1. INTRODUCTION

Pursuant to direction from Governor Mills, the Maine Department of Transportation (MaineDOT) retained Moffatt & Nichol (M&N) to study the feasibility of constructing port facilities in the Searsport region to support the offshore wind (OSW) industry on the eastern seaboard. Currently, the 42 MW of installed capacity, 9 GW of awarded OSW power, as well as all future proposed commercial scale projects along the east coast of the United States (US) consist exclusively of turbines supported by fixed bottom foundations (monopiles and jackets) (see Figure 1-1 and Figure 1-2). Fixed bottom foundations are typically used in waters of 200 ft (+/- 60m) or less and works well along the eastern US seaboard due to the wide and shallow continental shelf. However, at water depths beyond 200 ft it becomes uneconomical and inefficient to install this type of foundation.

Figure 1-1: Block Island Wind Turbines with Jacket Foundations (Source: Vineyard Wind).

Figure 1-2: Coastal Virginia Wind Turbines with Monopile Foundations (Source: Dominion Energy)

In the US, wind lease development areas have been located between 15 and 45 nautical miles (nm) off the coastline. The majority of the continental shelf along the eastern seaboard is both wide and shallow with depths of 165 ft and approximately 25 nm from shore. This allows for use of traditional fixed foundations in the US OSW market. There are currently no sanctioned federal lease areas off the coast of Maine. However, ocean seafloor depth in this region differs significantly from the areas to the south. Depths of over 250 ft are routinely reached at distances of no more than 10 nm from the shoreline. This deeper seafloor profile precludes the fixed foundation methodology from use in the vast majority of waters off the state of Maine.

Floating OSW turbines have emerged as a solution for waters deeper than 200 ft. The depth limit of this technology has not been established, however there are currently multiple installations in waters depths greater than 328 ft.

The wind turbine generator (WTG) foundation or hull floats and is held in place via an anchorage system connected to the seafloor. This anchorage system typically consists of chain or wire tendons running from the floating foundation to anchors embedded into the seafloor. There are three main types of floating OSW foundations under consideration (Figure 1-3). Each type can be constructed from concrete or steel, or a combination of these materials.

Figure 1-3: Types of Foundations for Floating Offshore Wind Turbines (Source: NREL)

- Spar Buoy (left-side of Figure 1-3) – Steel or concrete cylinder with a large, ballasted mass at its lower end. This mass and its distance below the waterline are used to maintain stability. The foundation is held on station with a catenary chain or wire tendon attached to an anchorage system embedded into the seafloor. This foundation can extend up to 80 meters.
- Tension Leg Platform (right-side of Figure 1-3) – This foundation system is secured to anchors embedded in the seafloor using tensioned wire tendons. The system uses the buoyancy of the foundation hull to offset the weight of the foundation to maintain tension in the wire tendons at all times.
- Semi-submersible (center of Figure 1-3) – These foundations are buoyant and maintain stability through various geometries, ballasting capabilities and dampening apparatus.

The spar buoy foundation requires water depths of up to 265 ft at the assembly port and during tow out operations and was therefore not considered in this study. The tension leg platform foundation was also not considered in this study due to its lack of popularity with the current announced and operating floating OSW projects.

A full floating turbine assembly (Figure 1-4) is typically comprised of the following elements:

- Nacelle – The outer covering that houses all the energy generating components including the WTG, gearbox and the drive train.
- Tower – Column that elevates the nacelle to the proper hub height to capture the optimal wind speeds. Towers typical come in two to three sections.
- Blades – Used to capture the wind energy and transfer it to the wind turbine.
- Foundation/Hull – Provides a platform for the tower, turbine and blades.

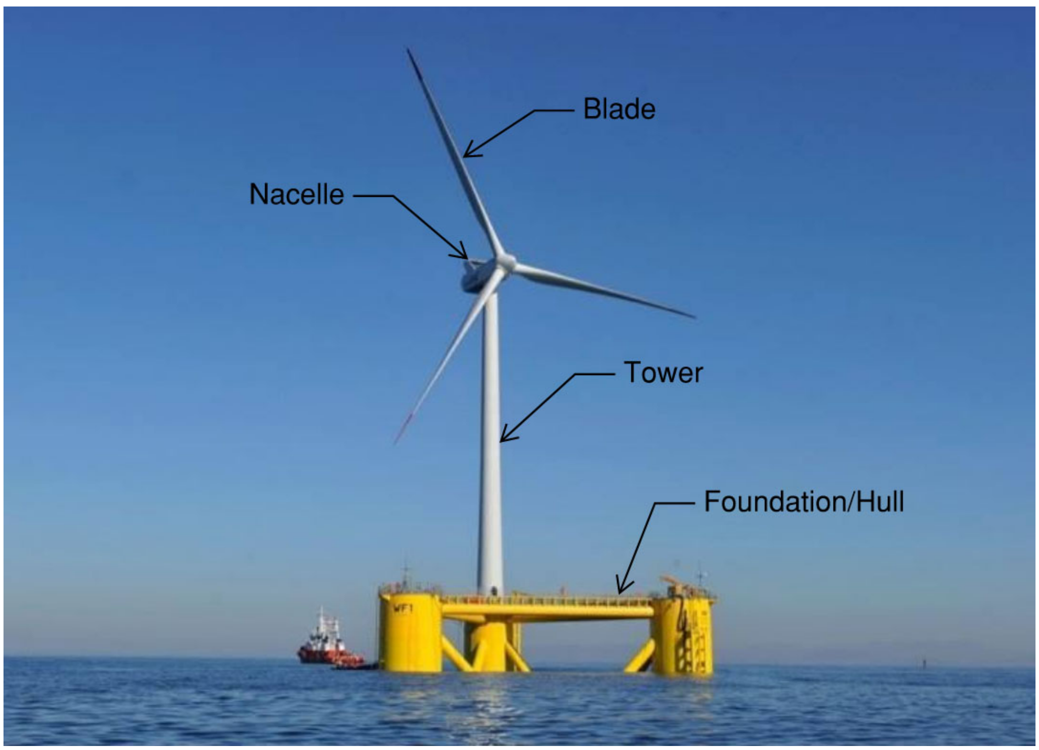

Figure 1-4: Floating OSW Components (Source: EDP Renewables)

Floating turbine technology is in its early stages and there are no existing commercial scale floating OSW installations anywhere in the world. However, there have been a series of demonstration projects installed. These types of projects are typically rated for less than 100 MW and are used as proof of concept for proposed floating OSW foundation and turbine technology. Currently there is a total of 85 MW of installed floating OSW power worldwide with an additional 50 MW now under construction (Table 1-1).

Table 1-1: Current Worldwide Floating Offshore Wind Installations (NREL)

Project Name	Location	Status	Project Size (MW)	Foundation Type	Turbine Size (MW)	Site Water Depth (ft)
Fukushima Phase 1	Japan	Operational	2	Semi-submersible	2	394
Fukushima Phase 2	Japan	Operational	7	Semi-submersible	7	394
Fukushima Phase 2	Japan	Operational	5	Spar buoy	5	394
Goto Sakiyama	Japan	Operational	2	Spar buoy	2	328
Hibiki Demo	Japan	Operational	3	Semi-submersible	3	180
Kitakyushu NEDO	Japan	Operational	3	Semi-submersible	3	328
Floatgen Demo	France	Operational	2	Semi-submersible	2	108
Hywind Demo I	Norway	Operational	2.3	Spar buoy	2.3	722
WindFloat Atlantic	Portugal	Operational	25	Semi-submersible	8.3	328
DEMOSath	Spain	Operational	2	Semi-submersible	2	262
Hywind Scotland	UK	Operational	30	Spar buoy	6	367
Kincardine Phase 1	UK	Operational	2	Semi-submersible	2	203
Kincardine Phase 2	UK	Under Construction	50	Semi-submersible	9.5	203

In North America there is one project, Aqua Ventus, in the permitting stage. This project proposes the installation of a single 10 MW turbine on a concrete semi-submersible foundation in the Gulf of Maine. This project is based at the University of Maine and, therefore, has particular significance to this study. It has also recently gained the backing of both Diamond Offshore Wind (Mitsubishi) and RWE (OSW development company). In addition, the State of Maine has recently filed an application with BOEM to open a floating OSW research array area off the coast of the state. The requested lease area is nearly 30 miles from the Maine mainland, approximately 15 sq miles in size, to support a demonstration project of up to 12 floating turbines. This research area will be one of the first steps in achieving the state's renewable energy goals of 80% by 2030 and 100% by 2050.

It should be noted that while there are currently only 85 MW of floating OSW installed, the prospect of floating bases gaining market share is well supported and, just as the fixed-base installations, have steadily improved their competitive position relative to conventional forms of energy over the past ten years. Floating bases will also leverage improvements in technology and reductions in production costs to improve its competitive offering over the coming decade, bringing its offering closer to both fixed-base and conventional energy sources.