global view of technology innovation and cost declines in mature markets, forms the basis of projections for the three OSW project cases. The modeling approach used in this study has taken the form of a hybrid modeling-benchmarking exercise due to the early stage of the deepwater OSW market.

RCG has leaned on its understanding of the New York Bight's technical conditions and its global knowledge of fixed-bottom and floating wind cost, factoring in U.S. data points for any and all comparable packages.

Key data sources include RCG's global and U.S. market knowledge, its proprietary LCOE model for cost sensitivity algorithms, and NYSERDA input on the AoA and representative baseline buildout scenario.

#### *4.1.2.2 Purpose*

This early-stage cost analysis aims to present a representative cost comparison to support early-stage project planning across the three AoA Zones. The primary purpose of this cost forecast is to compare the relative competitiveness of the developable project areas in the AoA.

This assessment presents a reasonable early view of a gigawatt-scale wind farm constructed in the New York Bight with a COD year in the mid-2030s, but all cost estimates in this report must be considered in light of the early-stage nature of the projects, and the assumptions and limitations outlined in subsequent sections.

Estimates have high uncertainty by nature, due to likely changes in assumed project locations, the evolution required in the OSW supply chain, and inherent macroeconomic uncertainties which impact costs. Additional site characterization, project design conception, supply chain engagement, and market maturation are essential to validate and update the numbers presented throughout this report.

### 4.1.3 Cost Forecasting Methodology

RCG's global cost forecasting model has been utilized for this analysis. The underlying cost methodology is described below.

#### *4.1.3.1 The Renewables Consulting Group's Cost Forecasting Model*

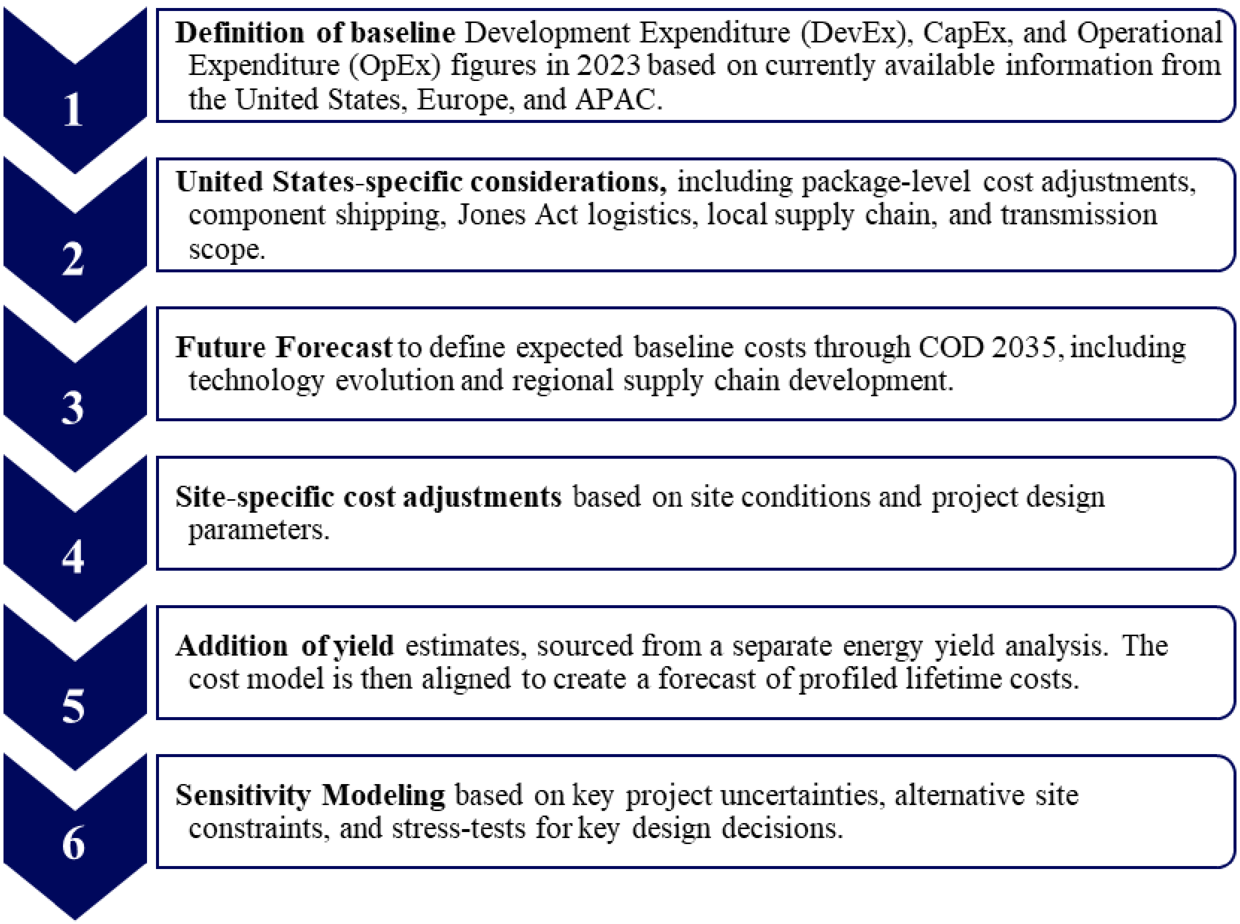
RCG's LCOE model, shown in Figure 20, is a cost forecasting tool that generates robust technical LCOE estimates for OSW globally. The model is underpinned by a series of cost baselines constructed using high-confidence data from 25+ OSW farms from the U.S. and abroad.

The tool synthesizes a series of market forecasts and site-level costing algorithms to produce a detailed cost and yield profile for each project scenario. Forward cost projections account for the market and technology landscape at COD and each project is individually adjusted based on site conditions with a series of package-level cost algorithms.

The resultant cost profile can be paired with a wind yield estimate in order to calculate a technical LCOE value for the estimated cost profile. For the purposes of this study, the energy yield assessment has been considered in a separate report as the focus of this assessment is lifetime costs.

This cost assessment leverages this tool to create a cost comparison of the three cost cases in this report.

**Figure 20. The Renewables Consulting Group Modeling Workflow**



### 4.1.4 Base-Case Definition

The base case cost outputs represent a reasonable view of each cost case's relative competitiveness based on technical costs.

#### *4.1.4.1 Level Playing Field*

The base case is structured to evaluate the relative competitiveness of each cost case area with a focus on each individual case's technical characteristics as the primary differentiators.

Deliberative assumptions in this base case have been made to create a neutral site versus site competition case. Accordingly, it is structured as an "overnight" case whereby all sites are developed with the same COD year, and each is most optimally interconnected and constructed.

Therefore, to create an even playing field, RCG evaluated each lease area at the same interconnection point and using port and logistics plans that sometimes overlap across sites. Likewise, sites are not differentiated according to onshore grid or port upgrade costs and are assumed to have the same onshore cable routing for costing purposes. Attempting to model these projects with a more likely combination of these constrained inputs would artificially advantage some sites and disadvantage others versus an "all else equal" approach.

#### *4.1.4.2 Universal Inputs*

In addition to the project-specific inputs outlined described later, all project cases assume the following baseline inputs:

- A generic 20 MW, 275-meter rotor diameter WTG.
- 68 WTG per project case, 1,360 MW total per project (an efficient project size for HVDC transmission building blocks).
- 2035 Commercial Operation Date (COD).
- 30-year project life.
- HVDC transmission system: 320 kV symmetrical monopole.
- Six mooring lines per floating wind turbine foundation.
- Both floating projects assume the same steel semi-submersible foundation with the same construction and procurement strategy: competitive procurement with foundations transported pre-assembled to the marshalling harbor.

### 4.1.5 Commercial Assumptions

RCG notes the following assumptions underpin its cost forecasting analysis:

#### *4.1.5.1 Assumptions and Cost Considerations*

- All CapEx and OpEx values are presented in real 2023-dollar terms; additional cost inflation would need to be applied to convert the figures presented here into nominal terms.
- Costs are based on historical average commodities pricing, excluding short-terms spikes observed in 2022. RCG has not applied any future price forecasts for raw materials markets up to COD 2035.
- The mid-2030s may be the first set of floating turbines constructed in 1000+ meter water depths. Sufficient industry experience exists from deepwater O&G, though the relative novelty of these technologies compared to shallower floating sites (especially floating substations and dynamic export cables) may drive added risk-premiums for first movers not included in RCG's baseline cost estimates.
- RCG has assumed that components will be procured on a competitive global basis for the purposes of this study. Accordingly, no-cost allowances have been made for added costs required to locally or domestically source components where it is not organically (excluding ITC bonuses) cost-effective.

#### *4.1.5.2 Inflation Reduction Act Tax Credits*

The Federal Inflation Reduction Act (IRA) recently signed into law creates substantial tax incentives for offshore wind, with bonuses for achieving domestic content requirements or for interconnecting into Energy Communities. A location is deemed an Energy Community under IRA definitions if it is a brownfield site, is located within a metropolitan statistical area or non-metropolitan statistical area that meets unemployment and fossil fuel tax revenue requirements or is located within or in a directly adjoining census tract that meets the coal closure category. Further, the IRA includes incentives for suppliers to invest in American manufacturing facilities for renewables. These incentives are expected to grow the domestic offshore wind supply chain and may ultimately drive and shape procurement priorities.

The financial impact of these tax incentives are not factored into the technical cost values estimated in this study because tax credits are a financial subsidy rather than a direct reduction to project expenses.

### 4.1.6 Cost Exclusions and Limitations

RCG notes the following considerations and scope exclusions underpin the cost forecasting analysis presented in this study.

### *4.1.6.1 Expanding on Relative Assessment*

In addition to the commentary included throughout this study, the following key exclusions and assumptions (see Table 11) underpin the cost numbers presented in the study:

- CapEx estimates cover assets from the offshore WTGs to the onshore substation, excluding port or grid upgrades.
- Costs include typical developer-investments in local facility preparation, though are not intended to cover major supply chain contributions as part of a market buildout strategy.
- Costs are intended to cover a standalone project, excluding potential premiums from front-loading costs across project phases (i.e., an O&M hub to support future buildout).
- Costs do not factor in the impact of any local content commitments or New York policy incentives. The project sources components and vessels are assumed to maximize technical cost and logistic efficiency alone.
- This assessment assumes no trade restrictions, and likewise, no additional costs have been added due to environmental, socioeconomic, permitting, or other macroscopic/development restrictions. Additional steel tariffs or other raw material restrictions have not been considered.
- CapEx costs exclude lease acquisition costs (i.e., BOEM auction payments).
- No stakeholder payments are included, such as to defense authorities, fisheries, communities, or other stakeholders.

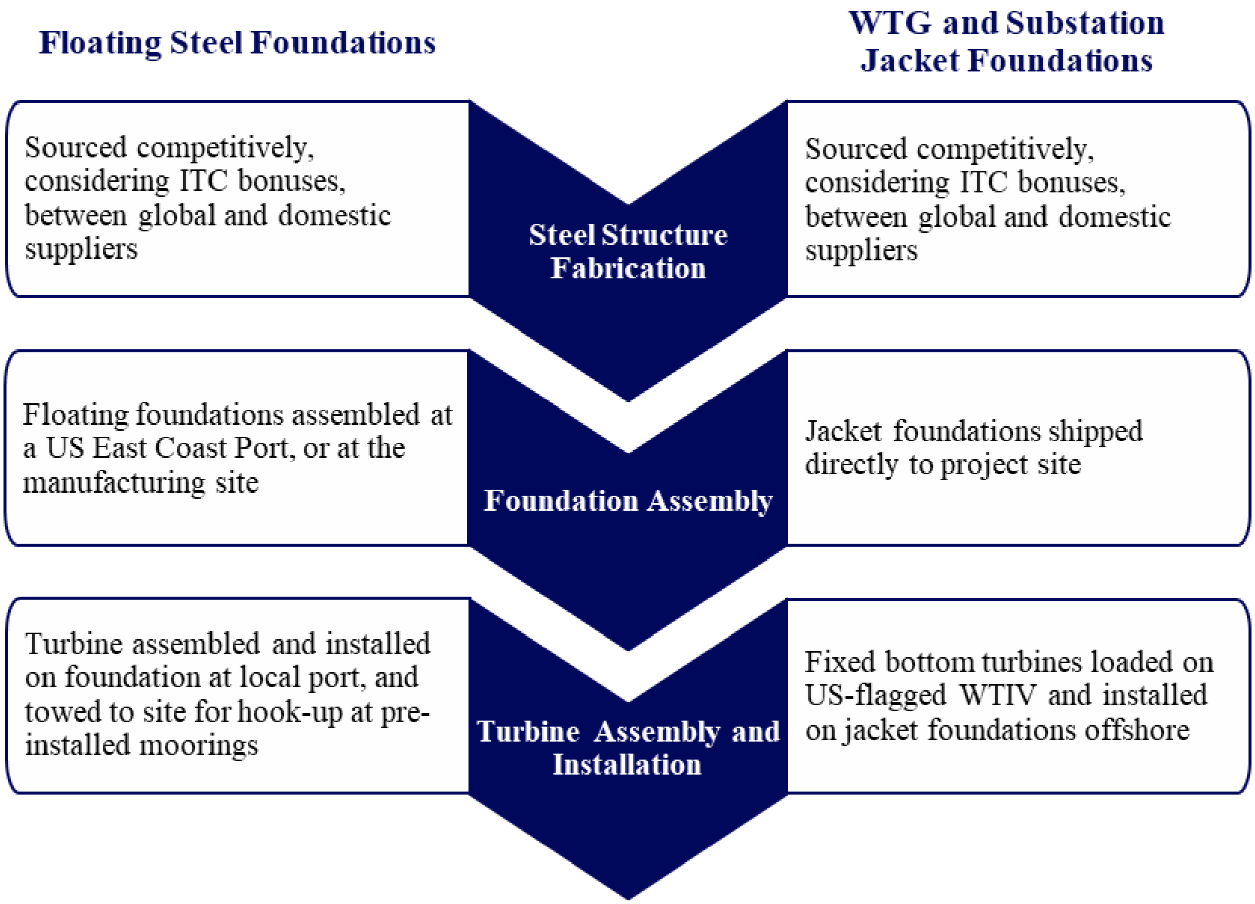
**Table 11. Cost Packages Considered in this Assessment**

| Packages Included | | | Costs Excluded |
|---|---|---|---|
| Generation CapEx | Transmission CapEx | Other CapEx | |
| Turbines | Offshore Substations | Project Management | Site Acquisition |
| Foundations | Offshore Export Cable | Contingency | Grid Upgrades |
| Mooring and Anchors (floating) | Onshore Export Cable | Insurance | Port Upgrades |
| Shipping, and Marine Operations | Onshore Substation | Auxiliary Project Costs | Stakeholder Compensations |
| Array Cables | | DevEx | Supply Chain Development |

## 4.1.7 Construction Philosophy

RCG assumes global competitive sourcing as an initial base-case procurement strategy. Figure 21 represents a base-case construction program for floating steel foundations as well as WTG substation jacket foundations.

**Figure 21. Base-Case Construction Program**




### *4.1.7.1 Key Considerations*

- Through discussion with NYSERDA, RCG has agreed to the following baseline assumptions for foundation procurement across the three cost cases. Unlike other packages, it is particularly important to define the procurement approach for foundation due to the wide range of logistics approaches feasible, each with their own cost and project risk implications.
- The objective of this base case is to present the lowest cost scenario that maximizes tax credit benefits where cost competitive to do so. Accordingly, this suggestion prioritizes competitive procurement and targeted domestic sourcing, rather than relying on a secondary effort to build out a complete local supply chain in New York State for FOSW.
- Due to the limited local port infrastructure for foundation manufacturing and foundation assembly, foundations are assumed to be delivered pre-assembled to the project site (fixed-bottom) or marshalling port (floating turbine).

- Notably, the IRA benefits include a bonus tax credit for sufficient domestic procurement; however, the requirements to qualify are not fully defined in the IRS guidance for floating wind steel foundations. Jacket foundations are identified as an "Iron and Steel" component and therefore must be 100% domestically sourced, unlike "manufactured products," which have a different and less prescriptive domestic content requirement. This level of definition is not yet available for floating wind foundations.

### 4.1.8 Summary: Project Modeling Cases

The key input assumptions and site characteristics shown in Table 12 underpin the cost modeling results presented in this study. These assumptions are based on NYSERDA input, RCG's recommendations, and GIS measurements.

**Table 12. Project Modeling Cases**

| | Cost Case 1: Upper Limits of Fixed-Bottom | Cost Case 2: Conventional Floating Wind | Cost Case 3: Ultra-deep Floating Wind | Units |
|---|---|---|---|---|
| **WTG Size** | 20 | 20 | 20 | MW |
| **Number of WTGs** | 68 | 68 | 68 | # |
| **Project Capacity** | 1,360 | 1,360 | 1,360 | MW |
| **Average WTG Water Depth** | 65 | 150 | 2000 | m |
| **Foundation Type** | steel jackets with pin-piles | steel floating semi-sub | steel floating semi-sub | |
| **Mooring Concept** | NA | Catenary | Semi-Taut | |
| **Number of Anchors** | NA | 6 | 6 | # per WTG |
| **Anchor Type** | NA | Drag-Embedded | Suction Piles | |
| **WTG Marshalling and Major O&M Port** | New York Harbor Region | | | |
| **Distance to Site** | 100 | 110 | 150 | nm |
| **Tow Distance from Foundation Assembly to Marshalling Port** | NA | 500 | 500 | nm |
| **POI** | Average of Zone J and Zone K | | | |
| **Transmission Concept** | HVDC | HVDC | HVDC | |
| **Offshore Transmission Distance** | 185 | 200 | 280 | km |
| **Onshore Transmission Distance** | 15 | 15 | 15 | km |

### 4.1.9 Metocean and Geotechnical

Limited metocean and geotechnical data are available for the AoA and, as a result, costs in this study are not differentiated according to these factors. A description of metocean and geotechnical conditions that may impact OSW development is provided in this section.

### 4.1.9.1 Metocean Conditions

Metocean refers to the combined effect of meteorology and oceanography. Metocean conditions include local surface wind, wind-generated local waves, swells from distant storms, surface currents from near storms, deepwater currents, and non-storm-related currents. Summer mean wind and significant wave heights impact installation and O&M activities, while extreme wave heights can impact foundation design and substation clearances. Specifically:

- Average metocean conditions primarily impact installations, O&M, and the design basis (fatigue loads).
- Seasonality impacts installation and O&M campaigns, dictating weather windows and vessel choices. These conditions must be viewed in light of transit distances. The calmest conditions occur during the summer months and are assumed to be the primary time for installation/ O&M campaigns.
- Extreme wave conditions primarily impact foundation and mooring design and thus costs. Extreme wave power (informed by both heights and wave period) set the maximum design loads and clearance requirements above sea level.

For this assessment, RCG found similar conditions to those found elsewhere in the U.S. Northeast, roughly in line with other open-ocean floating markets globally.

More data are needed to determine currents across the AoA. Tidal ranges and currents overall are expected to be only a minor cost consideration across the AoA, although these conditions must be factored into detailed design exercises.

- Surface currents introduce shear load to the mooring line system, mainly via interactions between the substructure and the currents. Semi-subs and tension leg platforms (to a lesser extent) are the foundation types most impacted.
- Seabed currents may impact seabed movements (e.g., sand waves) and scour. Seabed movements are an important consideration if surface anchors (drag-embedded) are used. Scour is particularly relevant for shallow anchors like suction caissons and gravity-based anchors. Accordingly, seabed currents are expected to be the primary consideration for future assessments of the three cost cases considered in this study.

In some floating locations globally, currents may exceed 1.0 meters/second (surface) in areas with high-tidal ranges and can be a key driver of the mooring system design.

### *4.1.9.2 Geotechnical Conditions*

Geotechnical conditions primarily affect anchor selection, mooring design, and marine operations for anchor/mooring installation and cable burial. Indirectly, the combination of soil conditions and bathymetry may impact site layouts due to localized challenges and mooring line footprints.

Overall, FOSW project viability is expected to be less sensitive to ground conditions than fixed-bottom OSW, cost impacts can be substantial given each foundation requires multiple anchor points.

Impacts to cable burial are similar to fixed-bottom offshore wind; however, dynamic array cables reduce the amount of cable to bury. Geotechnical conditions are also impactful for export routes, impacting burial costs and techniques.

Very limited data are available on soil conditions across the AoA. RCG has assumed the most cost-effective foundation and cable burial technology assuming largely sandy bottoms (as found elsewhere in the New York Bight), but a tailored study and surveys of ground conditions are required to validate these cost-impactful assumptions.

## 4.2 Results and Conclusions

The estimates shown in Table 13 result in a CapEx range of \$4.2 million to \$5.6 million per MW (\$2023), differentiated primarily by foundation design and export cable distances.

**Table 13. Cost Summary**

| | Cost Case 1: Upper Limits of Fixed-Bottom | Cost Case 2: Conventional Floating Wind | Cost Case 3: Ultra-deep Floating Wind | *Notes/Units* |
|---|---|---|---|---|
| **Cost Rank** | 1 | 2 | 3 | *1 = lowest cost* |
| **Nameplate Capacity** | 1,360 | 1,360 | 1,360 | *MW* |
| **WTG Size** | 20 | 20 | 20 | *MW* |
| **No. of WTGs** | 68 | 68 | 68 | *#* |
| **COD Year** | 2035 | 2035 | 2035 | *Representative* |
| **Export Route Length** | 200 | 215 | 295 | *km, incl. onshore* |
| **Site Depth** | 60–70 | 100–200 | ~2000 | *meters* |
| **CapEx per MW** | $4.18 m/MW | $4.88 m/MW | $5.62 m/MW | *m$ per MW real 2023* |
| **Annual Avg OpEx per MW** | $0.043 m/MW | $0.049 m/MW | $0.051 m/MW | *m$ per MW real 2023* |

### 4.2.1 Commentary

These results are meant to compare the three cost cases on an all-else-equal basis. To accomplish this, the nameplate capacity, WTG size, and COD year are modeled identically for each of the three cases.

The results of this cost analysis show an approximately 15 to 30% increase in lifetime costs from cost case 1 to cost case 3. For each cost metric, cost case 1 emerges as the most cost-effective technology due to its shallower depths and shorter port and transmission distances. Overall, there is a similar order of magnitude increase in costs from case 1 to case 2 and from case 2 to case 3.

Notably, these results are pre-IRA subsidies, and exclude some potential cost considerations such as port upgrades, supply chain development, interconnection costs, and BOEM auction payments.

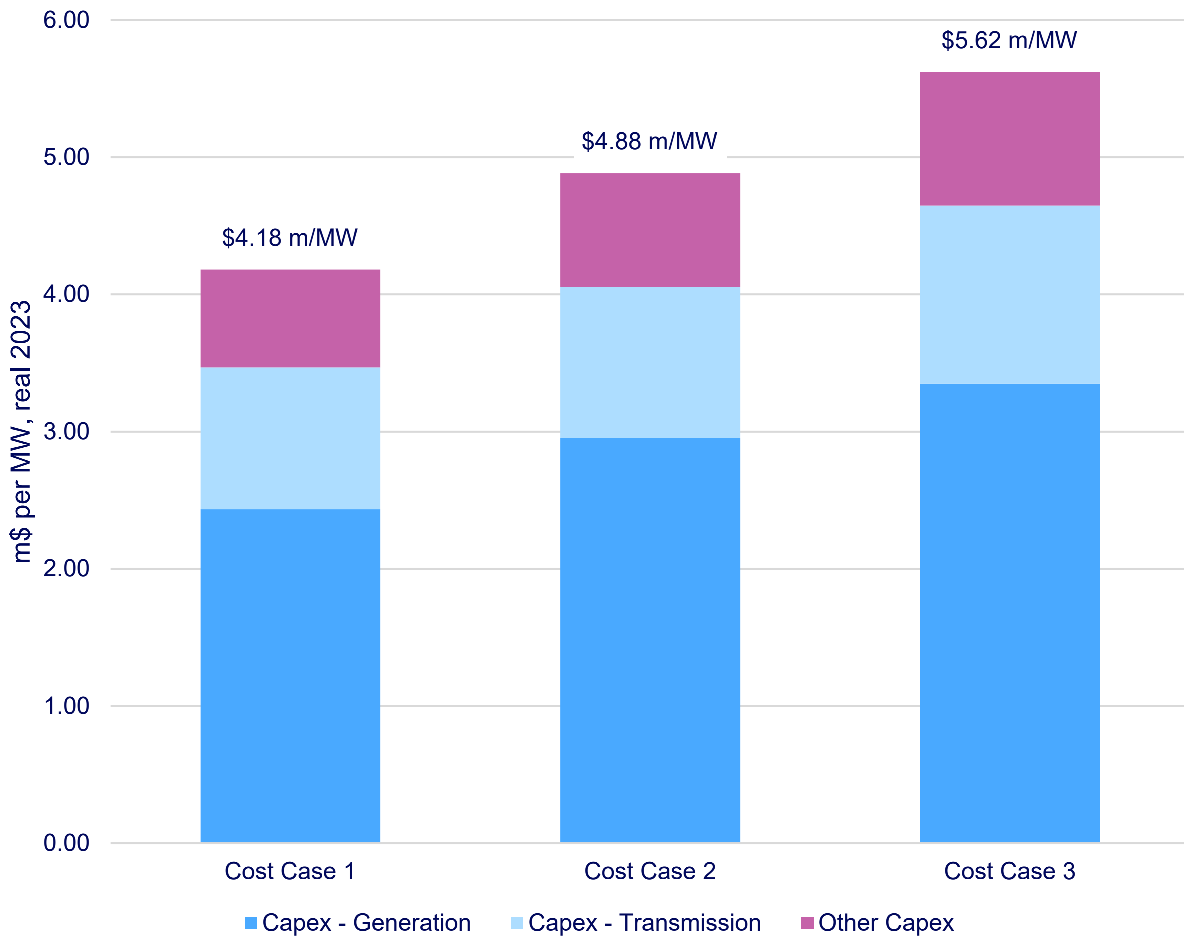
Overall, cost case 1 is expected to be a single-digit percentage cost increase compared to existing projects in the New York Bight. Benchmarking to current projects must consider (1) cost evolution to COD 2035 and (2) the costs excluded from this study, which would need to be considered in addition to the costs shown here—especially grid and port upgrade costs and supply chain contributions.

The estimates shown in Table 14 result in a total CapEx budget of $5.7 billion to $7.6 billion (real 2023) per 1,360 MW project case. A more detailed view of the CapEx per MW is provided in Figure 22.

**Table 14. Cost Summary ($m per 1,360 megawatts project)**

| | Cost Case 1: Upper Limits of Fixed-Bottom | Cost Case 2: Conventional Floating Wind | Cost Case 3: Ultra-deep Floating Wind | *Notes/Units* |
|---|---|---|---|---|
| **Cost Summary, $m total per project** | | | | |
| **Total CapEx and DevEx** | $5,687m | $6,641m | $7,644m | *real $2023* |
| **Capex – Generation** | $3,311m | $4,017m | $4,556m | *real $2023* |
| **Capex – Transmission** | $1,404m | $1,498m | $1,766m | *real $2023* |
| **Other Capex** | $972m | $1,126m | $1,322m | *real $2023* |
| **Annual Opex (Y0-Y5)** | $57m | $69m | $71m | *real $2023 per year* |
| **Annual Opex (Y6-Y15)** | $64m | $76m | $78m | *real $2023 per year* |
| **Annual Opex (Y16+)** | $53m | $63m | $64m | *real $2023 per year* |

**Figure 22. Cost Summary ($m per MW)**




### 4.2.2 Depth versus Distance

Overall, depth is considered the primary cost driver due to the step-changes in technology requirements across the AoA.

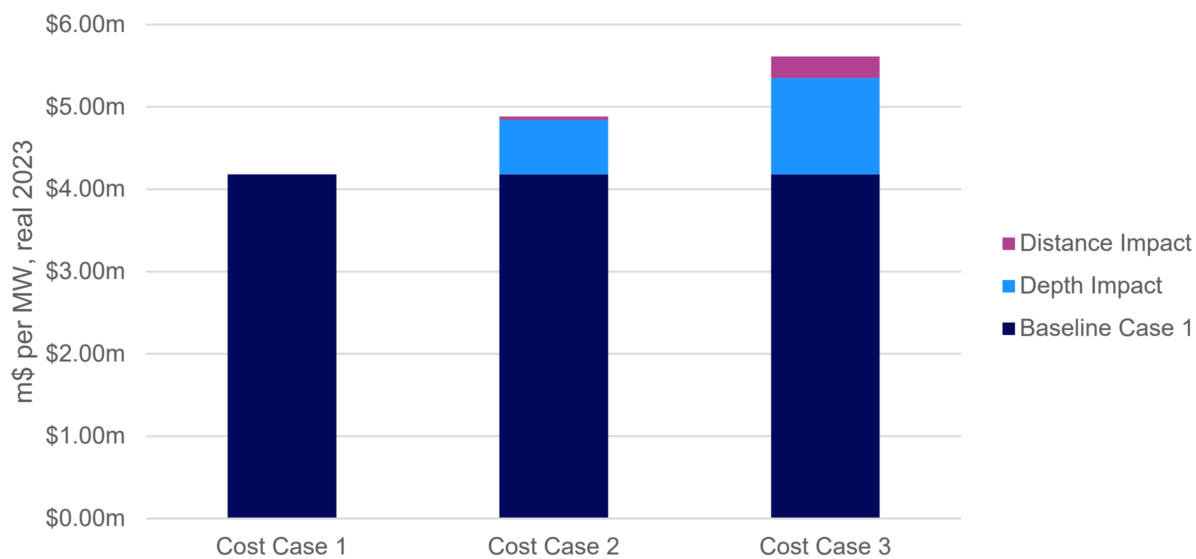
Table 15 outlines whether water depths or distance from shore are the key cost driver for each of the key offshore packages in this report.

This result is shown in Figure 23. In this chart, the depth and distance cost increases from cost case 1 to cases 2 and 3 are broken out independently, demonstrating the relative cost impact of these two parameters.

**Table 15. Key Cost Driver: Depth versus Distance to Shore**

| Package | Key Driver | Commentary |
| --- | --- | --- |
| WTG Supply | Depth | Floating wind may see cost premiums due to design differences and commercial risks. |
| Foundation Supply | Depth | Depth causes step-changes in cost by foundation design (fixed versus floating) and progressive cost increases to floating wind mooring costs. |
| Marine Operations | Distance and Depth | Installation times are driven by distance to port, but depth dictates the installation techniques by foundation and anchor design. In turn, depth dictates vessel requirements (e.g., heavy lift versus AHTSV versus OCV). |
| Array Cable | Depth | Dynamic cables add cable length/armoring needs, plus less market size and less track-record compared to fixed-bottom turbines. |
| Offshore Export Cable | Distance | Cable route length to shore is expected to exceed cost impacts of dynamic export cables (though this remains a key procurement risk due to immature supply chain). |
| Offshore Substation | Depth | Due to floating substation foundation, and potential impacts of motions on electrical equipment. |
| Other CapEx | Depth | Higher expected contingency, insurance, and project management costs for floating wind due to commercial interfaces, technical risks, and market novelty. |

**Figure 23. CapEx Results: Impacts of Depth versus Distance ($m per MW)**




These conclusions must be considered in light of the assumptions underpinning the three cost cases. Elsewhere in the OSW market, these conclusions may vary. For example, all projects here use HVDC technology. If one project were close enough to connect with HVAC transmission, then distance to shore would be the key driver of the offshore substation costs.

### 4.2.3 Commentary: Commercial Drivers

Competition and premiums for emerging offshore wind markets are described in this section.

#### *4.2.3.1 Competition*

Competition among developers and between supply chain partners is a critical underlying force driving CapEx and bid price declines globally. High competition drives cost innovation and puts pressure on developers and suppliers to maximize design and supply chain efficiency.

The level of competition within the supply chain is a major driver of uncertainty in estimating CapEx in this study, particularly for the floating wind farms. Due to rapid demand growth, supply chains may struggle to meet fixed-bottom demand through 2030, so suppliers may de-prioritize floating projects leading to higher costs. The following actions can maximize competition and decrease costs:

- Competitive open procurement, considering both local and global supply.
- Demonstrating sustained demand growth for key components.
- Collaboration between industry and governments to foster supply chain growth at key bottlenecks.

Notably, floating wind requires deeper collaboration between developers and foundation designers earlier in the development process. This may create tensions with competitive procurement of floating foundation design and should be considered part of the broader floating deployment strategy. By COD 2035, a growing pool of bankable floater designers and suppliers may engage in more open and traditional competitive solicitations to select foundation concepts. But before 2035, sustained early engagement and partnerships with foundation designers will be key to successful project development and foundation design maturation.

#### *4.2.3.2 Drivers of New Market Premiums*

Emerging OSW markets, such as floating wind globally and fixed-bottom markets outside of Europe, consistently see technical and nontechnical cost increases above just up-scaling costs due to project designs. These premiums account for the added complexity of novel offshore wind projects and typically result from:

- **Technical costs**, such as international vessel and equipment mobilization, and novel or more complicated transportation and installation logistics. For floating wind, these costs will manifest in floating port upgrades, added design conservatism for untested concepts, and more complex design and engineering scopes due to the level of optioneering possible for floating wind.

- **Industry set-up costs** due to the lack of trained labor forces, new permitting and contracting environments, and onshore infrastructure not set up for floating wind. These costs manifest primarily in project management, development expenditure (DevEx), and nontechnical CapEx. High-quality benchmarks are unavailable for commercial-scale floating projects, but new fixed-bottom markets show early mover nontechnical costs of up to two to three times the European levels.
- **Commercial premiums from suppliers:** RCG has observed suppliers charging top global developers up to 20+% premiums above European package costs in new markets. These premiums exceed the additional technical costs (e.g., shipping) alone and are understood to include new-market risk premiums. These costs are felt by first-movers and can be reduced through supply chain competition, strong purchasing power, and demonstrating certainty in sustained future demand. For FOSW, contract interfaces and risks between suppliers will be critical drivers of these premiums.

### 4.2.4 Conclusions

This study suggests that across the AoA, a fixed bottom site in 60-to-70-meter water depths will have approximately 16% lower lifetime costs than a 100-to-200-meter depth floating site, and a 33% lower cost than a 2,000 meter depth floating site. Key conclusions are provided below.

#### *4.2.4.1 Key Conclusions*

Depth is considered the primary cost driver across this analysis. This is primarily because the step-changes in technology as depth increases from 60 meter to 2,000+ meters have a greater marginal cost than added HVDC export cable length and port transit distances.

Notably, these results must be considered alongside the following key uncertainties, highlighting those with the greatest potential cost impact:

- This scope did not specify specific site locations; rather, it is meant to capture a range of possible areas across the AoA.
- Irrespective of technology choice, the overall evolution of the offshore wind market, such as the development of turbine sizes, will impact project LCOEs.
- The pace and location of floating wind deployment globally may vary and is a key determinant in technology innovation in floating foundation designs, the dynamic cable market, floating substation designs, floating electrical system requirements, and floating wind marine operations.
- Project budgets will ultimately be driven by port developments and the evolution of the U.S. supply chain, both of which are key to unlocking the technologies assessed in this report. For the purposes of this study, supply chains and ports are assumed to be sufficiently mature to support a gigawatt-scale project in 2035.

### 4.2.4.2 Opportunities for Further Refinement

This report presents RCG's forecast for COD 2035 deepwater offshore wind development from a 2023 vantage point. These results can help frame development priorities, but further analysis and supply chain engagement is required to increase cost certainty and define specific project sites.

This analysis necessarily relies on a set of key modeling assumptions. To further refine this forecast and the conclusions for development priorities, RCG recommends the following areas for additional analysis:

1. A site characterization study to identify the most promising potential project locations considering technical constraints, other marine stakeholders, and location-specific cost considerations.
2. A dedicated concept engineering study to refine and expand the three cost cases considering port capabilities for floating wind on the East Coast and site-specific project design options and site conditions.
3. An expansion of this base-case cost exercise with detailed sensitivity modeling to develop high-low cost cases and stress-test key project inputs.
4. A detailed look at the new IRA bill and domestic supply chain needs/capabilities for floating wind, assessing the implications for and incentives around supply chains for floating wind energy.

# 5 Bibliography

The majority of the content in this report is sourced from RCG's global expertise, supporting fixed and footing offshore wind projects, and RCG's internal Cost and LCOE model. The following are additional sources, as found in footnotes throughout: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