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16. Abstract

Offshore wind (OSW) development is a new undertaking in the US. This project is a response to New Jersey's 2011 Energy Master Plan that envisions procuring 22.5% of the state's power originating from renewable sources by 2021. The Offshore Wind Economic Development Act called for at least 1,100 MW of Offshore Wind generations to be subsidized by an Offshore Wind Renewable Energy Certificate program. The overreaching goal of this research is to provide information and recommendations for the maritime aspects, both vessel and port interface. The study, using the European experience, identifies vessel types, vessel installation methods, needs and operating characteristics through all phases of OSW development. It also identifies regulatory or legislative requirements and/or other road blocks to the use of particular vessels. The study seeks competitive advantages and disadvantages of vessel acquisition, lease, construction or other alternatives. The study proposes solutions and recommendations that best position the State of New Jersey to be the national leader in OSW development, including potential interstate or cooperative endeavors. Financial aspects and considerations of vessel acquisition are presented. The research also proposes a port/OSW industry interface strategy for short-, mid-, and long-term industry development. In general, the study identifies the maritime port life-cycle requirements for installation, construction, operation and maintenance based on geographic factors, and the potential for multi-use development at New Jersey's East Coast ports. Finally, the study highlights the economic impact of OSW development on the state population and the energy-generating industry. The study recommends the development of a clear OSW policy with a commitment of budgets and in partnerships with industry and other stakeholders.

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EXECUTIVE SUMMARY

Offshore Wind (OSW) development is in response to New Jersey's 2011 Energy Master Plan with 22.5% of the state's power originating from renewable sources by 2021.

The objective of this research is to identify the critical maritime components of OSW industry development for installation, construction, operation and maintenance of OSW. The research focuses on:

1. Identifying vessel types, needs and operating characteristics through all phases of OSW development. Identifying regulatory or legislative requirements and/or other road blocks to the use of particular vessels. Identifying competitive advantages and disadvantages of vessel acquisition, lease, construction or other alternatives. Proposing solutions and recommendations that best position the state of New Jersey to be the national leader in OSW development, including potential inter-state or cooperative endeavors.
2. Proposing a port/OSW industry interface strategy for short, mid-, and long-term industry development. In general, identifying the maritime port life-cycle requirements for installation, construction, operation and maintenance based on geographic factors, potential manufacturing, labor pool, and port development.

The project team was led by the principal investigator of SUNY Maritime and included the engineering firm CH2MHill and energy business consultants Douglas-Westwood.

To determine vessel requirements, the team members prepared a series of scenarios to determine possible paths of development for the New Jersey and the Atlantic Coast offshore wind industry over time. The scenarios were divided into three categories: sporadic development, steady growth and rapid development as indicated in Table ES1.

Table ES 1 - Cumulative Installed Capacity by Rollout Scenario

	Atlantic Coast		New Jersey	
	2020	2030	2020	2030
Sporadic Development	1,000 MW	2,500 MW	350 MW	1,000 MW
Steady Growth	2,000 MW	6,000 MW	1,000 MW	2,000 MW
Rapid Development	2,500 MW	12,000 MW	1,100 MW	3,000 MW

Source: Douglas-Westwood, "New Jersey Offshore Wind Outlook," p. 1, April 1, 2013.

We assume the distance from the staging port to the offshore wind sites is approximately 120-150 miles and that the weather windows range from 65% (the European experience) to 80% of the time.

MW development drives vessel demand and staging port characteristics. Vessel demand is also affected by turbine size, foundation, distance to shore and other factors. We assume 5 MW and 6 MW turbines predominate during the forecast period. In the two lower growth scenarios, we assume most foundations are mono piles; in the high growth scenario, jacket foundations predominate.

The extended study describes and identifies the technical characteristics of OSW farms, OSW farm installations, construction methodologies, inspection, testing, certification, operations, maintenance and security. The study provides details about the vessel types and functions and New Jersey's place along the East Coast for OSW farms. An economic impact analysis is also provided. The vessels, which come in different sizes and flags, include:

- Survey vessels
  - Environmental surveys
  - Geophysical survey
  - Geotechnical survey
- Jack-up vessels
- Turbine installation vessels
- Cable-lay vessels
- Heavy lift vessels
- Tugs
- Barges
- Offshore supply vessels
- Personnel transfer vessels
- Heavy maintenance vessels

The study indicates that:

- The Jones Act indirectly governs the installation process and costs.
- The bulk of the economic benefit to New Jersey from offshore wind will be from wages and onshore overhead related to turbine installation and operations and maintenance activities.
- The vessel demand by vessel type depends on the adopted growth scenario.
- Offshore wind developers face the choice between three installation strategies:
  - US Jack-up Strategy
  - US TIV Strategy
  - EU TIV strategy
- For a 200MW project the most cost-efficient solution is to use a jack-up vessel during the initial phases. At larger capacity it is recommended to construct a purpose-built US TIV.
- The installation vessels can be owned by: offshore wind construction or service companies, financial entities, wind farm developers and major utilities.
- The similarity of the US East Coast to the European market provides guidance for New Jersey.
- The offshore industry structure and function are based on five key sub-sectors in the offshore wind farm supply chain development:
  - Vessels
  - Ports
  - Electrical infrastructure
  - Wind turbine
  - Substructures (foundations)
- Staging port selection and installation is based on choosing between manufacturing ports and staging ports only.
- The offshore staging ports' characteristics are divided between criteria factors and sub factors.
- The port ranking is based on an overall grade as follows (Table ES 2):

Table ES 2 - NJ Port – offshore wind port ranking summary

Port Name	Overall Grade	Rank
Port Jersey (Global)	98	A+
Port of Bayonne	93	A
Port Newark	90	A-
Beckett Street Terminal	85	B
Port of Paulsboro*	78	C+

*Once port construction is complete, the Port of Paulsboro will rank similarly with ports above it.

- There are substantial benefits to be gained from the development of offshore wind power in New Jersey. These advantages include:
  - the creation of a new high-tech industrial sector in the economy
  - increase of manufacturing employment
  - increase of port infrastructure development
  - the development of offshore wind power cluster
  - value creation in the offshore wind power supply chain
  - R&D and education
  - greener energy mix for New Jersey

We recommend that New Jersey:

- Determine the OSW turbine generation that is planned for installation in order to be more specific about the equipment needed.
- Determine lead time for building vessels.
- Revisit the port preparation criteria for access to the port with the selected OSW turbine components dimensions.
- Identify the suppliers of equipment and the supply chain whose use is intended for delivery of components, given the access characterisitcs of each port.
- Identify benefits from getting into agreements with other states for OSW installation.
- Learn from other countries the time it takes from order to delivery.
- Develop an OSW power industry cluster of developers, manufacturers, logistics service providers, education & research institutes, industry advocacy groups, and government institutions.
- Map the offshore wind power supply chain.
- Encourage public-private partnership in order to bring in private sector expertise and investments.
- Encourage offshore oil & gas industry participation in order to draw on the oil & gas industry skills, knowledge and technology all the way to partnering.
- Develop human resources and R&D in order to increase R&D and the intellectual capital to gain a competitive advantage on the East Coast.

New Jersey has limited renewable options other than offshore wind.

BACKGROUND AND STUDY OBJECTIVES

New Jersey's 2011 Energy Master Plan envisions procuring 22.5% of the state's power originating from renewable sources by 2021. Offshore Wind (OSW) development is a significant goal of the current Administration and the current policy framework for OSW development is fixed by the Energy Master Plan (EMP) and the Offshore Wind Economic Development Act (OWEDA). The OWEDA called for at least 1,100 MW of Offshore Wind generations (i.e., wind farms[(1)]) to be subsidized by an Offshore Wind Renewable Energy Certificate (OREC) program.

The overreaching goal of this research is to provide information and recommendations that ensure that the maritime aspects, both vessel and port interface, of OSW development do not impede the state's desire to make a significant contribution to the achievement of the green electricity production objectives set by the federal government and New Jersey's 2011 Energy Master Plan.

The New Jersey Department of Transportation's Bureau of Research commissioned a study to determine port and vessel requirements related to the State's offshore wind development program, in a project designated as the *Offshore Wind Development Research Project, No. 2012-04*. This Report comprises a component of that study.

The objective of this research is to identify the critical maritime components of OSW industry development for installation, construction, operation and maintenance of OSW. The primary aspects of this research are:

1. Identify vessel types, needs and operating characteristics through all phases of OSW development. Identify regulatory or legislative requirements and/or other road blocks to the use of particular vessels. Identify competitive advantages and disadvantages of vessel acquisition, lease, construction or other alternatives. Propose solutions and recommendations that best position the state of New Jersey to be the national leader in OSW development, including potential inter-state or cooperative endeavors.
2. Propose a port/OSW industry interface strategy for short, mid-, and long-term industry development. In general terms, identify the maritime port life-cycle requirements for installation, construction, operation and maintenance based on geographic factors, potential manufacturing, labor pool, known port development and the potential for multi-use development at New Jersey's smaller East Coast ports and marinas.

The project consortium was led by the principal investigator of SUNY Maritime and includes Rutgers, the State University of New Jersey; engineering firm CH2MHill; and energy business consultants Douglas-Westwood LLC. **For the complete research and analysis see the extended report and appendices.**

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[1] Wind farms consist of one or more independently operating wind turbines that generate power and are connected to an electrical substation that transfers the power to the grid. (Source: Worker Health and Safety on Offshore Wind Farms, Transportation Research Board (TRB), Special Report 310, 2013, pp.5.)

STUDY APPROACH

The overall study approach is a literature review and analysis. The methodology includes a review and analysis of the European experience and a technology review of equipment and institution process. The approach includes a specific analysis of OSW for New Jersey and a general approach for states along the Atlantic Coast.

In order to determine vessel requirements, the consortium members prepared a series of scenarios to determine possible paths of development for the New Jersey and, more broadly, Atlantic Coast offshore wind industry over time. Understanding both the state and regional aspects are critical, as offshore wind installation vessels active in New Jersey will also be used elsewhere in the corridor bounded by Norfolk/Hampton Roads, Virginia to the south and Boston, Massachusetts, to the north. Further, the Atlantic Coast will rely on a common supply chain. For example, turbines manufactured in one state will likely be installed throughout the region.

In the rollout scenarios, we consider the likely pace of offshore wind installation in both New Jersey and the region more broadly.

- Sporadic Development Scenario, New Jersey sees 350 MW installed by 2020, and 1 GW by 2030.
- Steady Growth Scenario, New Jersey sees 1GW by 2020, and 2 GW by 2030.
- Rapid Deployment Scenario, the State attains 1.1 GW installed by 2020, and 3 GW by 2030 (Table 1).

Table 1-Cumulative Installed Capacity by Rollout Scenario

	Atlantic Coast		New Jersey	
	2020	**2030**	**2020**	**2030**
Sporadic Development	1,000MW	2,500MW	350MW	1,000MW
Steady Growth	2,000MW	6,000MW	1,000MW	2,000MW
Rapid Development	2,500MW	12,000MW	1,100MW	3,000MW

Source: Douglas-Westwood, “New Jersey Offshore Wind Outlook,” pp. 1, April 1, 2013.

We discuss the rationale for these scenarios in Chapter 10 of the extended report, but in short, all of these are plausible, being consistent with the European experience at various phases of development as well as with the need for incremental power on the Atlantic Coast. In addition, the burden imposed on rate payers in these scenarios is in line with the experience in, say, Great Britain.

The aggregate megawatts installed are a key driver of vessel demand. However, vessel demand is also affected by other factors, most notably turbine size, as well as type of foundation, distance to shore and other factors. We assume 5 MW and 6 MW turbines predominate during the forecast period. In the two lower growth scenarios, we assume

most foundations are mono piles; in the high growth scenario, jacket foundations predominate.

In the case of New Jersey, we assume the distance from the staging port to the offshore wind sites is approximately 120-150 miles, about the distance from Elizabeth, Camden or Paulsboro to the New Jersey lease sites. For the Atlantic Coast as a whole, the distance from the staging port to the offshore wind site will vary greatly but is generally assumed to be 50-150 miles. We also assume weather windows ranging from 65% (the European experience) to 80%, as measured by buoys placed between Islip, New York and Cape May, New Jersey.

These factors, taken together, determine the vessel demand, installation strategy and logistics port. The study identifies the background of OSW farms and its technology and characteristics, OSW farm installations (strategies and guidelines), construction, inspection, testing, operations and maintenance, vessel types and function, New Jersey's place along the East Coast for OSW, European and other countries experience, and the economic impact.

NEW JERSEY IN THE REGIONAL CONTEXT

The history of the European market provides guidance for expectations on the US East Coast and New Jersey. Offshore wind evolved in Europe in relatively few countries: Denmark, Germany, the Netherlands, and Great Britain. All these countries share common traits. They are all industrialized, densely populated, coastal, high tax, wealthy and green, politically speaking. Offshore wind was able to develop by allocating capital costs to a large population with high incomes.

If we look for the analogous region in the United States, the East Coast, from Washington DC to Boston, meets these criteria. This area is relatively densely populated, with five of the country's largest cities spaced within five hundred miles north to south, 166 Nautical Miles (NM) to Rhode Island and 100 NM to Virginia. In the center of the region lies New Jersey, itself the most densely populated state in the union. A number of the country's wealthiest counties can be found in the region. New Jersey, downstate New York, Connecticut and the Washington suburbs enjoy some of the highest incomes in the country. These states also tend to have active governments and a greater propensity to devote public resources to renewable energy objectives. Finally, like northwest Europe, the East Coast has an excellent offshore wind resource in relatively shallow waters located near major load centers.

Offshore wind is an expensive business. Even a project with economies of scale may cost $6 million per megawatt of nameplate capacity and run into the billions of dollars in total. For example, Cape Wind, with a planned capacity of 468 megawatts (MW), has a projected capital cost of $2.5 billion, about $5.3 million per megawatt of capacity in arguably the country's single best offshore wind site.

In the United States, a number of federal programs exist to promote renewable energy, including offshore wind. These include investment and production tax credits, as well as

loan guarantees and other support mechanisms. Notwithstanding, the primary source of public support for offshore wind must come from the state level, that is, either from state taxpayers or electricity rate payers. Thus, state population size and the level of income per capita are both primary determinants of the scale of offshore wind which may be developed in any given state. In this, all states are decidedly not equal.

One method to determine the scale of potential development by state is to assess the viable ratepayer burden, that is, the capacity of offshore wind that a given state could install for a given increase in monthly utility bills per household. In the study, we have assumed a monthly increase in the $15-20 range per household as an acceptable premium per household for renewable power. Of the $6 million per megawatt of capacity, perhaps half might represent a requirement for public support above current utility rates. Thus, 1 giga watt of offshore wind capacity would require public support in the range of $3 billion. If we allocate this cost among the, say, 2.5 million households of Massachusetts and assume the amount would be retired in seven years, then the average cost per household per month in that state would equal approximately $18. This assumes that all costs are ultimately allocated back to households, and not businesses or other entities. To put it another way, if we assume that $18 per household per month represents the maximum appetite for renewables at any given time, then Massachusetts could afford to install about 1 giga watt of offshore wind every seven years.

We can apply this same methodology to other states to determine the scale of offshore wind which might be installed there. For example, Rhode Island has outstanding ports and offshore wind sites, but its small population suggests that it can only support 150MW every seven years, if we allow that $17 per household per month is its maximum budget.

New Jersey, by contrast, can afford 1.4 giga watts of capacity every seven years if we allow a monthly burden of $19 per household. Therefore, New Jersey can carry approximately ten times as much offshore wind development as Rhode Island.

New York has its own complicating factors. While its population is more than twice that of New Jersey, New York in many ways constitutes two separate economic and cultural regions. Downstate New York is dominated by New York City, with very high incomes and a tradition of significant government involvement. By contrast, Upstate New York has more in common with Pennsylvania or Ohio, and is characterized by a more rural environment, lower relative incomes, and a greater preference for small government. Further, Upstate New York has greater access to renewable power, whether from onshore wind or hydropower from Hydro-Quebec.

As the map (Figure 1) shows, the East Coast can be divided broadly into three geographic markets.

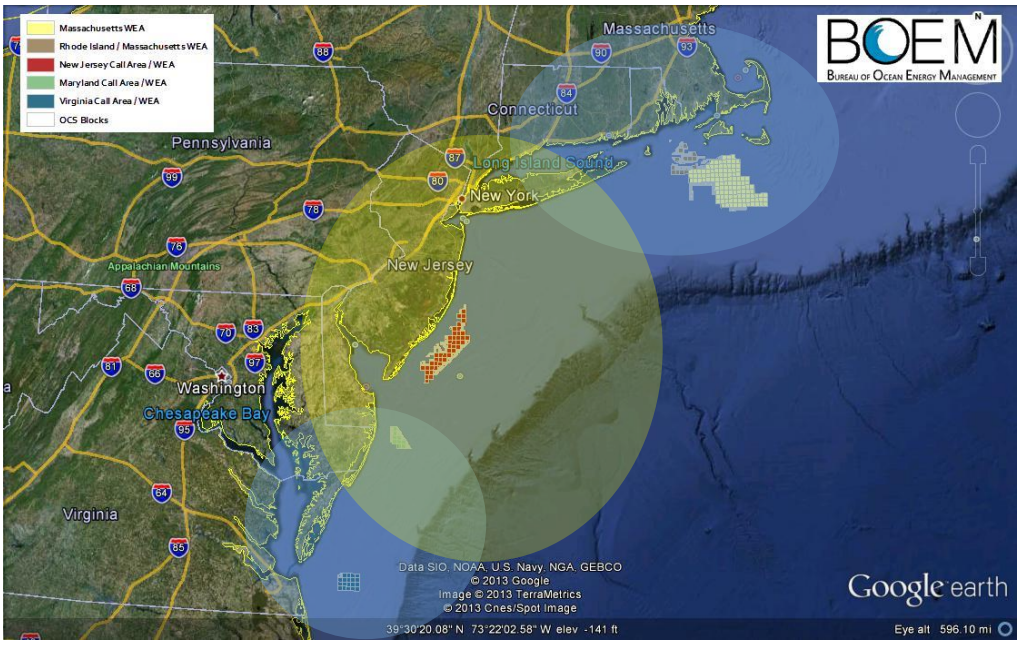


Figure 1.Regional Market Structure

- Rhode Island and Massachusetts dominate the Northeast. Both have suitable ports, a strong commitment to offshore wind, a notable maritime tradition, and projects in advanced stages of planning.
- At the southern end of the region lie Maryland and Virginia. Maryland is handicapped by the length of the Chesapeake Bay, which provides an ocean exit barely shy of the North Carolina border. The eastern shore of Maryland is lightly populated, and does not have significant heavy industry. Virginia, by contrast, offers excellent deepwater ports at Norfolk and Hampton Roads.
- Delaware, New Jersey and New York dominate the center of the region. Delaware's small population dictates that it could afford only about a tenth as much offshore wind as New Jersey. New Jersey has a number of options. The ports of Paulsboro and Camden, on the Delaware River near Philadelphia and potentially other ports on the Delaware River could easily support mid-Atlantic offshore wind installation.
- New York area ports could also serve the industry. This area is already congested, and both land and labor are expensive. But the location is ideal to serve New Jersey, New York and Connecticut, with good access to Rhode Island and southern Massachusetts, as well.

Thus, from a ports and vessels perspective, the Atlantic Coast offshore wind market would appear to segment into three clear regions: The New England ports, including New Bedford and Quonset; the Middle Atlantic ports, increasingly looking to be Paulsboro, Camden or other Delaware River ports; and the ports near Norfolk, Virginia.

Geographically bordering on the Atlantic Ocean, the State of New Jersey presents a total of 130 miles of coastline. An area is identified off the coast between Point Pleasant Beach (North) and North Wildwood (South) to support New Jersey's OSW program.

This zone appears best for its wind energy capture and proximity with port facilities. Eleven leased blocks are slated for OSW development in this zone. Developers have expressed an interest in the installation of over 12,000 MW and as a result a competitive bidding process will take place in 2012.

OFFSHORE WIND FARMS DESCRIPTION

Offshore wind farm is a complex power plant facility made up of offshore wind towers, turbines and cables. The plant generates electricity that is fed into an electric grid by cables. An offshore wind farm is visible from a distance.

The number of turbines that make up an offshore wind farm facility varies depending on the amount of electricity an OSW farm is expected to generate. Each tower and turbine in the facility is large. The wind farm distance from shore varies by location. Some wind farm locations are near or along navigation routes, fishing routes, bird migration routes, and other facilities. The location of an OSW farm could create various constraints or it can be effected by tidal range variation, the daily changing wind speed and the daily changing temperature effect on airflow.

In recent years the offshore turbines technology developed specifically for offshore use offering 5 MW[(2)] technology, 7 MW technology and is in the process of developing 15 MW technology as well.

Overall, the total weight increased from 217 tons to 757 tons for the RePower 6 model (Table 2). The total mass and maximum dimensions of each component also increased from the 3 MW to the 5 MW as indicated in Table 3.

Table 2 -Offshore Wind Farm Component - Technical Information

Model	Power (MW)	Hub (tons)	Blade (tons)	Rotor (tons)	Nacelle (tons)	Tower (tons)	Total (tons)
Vestas V80	2	18	6.5	38	69	155	217
Siemens 2.3	2.3	32	9	60	82	130	273
Vestas V90	3	40	9	67	70	110	247
Siemens 3.6	3.6	42	17	95	125	180	420
Areva M5000	5	62	17	110	233	200	543
RePower 5	5.1	84	24	126	290	210	656
RePower 6	6.15	84	24	156	316	285	757
Vesta V154	7	N/A	35	228	+/-390	N/A	N/A

*Tower weights are not given in the technical sheets. Values are evaluated from the tower weights of the existing turbines.
** Is not in the market. First prototypes are expected in 2012. Serial production will begin in 2015; its nacelle weight includes hub.
Source: EmreUraz, pp.24, also Source: Guillen, 2011.

[2] A single 5 MW wind turbine can supply enough energy annually to power 1,250 average American homes.

These enormous sizes of the components pose major challenges for the logistics of the infrastructure development with respect to vessel carriage, land carriage and port facilities.

Table 3- Approximate Mass and Maximum Dimensions of Wind Turbine Components

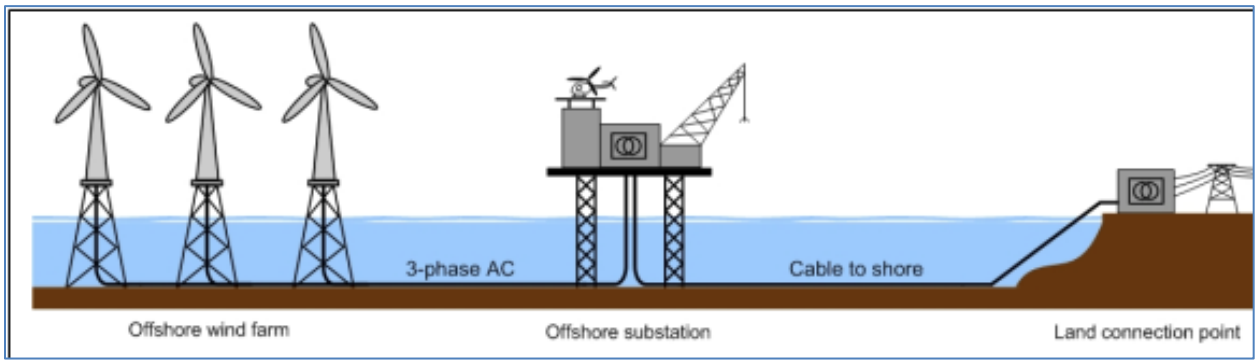
Component	5 MW	3 MW
Tripod	850 tons, L/W/H: 32/32/60m	550 tons, L/W/H: 20/20/60m
Jack Concrete	3,000 tons, D: 30-34 m, H: 60m	
Monopile		300 tons, D: 5.5 – 7m, L:60m
Tower Segment	125-150 tons, H: 35m	77 tons, H: 33m
Nacelle	350 tons, L/W/H: 21/8/9m	165 tons, 14m long
Rotor Blade	25 tons, D: 5m, L: 65m	15 tons, D: 5m, L: 55m
Rotor Hub	35 tons, D:6m, L:6m	18tons, D: 4m, L:5m
Complete Rotor	150 tons, D: 130m, L: 6m	100 tons, D: 110m, L: 5m
Rotor Bunny Ears	110 tons, L/W/H: 6/120/20m	85 tons, L/W/H: 6/110/15m
Sub Station	1,000 tons, L/W/H: 34/27/24m	

Source: Guillen, 2011.

The extended report concentrates on the second and higher generations of offshore wind power.

Offshore Wind Farm Facility - Technical Information

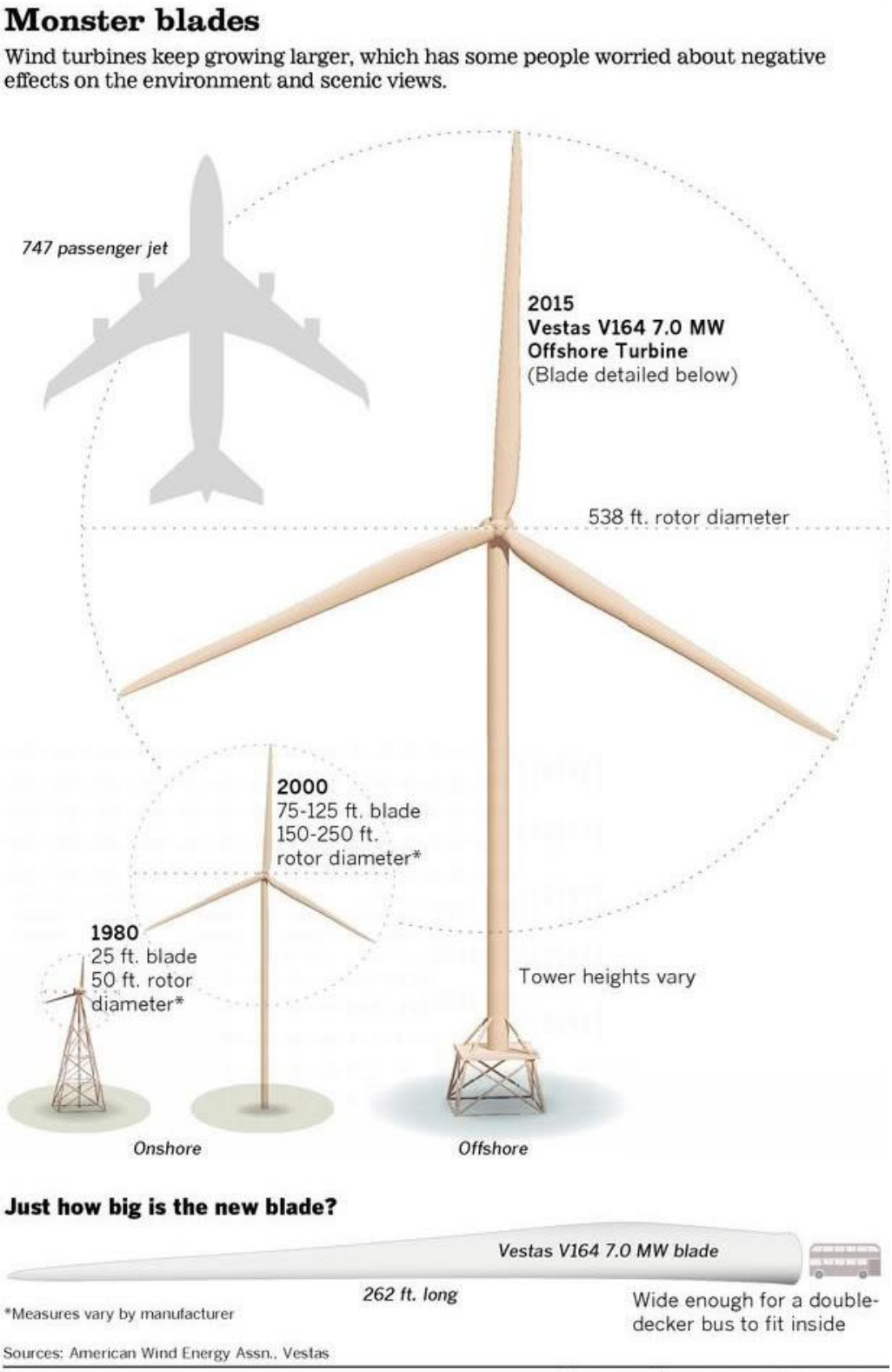
A wind farm is made up of a few static components: tower, turbine, cable and the foundation. The components are large and heavy(Box 1). The electricity that is generated in a turbine transformer is transferred via cables to a collection system, the offshore substation (Figure 2). From the offshore substation the electricity is transferred to an onshore transmission unit which connects to the land grid system. There are OSW farms that also include offshore wind condition observation towers.



Source: www.sse.com and AWS Truewind, *Offshore Wind Technology Overview*, Long Island - New York City, Offshore Wind Collaborative, September 17, 2009, pp. 5. (Accessed 04/20/13)

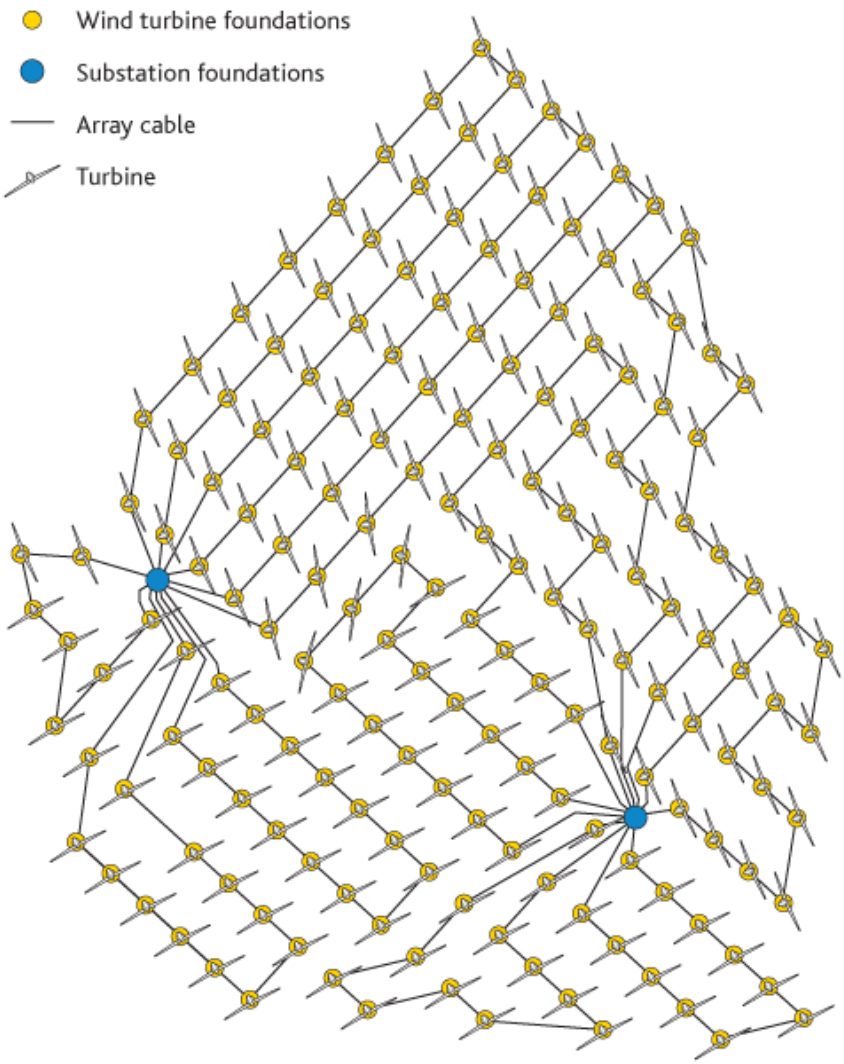
Figure 2.System View of an Offshore Wind Farm

Box 1: Offshore Wind Turbine Dimensions



Source: "Monster Wind Turbines,"http://www.superlogical.net/science/2011/07/monster-wind-turbines/#.UZkN5aPD-Uk (Accessed 5/19/21013)

An OSW farm could be made up of a large number of turbines (Figure 3) and it could also include a few offshore substations. New technology under developments for larger turbines includes floating turbines, new foundations, and new turbine designs to be installed further away from shore to capture stronger winds.



Source: Construction Updates, http://www.londonarray.com/news-developments/construction-updates/, (Accessed 5/23/2013)

Figure 3. Subsea Cable Map (London Array Site)

The construction of OSW has three phases: pre-construction (survey), construction (installation) and post-construction (operation and maintenance). Each phase utilized specialized equipment and requires different facilities and skills.

1. The first phase requires an environmental survey in order to obtain an Environmental Impact Assessment (EIA), geophysical survey, and geotechnical survey.

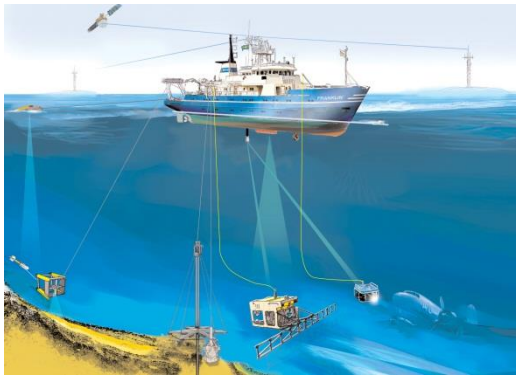
2. Installation stage utilizes a staging port and various transportation methods to get the equipment to the staging port and thereafter to the installation sites. The installation starts with foundation, transition piece, turbine installation, substation installation, and cable-laying operation. Some of the installation is carried out at the staging port prior to the installation site.
3. Operational support is provided 24/7, 365 days a year, including responding to unexpected events and turbine faults, weather monitoring, turbine condition monitoring plus customer and supplier interaction.

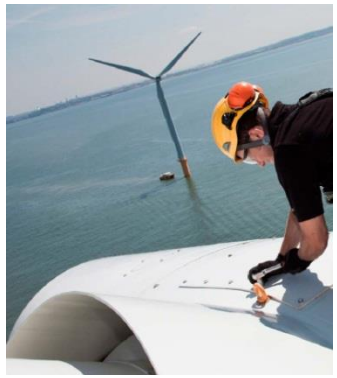
Finally, before an OSW farm can start operation, it must be commissioned. The commissioning process includes tests, inspections and finally commissioning.

Offshore Wind Power Supply Chain

The OSW construction and installation has a few phases (Figure 4). First there is a pre-construction phase which includes various surveys. This stage follows with the construction and installation of the wind farm followed by a post-construction phase of operations and maintenance. All stages require equipment in the supply chain of carrying out their mission.

Pre-Construction Phase **Surveys**	Construction Phase **Wind Farm Installation**	Post-Construction Phase **Operation & Maintenance**





	Environmental Surveys	Geotechnical Surveys	Geophysical Surveys	Foundation Installation	Transition Piece Installation	Turbine Installation	Substation Installation	Cable Laying	Routine Maintenance	Heavy Maintenance
Vessel Requirements Gross*	N/A	N/A	N/A	**Monopiles:** less than 24 hours from arrival at the site **GBS:** less than 24 hours from arrival at the site **Tripods:** 2-3 days from arrival at the site **Jackets:** 2-2.5 days from arrival at the site	Transition pieces can theoretically be installed at a rate of more than one per day, once the installation vessel is on the site.	Gross installation rate is about 1 day per turbine after arrival at the site.	Ca. 15 days for support structure and substation installation based on recent European projects (Thanet, UK)	N/A	N/A	N/A
Vessel Requirements Net**	Environmental surveys require ca. 15 – 20 weeks vessel time per project but are extended over up to 2 years.	Geotechnical surveys take ca. 8 – 20 vessel weeks per project to complete	Geophysical surveys need ca. 12 – 20 weeks of vessel time per project.	Net installation rate is ca. 2 days per foundation for monopiles and GBS units, and ca. 3 days for tripods and jackets.	Based on the recent European projects, ca. 1.5 days per transition piece is typical, when accounting for limiting factors.	Net installation rate is 2-3 days per turbine, depending on seasonal, weather-related and other factors specific to the given geographic region.	Substation installation requires ca. 5 – 8 weeks of vessel time per project after accounting for seasonal and weather constraints.	**Array cables:** ca. one day per array cable, cable laying with simultaneous burial can take 1.5 days per cable **Export cables:** typical rate is 3 miles per day (200 meters per hour) with simultaneous ploughing	One PTV is required for every 10 turbines through the construction phase and for every 25 turbines through the O&M phase.	One heavy maintenance vessel is required approx. for each 1,000MW of installed capacity.

Source: Douglas-Westwood

* Gross vessel time requirement: installation time from arrival at site

** Net vessel time requirement: installation time after accounting for seasonal, weather and other constraints

Figure 4. Offshore Wind Project Phases – Overview

Installation Process[3,4]

The OSW farm installation and the commissioning processes utilize equipment and space. The operation is both on shore and at sea. The general installation process starts with an inbound delivery of the wind Turbine components and materials via water or land to the staging port or terminal. The components are fully or partially assembled at the staging port before they are delivered, via water to the installation site as described in Figure 5.

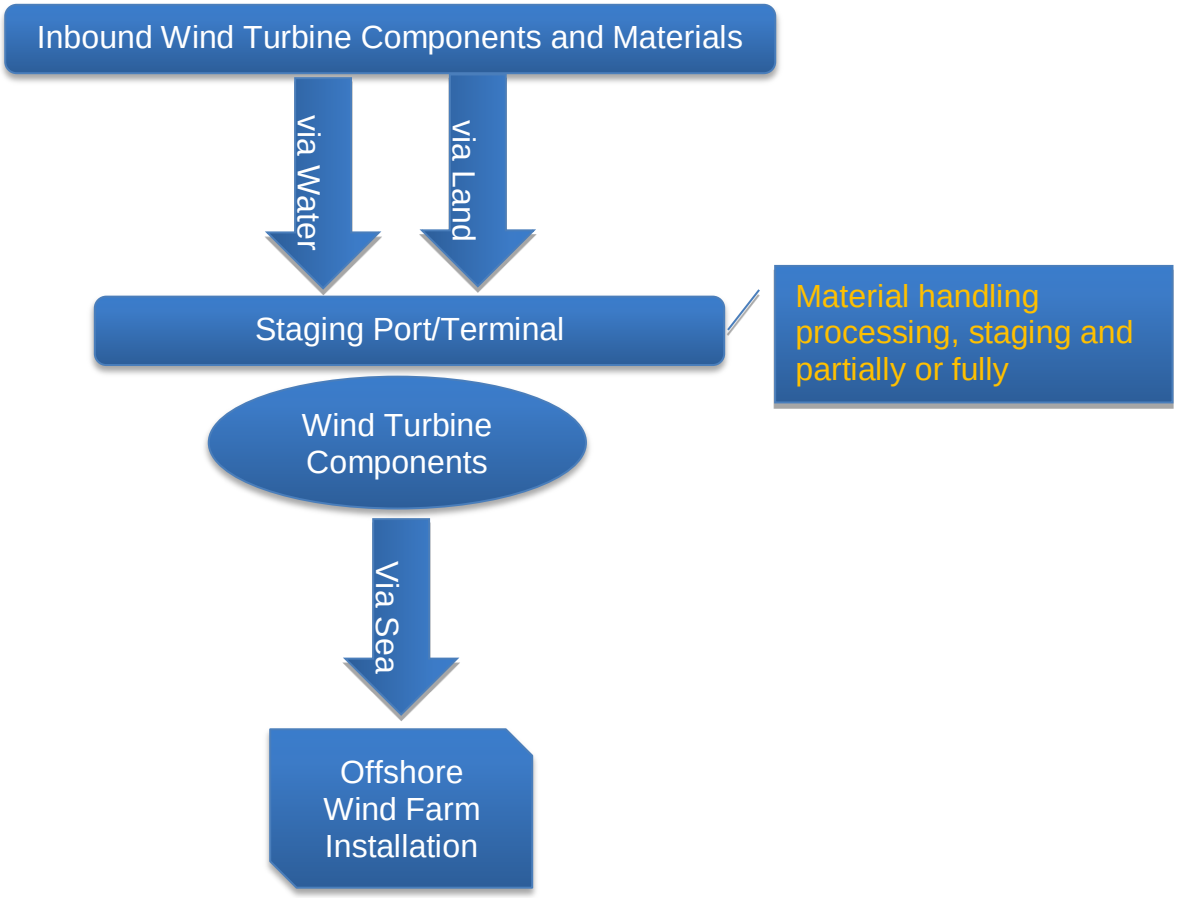
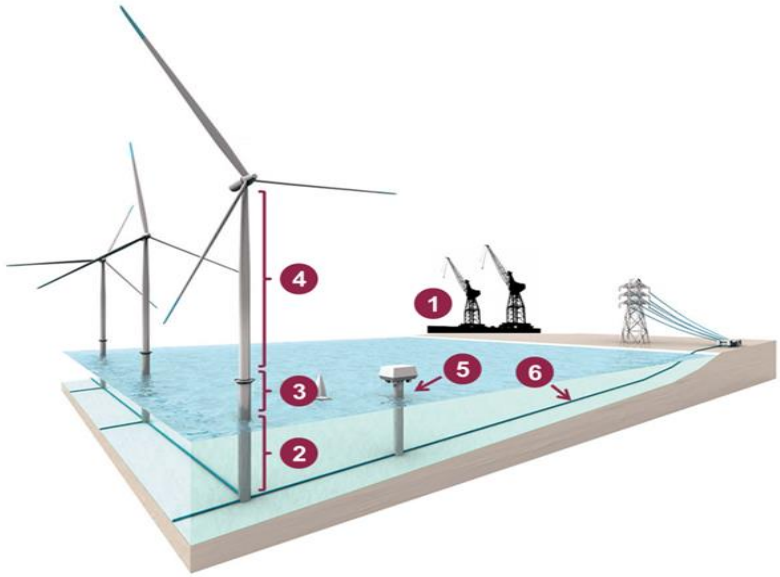


Figure 5.Offshore Wind Farm Installation Process

On shore the "construction port" or "staging port" is the base for all shore operations and logistics. In general, installation starts with foundation, substation installation and cable-laying operations. Figure 6 demonstrates the process.

[3] Douglas-Westwood
[4] A Guide, pp. 54-63



Port Logistics 1

- To the extent possible, turbine components have to be pre-assembled onshore.
- In the construction phase, staging ports need to be able to accommodate the pre-assembly and storage of foundation and turbine components.
- In the O&M phase, service ports have to enable quick loading of spare parts and 24/7 departure to the wind farm site.

Foundation Installation 2

- Method depends on foundation type. The most widely-used monopiles are driven into the seabed by large pile hammers, often by the same vessel used for turbine installation.
- Much heavier gravity-based and tripod-type foundations require vessels with heavy lifting capability.
- Floating turbines are pre-assembled onshore and towed to the site by tugs.

Transition Piece 3

- The transition piece is connecting the most widely-used monopile foundations with the turbine tower.
- They are typically installed by the same vessels as turbines themselves.
- Other foundation types are already fitted with transition pieces prior to installation (e.g. tripods), or do not require transition piece at all (e.g. jackets, gravity-based structures).

Turbine Installation 4

- Turbine installation can take several forms. Smaller turbines can be installed in one piece by heavy-lift vessels.
- The largest turbines are assembled piece by piece, typically by using purpose-built TIVs.
- Medium-sized turbines are typically assembled by using either the "bunny-ear" or the "rotor star" configurations (pictured).

Substation Installation 5

- Substations are pre-assembled onshore and installed at the site as a single unit, typically by a heavy-lift vessel, or by a jackup vessels with heavy-lifting capabilities.
- Substation foundations are also heavier than those used for turbines.
- Larger wind farms have multiple substations (roughly one for each 250 to 400 MW of installed capacity).

Cable laying Operations 6

- Array cables connect wind turbines with each other and the substation, export cables connect the substation to the onshore grid. Both array and export cables are installed by specialized cable-lay vessels.
- Offshore cables are typically buried under the seabed, either via trenching and burial, or via less costly rock dumping.

Source: Douglas-Westwood

Figure 6.Overview of the Offshore Wind Farm Installation Process

The installation process leads to contracts and equipment needs for “cable-laying (export and array), substation installation, foundation installation and turbine installation. …, construction port, …, sea-base support, …, commissioning.”[(5)]

The tower, nacelle and rotor al together are the turbine. These components can be preassembled completely or partially on shore before transporting them to the offshore site. This creates many alternatives for assembling. The vessel choice for transporting the turbine and foundation depends on the OSW farm installation site distance from the staging port, the pre-assembly choice (completely, partially or none), the sea depth, sea conditions, and weather conditions.

The OSW installation vessels presently used are not designed specifically for this type of operation. As turbines increase in size and weight and installation is carried out further away from shore in deeper waters to seek stronger winds, the vessels that are currently used reach their limits. The further the distance from the staging port, the less economical it is to move support and service vessels back and forth. Therefore, larger staging and service vessels are built with more space and services for the installing crew who will live on-board. The service vessel would stay on site for a long period of time serving as a floating hotel. Vessels of this type are identified earlier in the study.

OSW installation is a challenge due to the operation in the open ocean, frequently in harsh weather conditions of winds and high waves leaving a limited or narrow weather window for safe installation. Pre-installation could save time at the installation site. However, the tradeoff is potential damage to the turbine or its components during transport in rough seas.

Testing, Inspection, Commission, Operation, Maintenance and Security

The last step before an OSW farm can start operation it must be commissioned. The commissioning process includes a serious of tests, inspections and finally commissioning. The inspection is of a different nature at different stages of OSW development and manufacturing, some of which include: visual inspection, mechanical testing, electrical testing, insulation testing, protection testing, operation testing, safety testing, emergency operation testing, stability testing, sensors testing, and more.

It is normal practice for the supplier of the wind farm to provide a warranty for between two and five years. This warranty will often cover lost revenue, including downtime, to correct faults, and a test of the power curve of the turbine.

After commissioning, the wind farm will be handed over to the operations and maintenance crew (O&M). A typical crew will consist of two people for every 20 to 30 wind turbines in a wind farm.

The process of inspection and certification is handled by certified firms such as: American Bureau of Shipping (ABS) Consulting, ClassNK, SGS Renewable Energy Services (SGS), Det Norske Vertias (DNV), or others. A successful inspection

[5] A Guide, pp. 54

authorizes the OSW farm operation. Furthermore, every vessel used in the installation and/or maintenance stage must have been inspected and certified according to the Coast Guard rules and regulations for operation as well.

OSW is subject to theft, vandalism and terrorist attacks. Attacks could be at the staging port and the OSW farm. All need some security measures.

A security plan should be developed and implemented for every stage of development and installation. The security plan should match the security threats. The preventive measure could include, for example: water patrols, sensors, under-water technological protections, air patrol, divers, and others. A complete analysis and the appropriate strategy should be undertaken at an advanced stage of OSW farm planning for the staging port and the OSW farm.

Installation Strategies and Guidelines

The vessel operators have to comply with agencies' regulations such as:

1. Bureau of Ocean Energy Management (BOEM)
2. U.S. Coast Guard (USCG)
3. U.S. Army Corps of Engineers (USACE)
4. U.S. Environmental Protection Agency (EPA)
5. U.S. Fish and Wildlife Service (FWS)
6. Federal Energy Regulatory Commission (FERC)
7. National Oceanic and Atmospheric Administration (NOAA)
8. Occupational Safety and Health Administration (OSHA)

These agencies typically enter into Memorandums of Understanding (MOUs) with other federal and state agencies, and in some cases, tribal governments to delineate jurisdiction and facilitate cooperation and coordination.

Each of the agencies listed above has specific statutory and regulatory authority over offshore wind farms. The two areas of paramount concern related to the permitting and siting of facilities offshore are:

- The Energy Policy Act of 2005 amended the Outer Continental Shelf Lands Act to authorize The Department of Interior (DOI) to, in consultation with the Secretary of the Department in which the Coast Guard is operating and other relevant departments and agencies of the Federal Government, grant a lease, easement, or right of way on the Outer Continental Shelf (OCS) for alternate energy related uses of the OCS that produce or support production, transportation, or transmission of energy sources other than oil and gas (43 U.S.C. § 1337(p)(1)(C)).
- The Ports and Waterways Safety Act (PWSA) (33 U.S.C. 1223(c)) authorizes the Secretary of the Department in which the Coast Guard resides, to designate necessary fairways and traffic separation schemes (TSSs) to provide safe access routes for vessels proceeding to and from United States ports.

JONES ACT

A major issue, for consideration when installing the OSW farm is the Jones Act. Indirectly the Jones Act governs the installation process and the installation costs. In the United States, the law known as the “Jones Act” (Merchant Marine Act 1920 sponsored by Sen. Wesley L. Jones) which can be traced back to a law enacted in 1789 preferring U.S. vessels to foreign vessels in U.S. domestic commerce can have a substantial impact on offshore wind farm projects.

Section 27 of the Act restricts the “transportation of merchandise by water” between “points in the United States” to qualified U.S. vessels. Another section of the Act includes a workman’s compensation provision for seafarers. Today, federal maritime laws restrict the transportation of passengers, as well as towing and dredging in U.S. waters.

The Jones Act restricts certain activities to vessels, which must be built in the United States, owned by U.S. citizens (unless an exception applies), operated by U.S. citizens, and registered with the U.S. Coast Guard. By virtue of being registered with the U.S. Coast Guard, a vessel must be crewed primarily by U.S. citizens (a certain number of non-officer crew members can be permanent resident aliens).

The Jones Act applies to the transportation of “merchandise” between “points in the United States.” Merchandise is broadly defined to encompass most commercial items, although there are notable exceptions, such as for “vessel equipment.” Although “points” are not defined in the law, there are substantial administrative precedents on what constitutes a point. Every port and terminal in the U.S. is a “point in the United States” and, as such, the movement of commercial cargo between U.S. ports is also covered by the Jones Act. Moreover, any place within three nautical miles of the U.S. coast is a “point in the United States,” such that a vessel picking up damaged pipe or cable from the seabed within three nautical miles, and returning it to a U.S. port, is covered by the Jones Act as well.

The application of the Act outside of the three-nautical-mile limit is more challenging. The Jones Act generally only applies outside the three-mile limit by virtue of the Outer Continental Shelf Lands Act (OCSLA), enacted in 1953, and significantly amended since then. OCSLA indicates that a “point” outside the three-mile limit is anything permanently or temporarily attached to the seabed on the U.S. outer continental shelf, “erected thereon for the purpose of exploring for, developing, or producing resources.” Based on OCSLA itself, related laws, and judicial and administrative precedents, it appears that the concept of “resources” is limited to oil and gas resources.

Where the Jones Act applies as a matter of geography, it only applies, of course, to the transportation of “merchandise” between U.S. points. Therefore, the Jones Act doesn’t apply to a stationary vessel, such as a vessel engaged in offshore drilling. The Deepwater Horizon, a foreign vessel working on the U.S. outer continental shelf, is a good example of this rule. When applied to an offshore wind farm, it’s important to note that the Jones Act doesn’t apply to a stationary vessel installing a wind tower. This not

only follows from the oil and gas administrative precedents, but has also been confirmed by administrative rulings issued in May 2010 and February 2011. Numerous oil and gas related precedents also indicate that the Jones Act generally doesn't apply to the laying of pipe or cable— although dredging restrictions might apply, depending on how the pipe or cable are laid. This aspect of the Jones Act is obviously important to connecting offshore towers to the energy grid. Once a U.S. point is established (assuming the Jones Act applies geographically), such as when a pile is driven into the seabed, anything transported to that point from the U.S. coast thereafter is covered by the Jones Act under the rule established by OCSLA.

So, even if the installation vessel is foreign, once it creates a "point" through its activities, all wind tower components and parts brought for installation to that place from a U.S. port must be brought in a Jones Act vessel. Great care should also be taken if a foreign construction vessel moves from one construction site to another because such movements may again implicate the movement of "merchandise" between U.S. "points."

Some aspects of the application of the Jones Act to offshore wind farms are well settled, such as with respect to near-shore projects and direct construction activities. Other aspects, such as with respect to projects further from shore, are unsettled, leaving developers in an untenable position of uncertainty. One thing is for certain - the Jones Act will continue to play a significant role in the development of offshore wind farms.

The Jones Act is unlikely to constrain the development of the US offshore wind industry, although it will increase costs and delay installation in some cases. For two of the three firm US projects—Cape Wind and the Block Island demonstration project—the intended method of installation calls for barges or tugs to ferry turbine components to the designated offshore site. In the case of Cape Wind, installation can in all likelihood be accomplished using only US vessels. In the case of Block Island, the situation is more nuanced. The weights and dimensions of the proposed 6 MW turbines during installation may exceed the capabilities of available vessels in the United States. The employment of a specialized European TIV has been mooted as one potential solution, with the turbines components to be ferried to the installation location by US-flagged vessels.

Therefore, in the short to medium term, the Jones Act should not present an insurmountable obstacle to the development of the US offshore wind industry. In the longer term, the Jones Act may become a more substantial impediment. A US-built TIV may cost twice as much as an Asian-built counterpart, and the most sophisticated of these may exceed $300 million in cost. Should the offshore wind industry take off, the Jones Act may compel developers to rely on more costly or less efficient solutions than those available in Europe. But these concerns are well into the future. In the near term, the Jones Act should not impede the development of the offshore wind business in the United States, although it may increase project costs by as much as $20-40 million for a 100 turbine development, in our estimates.

INSTALLATION STRATEGIES ON THE ATLANTIC COAST

Offshore wind developers will face the choice between three distinct installation strategies in the Atlantic Coast, when planning fixed platform offshore wind projects. These strategies are:

- US Jack-up Strategy: the use of a US-built jack-up vessel, such as the RD MacDonald for offshore wind installation with feeder barge support
- US TIV Strategy: the use of a US-built TIV, which requires no feeder barge support
- EU TIV Strategy: the use of a European purpose-built TIV with feeder barge support

Turbine Parts for Installation

Floating substructures may open up additional strategies in the future, but floating technology is currently not considered to be commercially proven.

The key limiting factors underlying the three available installation strategies are the Jones Act and the limited availability of US-flagged installation vessels in the initial phases of offshore wind development in the US.

Vessel Economics in New Jersey under Various Installation Strategies

Our analysis on the vessel economics of an illustrative 200 MW project in the New Jersey OCS lease area indicate that the most cost-efficient solution would be to use a simple jack-up vessel during the initial phases of offshore wind development. As capacity additions ramp up, it will probably be justified to construct a purpose-built US TIV at some point in the future, which is still a more cost-efficient solution than to charter a relatively advanced TIV from the European installation fleet.

Our illustrative project is a medium-sized utility-scale offshore wind project consisting of 40 x 5 MW turbine units (Table 4). The distance between the wind farm site and the staging port is 144 nautical miles, which is roughly in line with the distance between the southern part of the New Jersey OCS lease area and Paulsboro. The travel time between the port and the installation site is 18 hours one-way at 8 knots of transit speed.

Table 4 -Indicative vessel economics in various installation strategies

Indicative Vessel Economics for Turbine Installation									
	Unit	RD MacDonald as Jackup		RD MacDonald as TIV		US Purpose-Built TIV		Euro TIV	
Sample Project - Installed Capacity	*MW*	200		200		200		200	
Sample Project - Turbine Size	*MW*	5.0		5.0		5.0		5.0	
Sample Project - No. of Turbines	*units*	40		40		40		40	
Mobilization/Demobilization Time	*days*	-		-		-		2 x 21	
Turbine Installation Time	*hours/turbine*	36		36		24		24	
Staging Port - Installation Site Distance	*nautical miles*	144		144		144		144	
Staging Port - Installation Site Shuttle Tim	*hours*	18		18		18		18	
Loading Time in Staging Port		-		12		6		-	
Feeder Barge Support	*yes/no*	One Required		Not Required		Not Required		Two Required	
Tug Support	*yes/no*	One Required		One Required		Not Required		Two Required	
Installation Vessel Dayrate	*$/day*	130,000		130,000		212,000		169,000	
Barge+Tug-related Dayrate	*$/day*	25,000		0		0		50,000	
Other Administrative Vessel Costs	*$/day*	0		0		0		6,760	
Total Day Rates	*$/day*	155,000		130,000		212,000		225,760	
Weather Uptime	*%*	65%	80%	65%	80%	65%	80%	65%	80%
Installation Period	*days*	96	78	154	125	88	72	62	50
Installation Cost	*$ mn*	15	12	20	16	19	15	14	11
Demobilization Cost	*$ mn*	-	-	-	-	-	-	9	9
Total Vessel-Related Cost	***$ mn***	**15**	**12**	**20**	**16**	**19**	**15**	**23**	**21**

Vessel Utilization in the Atlantic Coast

Sea state is a key determinant of vessel economics, with significant wave height being the most important consideration, as wind and waves are generally closely correlated (Figure 7). TIV vessel operators in Europe report average, year-round uptime of approximately 65% in western Europe based on sea state, with conditions more benign to the east, and harsher to the open sea in the west, for example, off the coast of Ireland. This uptime is based on average fleet conditions, but mostly those achieved by purpose-built TIVs.

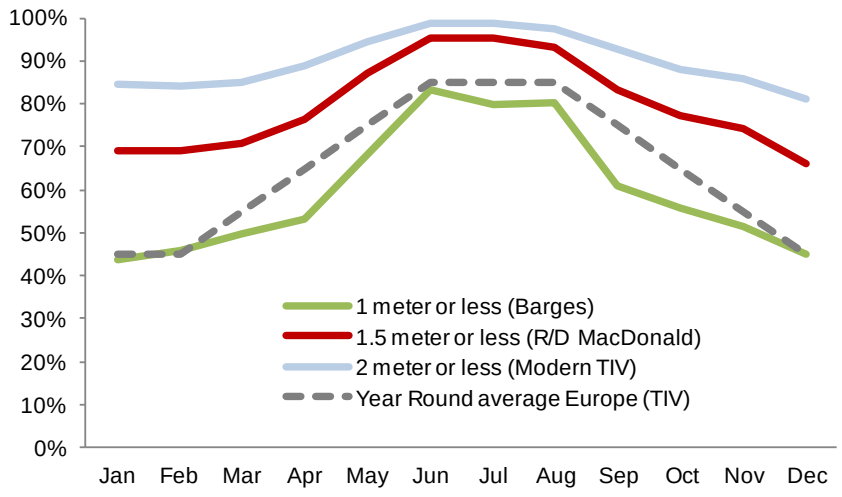


Figure 7.Percent of days with sea states suitable for various offshore wind operations in Northeastern US

Conditions in the Northeast United States, off the coasts of New York and New Jersey, appear more benign. The graph shows the combined seasonal averages for National Data Buoy Center buoys stationed approximately 20-30 nautical miles into the Atlantic

from Montauk and Islip, Long Island, New York; and Cape May, New Jersey. These buoys are located at the distance from shore and in the general location of a number of wind farms currently proposed or planned.

Installation conditions appear favorable in the Northeast United States. Significant wave heights remain below 1 meter (3 ft) at least 80% of the time during the summer months, falling to 45% in the depths of winter, and averaging 60% for the year overall. Non-stabilized barges can operate under such conditions. Thus, conditions are such in the US that simple barges would enjoy a sea state determined utilization rate almost as high as the purpose-built TIV fleet in Europe, based on significant wave height alone.

The RD MacDonald, Weeks Marine's turbine installation vessel can jack-up in up to 1.5 meter (5 ft) waves. This provides a broad operating window in the Northeast, where the RD MacDonald is stationed. Sea states would be favorable more than 90% of the time during the summer, falling to about 65% in the depths of winter, and 80% for the year as a whole. Thus, the vessel would enjoy nearly 25% more operating days than a comparable TIV in Europe.

Finally, a large, state-of-the-art TIV can operate in sea states to up to 2 meters (7 ft). In the Northeast, such sea states are achieved 90% of the time, and nearly 100% during the summer months. Such a large vessel would improve utilization compared to the RD MacDonald, but in the Northeast, only by 12% or so. Certainly, more is better, but a vessel capable of jacking up in 1.5 meter (5 ft) waves would appear entirely suitable for operations from Rhode Island to Delaware, at a minimum.

Vessel Ownership and Financing

As a practical matter, installation vessels can be owned by one of four types of entities: offshore wind construction or service companies, financial entities, wind farm developers and major utilities. Let us consider these in turn.

- *Vessel Operators / Offshore Construction* - Ordinarily, offshore wind vessels are owned by offshore construction or service companies. Thus, in Europe, most turbine installation vessels (TIVs) are owned by installation companies like MPI or A2SEA.
- *Financial Owners* - Alternatively, a vessel could be owned by a financing entity like a private equity fund. These are more likely for commodity vessels like bulkers or tankers, in which the vessel itself is generic and crews with adequate skills, for example Russian captains and Philippine crews, are readily available on the market.
- *Developers* - In theory, a wind farm developer like Cape Wind could own an installation vessel. This lacks both strategic and financial sense. A developer will only use the vessel for his own projects, and therefore does not need a permanent installation capability. At the same time, investing in a vessel would tie up valuable capital. A developer could commission a vessel if financing were plentiful and vessels scarce. Given the lightly capitalized nature of US developers, such an outcome is unlikely.

- *Utilities* - Another set of potentially important vessel owners are the major utilities, which may also be wind farm developers or owners. Utilities rarely own vessels, but such a situation is not unprecedented. In Europe for example, RWE, a leading German utility, has owned an installation vessel.
- *Debt Financing* - Debt financing can be of two types: recourse and non-recourse. Non-recourse financing is secured only by the asset and its revenue stream, or more precisely, its debt servicing capability. In order to provide such financing, a bank or other lending agency must be convinced that the flow of revenues, less cash expenses and other outlays, are sufficient to service the debt, which includes interest and principal, as may be agreed between the lender and the borrower.

  In the case of a commoditized vessel like a bulker or tanker, vessels have known day rates, utilization rates, operating costs and public second hand re-sale values. For the lender, the financial performance and attendant risks to a bulker or tanker's cash flows and re-sale value are easily determined. As a result, a generic bulker or tanker has been able historically to secure financing around 70% of its construction cost (and as much as 85-90% at the business cycle peak, and around 50% in a down market). This debt could be non-recourse, that is, secured only by the vessel and its related cash flows. Thus, the debt financing of commodity vessels like bulkers or tankers could be treated by banks in a routine manner similar to, say, automobile leasing.

  For a number of reasons, this model is not applicable to the financing of offshore wind vessels in the United States. To begin with, the financing of tankers and bulkers has largely collapsed due to an overbuilding associated with the recession. These vessels were provided debt by European and Asian banks, primarily the Germans, Scandinavians and Japanese. The appetite of lenders for incremental vessel debt is constrained. For example, *The New York Times* reports that German and Scandinavian banks have $350 bn in loan exposure to the shipping industry, much of which is impaired. Over time, Europe's economies will likely improve and sources of funding will be increasingly available.

  However, even allowing for its availability, non-recourse funding will likely play a limited role. For non-recourse funding to apply, offshore wind vessels would require a steady stream of revenues and a liquid second-hand market for vessels. Neither of these conditions apply in the United States. For one, the lack of predictable project flows in the US offshore wind supply sector means that both the timing and value of installation contracts and vessel revenues remain highly uncertain. The bank cannot determine whether a US TIV will earn sufficient revenues to repay any loan.

New Jersey Vessel Financing

- *New Jersey Vessel Finance* - From a policy perspective, should New Jersey become involved in providing financial support for vessel construction? The logic argues against it.

- *Offshore construction companies have the financial strength and incentive to invest* **-** As Weeks Marine has demonstrated, offshore construction companies are capable of making investments in vessels if they believe the market will provide adequate revenues.
- *Risk and return are asymmetrical for New Jersey* **-** Any financial support for vessel construction by New Jersey would provide a vessel for use in other states, as well as New Jersey. Thus, the benefit of the vessel would be enjoyed broadly along the Atlantic Coast. This is a positive. However, were the vessel unable to find employment, New Jersey would be assuming all the risk of a non-performing loan or guarantee. Thus, New Jersey would be providing a benefit to the region, but taking the risk alone.
- *Vessels are not fungible – Expertise is required* -In backing any particular vessel initiative, New Jersey risks being trapped in a vessel type which may not prove optimal. For example, the RD MacDonald can easily install 3.6 MW turbines, and even 5 MW turbines in shallow waters. However, it is not suitable for 6 MW turbines, which are increasingly popular, and has a maximum operating depth of 60 ft or so, more shallow than most of the offshore New Jersey lease areas. By backing any given vessel initiative, New Jersey could risk backing an owner whose vessel may proves unsuitable for the trends in offshore wind installations which eventually emerge, with New Jersey ultimately absorbing a disproportionate share of the risk.

It is not inconceivable that New Jersey at some point in the future could become involved in a vessel financing, perhaps in the context of the bankruptcy of a vessel operator or wind farm developer, and that such a restructuring would involve some active collaboration and risk sharing with a large utility like PSE&G. However, such an event would be both contingent and years into the future. As for more routine guarantees or loans related to vessel construction, our analysis does not support the notion that they are necessary at this time, and moreover, the risk/reward ratio is not symmetrical in New Jersey's favor.

New Jersey should focus on the program to which it has already committed: insuring a project with sufficient scale to provide several years of work, thereby stimulating the supply chain, including the ordering of installation vessels as the market requires.

EUROPEAN EXPERIENCE

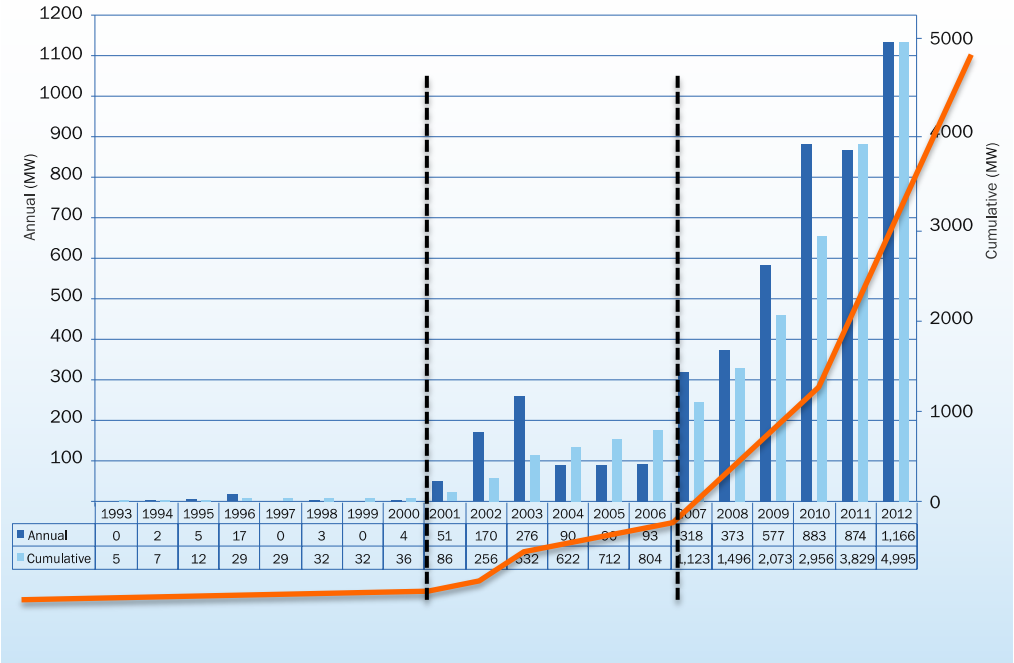
The United States has started exploring offshore wind (OSW) farm development in recent years. Thus, the European experience provides a good foundation for learning of OSW specifications, installation methods, vessel requirements, port requirements, costs and O&M.

The European Wind Energy Association (EWEA) is an advocacy group and non-profit organization that actively promotes wind power in Europe and worldwide. Its members include over 700 members from almost 60 countries, including wind leading turbine manufacturers with a major share of the world wind power market, plus component

suppliers, research institutes, national wind and renewables associations, developers, contractors, electricity providers, finance and insurance companies, and consultants.

Considerable investment has been made in a number of northern European port facilities to meet the requirements for the offshore wind industry. The major countries that participate in offshore wind farm development include: UK, Germany, Denmark, France, the Netherlands, Finland, and Belgium. However, other countries assist, including Spain, Poland and the Baltic countries of Estonia, Latvia and Lithuania which have identified opportunities for supply chain involvement of their ports. Additional countries that are studying the installation of offshore wind farms include: Australia, East Timor, Brunei, Indonesia, Malaysia, New Zealand, Qatar, Saudi Arabia, Thailand, Trinidad, Vietnam, and Egypt.

As of 2012 the UK has by far the largest capacity of offshore wind farms with 2,947.9 MW and 870 turbines. The UK is followed by Denmark, Belgium, Germany, the Netherlands, Sweden, Finland, Ireland, Norway and Portugal. Figure 8 includes the annual and cumulative offshore wind capacity of 10 EU countries with the largest offshore capacity build-up in 2012.



Country	UK	DK	BE	DE	NL	SE	FI	IE	NO	PT	Total
No. of farms	20	12	2	6	4	6	2	1	1	1	**55**
No. of turbines	870	416	91	68	124	75	9	7	1	1	**1,662**
Capacity installed (MW)	2,947.9	921	379.5	280.3	246.8	163.7	26.3	25.2	2.3	2	**4,995**

Sources: The European offshore wind industry key 2012 trends and statistics, The European Wind Energy Association (EWEA), January 2013, pp. 9-10. http://www.ewea.org/fileadmin/ewea_documents/documents/publications/statistics/EWEA_stats_offshore_2011_02.pdf

Figure 8.Cumulative and Annual Offshore Wind Capacity in 10 EU Countries (1993 – 2012)

The summary of EU's offshore wind power projection from 2011 – 2030 is provided in Table 5.

Table 5 -Projection of EU Offshore Wind Power Development

	2020	2030
Total installed capacity (MW)	40,000	150,000
Annual installations	6,900	13,700
Total electricity production (TWH)	148	562
Percentage of demand	4%- 4.2%	13.9%
Annual CO_2 Avoidance (million tons)	102	315
Annual investments (€bn)	10.4	17
Cumulative investment (€bn)	65.9 (2011-2020)	145.2 (2011-2030)

European Offshore Development Trend – Bigger, Deeper, and Further

Technological development of the offshore wind industry is moving turbine installation into deeper waters, further away from shore and with bigger wind farms (Figure 9). Figure 10 shows planned offshore wind farms after 2015. Future offshore wind farms will have larger capacity (see bubble size). The wind farms are divided into four categories by distance (km) and water depth (m):<20km and <20m, <60km and <60m, >60km and <60m, and <60km and >60m.

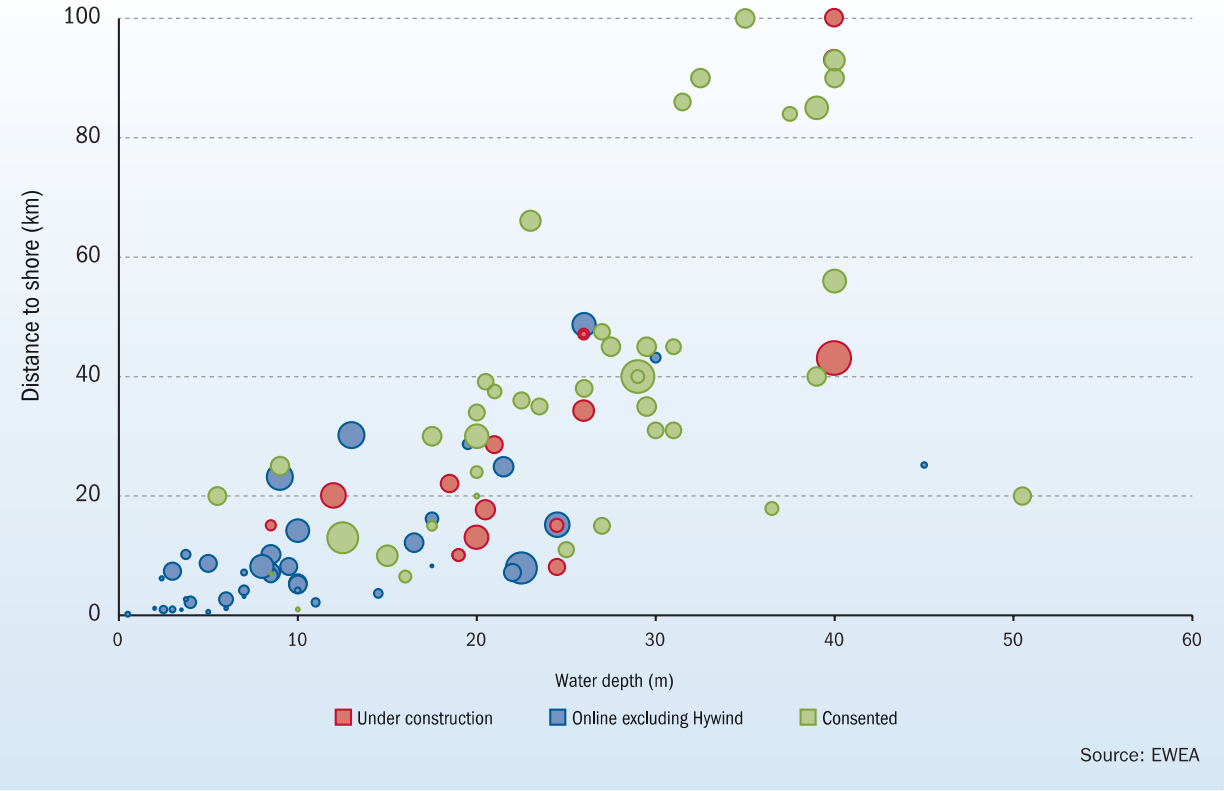


Figure 9.Distance and Depth of Installed, Constructed and Under Construction Offshore Wind Farms

- <20km and <20m zone is the home of the majority of the wind farms in operation. They are concentrated in the 20 x 20 zone (less than 20 km from shore and less than 20 meters deep), and a large number of future planned farms are in this zone as well (Figure 9 and Figure 10).
- <60km and <60m zone includes a large number of current and future planned wind farms.
- >60km and <60m zone is far offshore currently mainly in Germany. Future development in UK is included in this category.
- <60km and >60m zone is deep water development planned for the future. It includes using floating platform technology in the next decade.

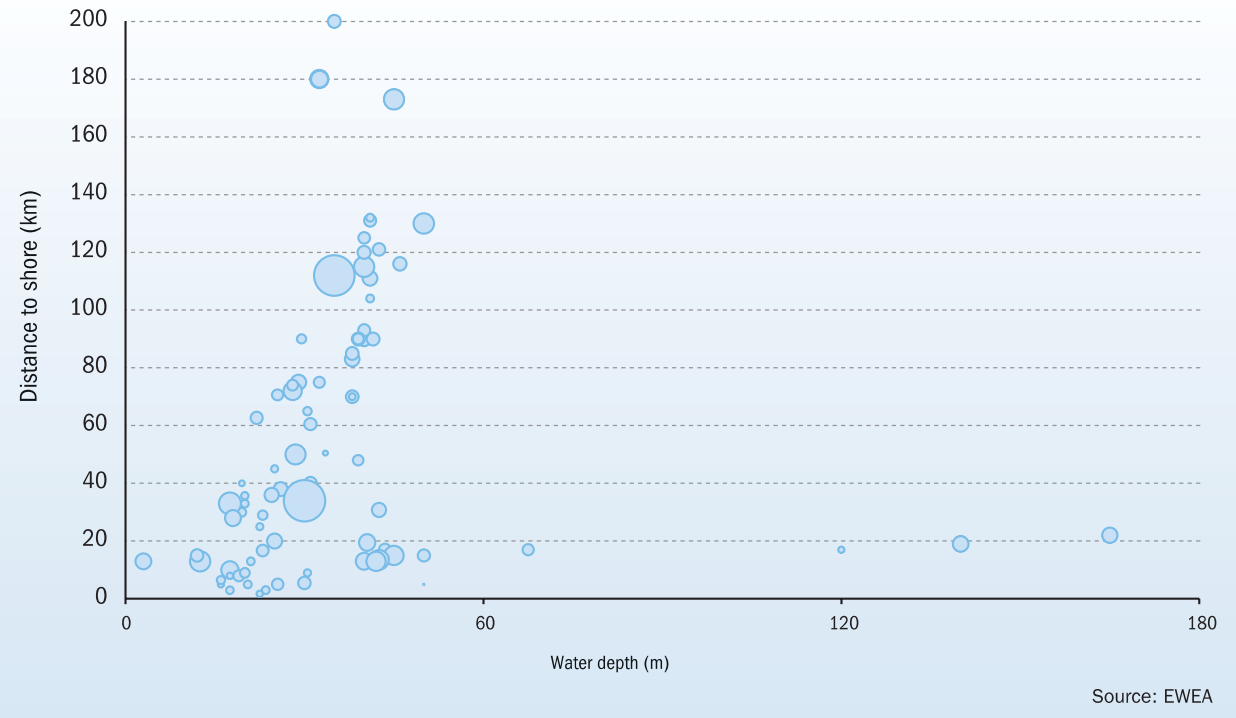


Figure 10.Distance and Depth of Planned Offshore Wind Farms

The Supply Chain of Offshore Wind Farm

An important aspect of offshore wind farm development is the offshore industry structure and function. There are five key sub-sectors in the offshore wind farm supply chain development: vessels, ports, electrical infrastructure, wind turbine, and substructures (foundations). The EU experience and evolution of this managerial and operation structure could shade light and provide a guide as well.

The types of companies that participate in the offshore wind supply chain include: wind turbine manufacturers, structural manufacturers, electrical equipment suppliers, marine contractors, cable suppliers, cable installers, EPCI (Engineering, Procure, Construct, and Install) contractors, and port operators. In addition subcontracts are also awarded to specialist design houses (mainly for foundation design), certification authorities,

project management companies, health & safety consultants, marine warranty surveyors, insurance providers, and other minor contractors.

Firms' investment in the production of offshore wind farm components had its ups and downs due to inconsistent demand and to low margins. However, even though the supply of components is still at low margin and high risk, it changed since 2009 due to an increase in the scale of demand with the renewed emphasis on offshore wind energy and the attempt to produce nearly half of the European capacity in the overall wind energy market by 2030. Thus, new developments have been emerging and new manufacturers join the industry including firms' restructures and partnerships. The supply chain of suppliers, including non-European firms, to the industry and their capacity has been increasing.

European Ports

Staging port selection and installation methodology have been changing. Ports are divided into two types: manufacturing ports and staging ports. The use of the staging port as a distinct port is dependent upon the decision to deliver turbines, substructures or sub-assembled components directly to the offshore wind farm site or not. A second decision is whether to transport components from the port to the main installation vessel itself, or to use feeder vessels for ferrying components between port and site before transferring them offshore for actual installation.

The determination of the best approach to use depends on benefit-cost analysis. Staging ports may be economically advantageous if the offshore wind site is located at some distance from the manufacturing hubs but not in an area with significant enough activity to justify long-lasting local supply chain development. A determination would take into consideration labor costs and transportation costs. In addition, there is the consideration of the port owner between proximity to long-term manufacturing facilities and/or just offering mobilizing services.

Depending on the role played by a particular port in Europe or elsewhere in the construction and operation of offshore wind farms, there are different requirements placed upon their technical and logistical capabilities. Some technical requirements, in terms of maritime limitations, derive from the physical dimensions of the vessels used for both the construction phase, or used for transportation as logistical elements of the supply chain. Consideration is needed for:

- Vessel beam (width)
- Vessel draft laden and unladen
- Vessel length overall
- Overhead clearance required

Other technical limits are derived from the dimensions and weights of wind farm components, at the various stages of assembly at which they are transported between manufacturing and construction facilities. Consideration is needed for:

- Physical size of foundation and turbine components

- Length, breadth, and height required – not only of the component itself, but also of the area surrounding it in any storage areas to allow access for the lifting and other mechanical handling plant required to move it
- Numbers of components that require storage during conventional project

There are different infrastructure requirements for staging ports with manufacturing facilities as opposed to staging ports used purely for mobilization and construction purposes. Even when the same components are loaded onto the different vessels, different crane specifications and therefore different quayside loadings are needed.

Staging port infrastructure should take into consideration the manufacturing and the construction phases. In some cases (particularly for jacket foundation structure sub-assemblies) there are intermediate requirements of sub-components.

European Offshore Staging Port Characteristics

The offshore staging ports' characteristics are divided between criteria factors and sub factors. The selection criteria indicate that there are four key critical factors and sub factors: navigational, port access, primary operational and secondary operational. For example, the navigation factors have four sub factors of channel depth, overhead clearance, horizontal clearance and distance to the offshore wind farm. Similarly other factors have their own sub factors as outlined in Table 6. The specific criteria measures for European ports are also incorporated in the table. These measures are the typical requirements for offshore wind farm installation in Europe largely based on the EWEA criteria.

Table 6 -Typical Port Criteria Factors and Sub Factors for European Ports

Factor	Sub Factors			
Navigation access	Channel depth	Overhead clearance	Horizontal clearance	Protected harbor
	Larger 41 ft	No Obstructions	Larger 515 ft	Protected
Port access	Berth water depth	Berth length	Berth width	Port upgrade required
	Larger 35 ft	Larger 1,260 ft	Larger 580 ft	
Port operations	Open storage yard area	Operations	Rail access	Highway access
	Larger 100 acres	24/7	Yes	Yes
Additional port operation	Additional storage area	Cranes	Ship repair & services	Fuel oil, water and other supplies
	Yes	OSW terminal	Yes	Yes

An analysis of offshore European ports' characteristics gathered from 26 offshore ports using the selection criteria layout in Table 6. The specific criteria measures for European ports are also incorporated in the table. These measures are the typical

requirements for offshore wind farm installation in Europe largely based on the EWEA criteria.

Table 6 highlights the range (low, average and high) that was observed in the European offshore staging ports (Table 7). The range of figures observed is very large so a simple average is also provided. However, historically these figures also include the early generation of wind farm size mixed with the new generation. Therefore, the European figures are not the measure to go by when installing 5 MW turbines or larger. The European data does not distinguish between turbine generations, so some staging ports are still used to installing all generations of turbines. The actual figures should be directly derived from the size of the turbine and the number of turbines installed with the minimum criteria requirements identified in Table 7. Furthermore, the analysis also indicates that terminals that were used in recent times are larger with respect to minimum and maximum depth.

Table 7 -Actual Factors and Sub Factors for European Staging Ports

Factor	Sub Factors			
Navigation access	Channel depth (ft)	Overhead clearance (ft)	Horizontal clearance (ft)	Protected harbor
			88 to 2,756 Avg. 388	Sheltered
Port access	Berth water depth (ft)	Berth length (ft)	Berth width (ft)	Port upgrade required
	16 to 59 Avg. 27.2	164 to 17,641 Avg. 3,342		
Port operations	Open storage yard area (Acres)	Operations (hours/days)	Rail access	Highway access
	0.6 to 1,599 Avg. 81	24/7	Direct or indirect	Direct or indirect
Additional port operation	Additional storage area (Acres)	Cranes (ton)	Ship repair & services	Fuel oil, water and other supplies
	4.9 to 1,599 Avg. 103	50 to 100	Yes – all	Yes – all

The analysis also demonstrates that staging ports have direct or indirect access to rail and highway. From the 23 staging ports that report rail information, 11 have direct link to rail and others are planning to and/or developing direct link to rail. Most of the staging ports with direct link are in the UK. The highway links are more common with some ports having direct connection to the highway.

The operational conditions of the European experience address the wave height that the installation vessels have to withstand. The wave height for jack-up vessels ranges between 1.5 and 3.72 meters; the current range is between 1 and 2.5 meters; and the air gap range is between 3 and 20 meters. It is also indicated that more recent installation vessels have a larger air gap. Furthermore, the wind turbine installation vessels are self-propelled units that are specially designed in line with the industry demands. These purpose-built self-propelled installation vessels have jack-up legs and cranes with big lifting capacities.

Today the cargo capacity of the WTIV's (wind turbine installation vessels) varies from 1,300tons (metric) to 8,000tons while the area of available deck space for placing the cargo varies from 900m^2 to 3,750m^2. Maximum operational water depth for WTIVs ranges between 24 meters and 45 meters while the leg lengths vary from 32meters to 85meters

The service speed of these vessels is in the range of 7.8 to 12.5knots and the jacking speed is also in the range of 0.35 to 0.8meters/minute (due to weight of the cargo "jack-up," speeds can vary). WTIVs have Dynamic Positioning Systems which enable them to stay constant at a certain point to be able to land their legs on the exact locations precisely. Onboard accommodation capacities of these vessels range from 16 beds up to 112 beds.

The site-specific conditions, such as water depth and "distance to shore" of the proposed offshore wind farm locations, have influence in the design considerations of newly built WTIV's. The industry trend towards installing multiple wind turbines in one haul (using larger turbines of up to 6MW) created a larger deck space requirement.….Therefore, incoming vessels will have larger available deck space in the range of 2,000 to 4,300m^2 and cargo capacity (weight-wise) in the range of 2,850 to 8,400tons. Operational water depths of the incoming vessels will be in the range of 45 to 75meters".

In short, an efficient purpose-built installation vessel must have a strong jacking system which is able to make 300 cycles per year, 4,000 tons payload, 3,000 m^2 deck available area, and an onboard crane with a "safe working load" of 700 tons."

Both WTIVs and Jack-ups have onboard cranes to be able to carry out the installation work at the construction site offshore. The turbine pieces, which can weigh up to 400 tons, must be lifted and assembled at certain heights ranging from 70 to 100 meters in general.

Today the blade lengths of the turbines vary from 40 meters to 60 meters. The main challenge in blade installation and transportation is due to their sizes instead of their weights. Weight of a blade varies from 6.5 to 24 tons, which is not a challenge for lifting in terms of weight but, since it is an aerodynamic component, the wind plays an important role in the lifting and assembly process.

The European experience of installation time varies. In general, it takes to install a 5 MW turbine hub (turbine, nacelle, and blades) about one day. The variation in installation time is a function of various parameters such as:

- the hub lay-out components on the installing vessel
- if the hub components are pre-installed or not (there are different scenarios of pre-installation, each require a different amount of time at the installation site)
- how many hubs are loaded on the installation vessel
- the depth of the water at the installation site
- the distance of the OSW farm from the staging port
- the weather conditions
- how many hubs are loaded on the installation vessel

The extended report illustrates the OSW farm development and installation in select countries and locations such as: UK (several locations), Germany (several locations), and Denmark (several locations).

In conclusion, the offshore wind power is a new industrial sector in the EU, putting the industry in the forefront of EU's core energy and climate strategy, playing a key role in the future EU's renewable energy economy. There are two important aspects to this success: stable and consistent legislative framework for offshore wind power, and access to and the availability of sufficient levels of financing. In order for this to succeed there has to be a strong public-private partnership, each sector needs to play a respective role in order to gain the benefits offered by the offshore wind power industry.

NEW JERSEY ENERGY LINK

The New Jersey Energy Link initiative will be capable of accommodating up to 3,000 MW of power and providing a connection between prospective offshore wind farms in the New Jersey lease areas and consumption centers within the state. The project would see the installation of almost 200 miles of underwater cable and the construction of 3 large offshore transformer stations. For complete detail see extended report.

The project would enable offshore wind developers to take advantage of arbitrage opportunities that may emerge within the state of New Jersey, and promises to reduce the capital cost of offshore wind projects by eliminating the need for long export cables linking wind farm sites to the onshore grid.

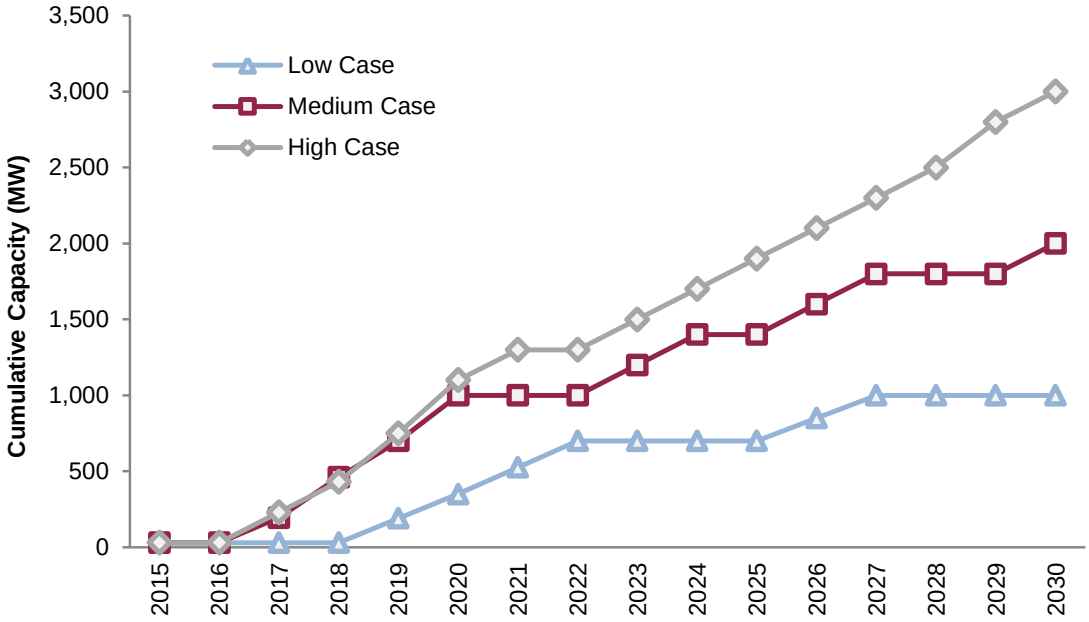
Rollout Scenarios in New Jersey

The rollout scenarios outlined above are the foundation of maritime equipment and port characteristic determination that follow below and in the extended report.

Sporadic Development

This scenario brings total installed capacity in NJ to 350 MW in early 2020, and 1,000 MW in 2030. These numbers are not insignificant, Germany had about 280 MW of installed capacity at the end of 2012, while Denmark, one of the pioneers of offshore

wind development, had slightly less than 1 GW. The scenario assumes about three utility-scale projects to be installed in New Jersey through 2030, but the pace of installation will be intermittent, with no activity at all in several years (Figure 11).



New Jersey	Cumulative Installed Capacity			
Low Case	30	350	700	1,000
Medium Case	30	1,000	1,400	2,000
High Case	30	1,100	1,900	3,000

Figure 11.Cumulative Installed Capacity by Rollout Scenario in New Jersey

Steady Growth

The Steady Growth scenario sees an annual pace of installation reach 400 MW by the second half of the decade for the region as a whole. This average pace, with significant annual variations, is sustained throughout the 2020s, bringing the New Jersey total to 2 GW by 2030. For purposes of comparison, more than 4 GW of offshore wind capacity were installed in northwestern Europe in the six years to 2012. New Jersey, with 2 GW of installed capacity, would see an average household burden of around $16 per month.

Rapid Deployment

For New Jersey, the high case scenario to 2020 is not much changed from the medium case, with 1.1 GW installed to 2020. This is consistent with the New Jersey Offshore Wind Economic Development Act (OWEDA), which calls for at least 1,100 MW of offshore wind generation to be subsidized by an OREC program. This scale of project of investment would also be sufficient to provide multiple years' work for offshore wind manufacturers and service providers. Our analysis suggests this should be sufficient to prompt investment in supply chain development, including turbine and cable manufacture. In the late years of this decade, the pace of installation would reach 300 MW per year in New Jersey. Thus, New Jersey would see the equivalent of two Cape

Wind-scale projects in this decade. The burden per household would be about $24 per month in New Jersey in this scenario. This is before considering any benefits from supply chain capture.

Benefits to the New Jersey Offshore Wind Industry

If built, the New Jersey Energy Link (Figure 12) may improve the economic viability of New Jersey offshore wind projects in general, and of far-offshore wind projects in particular. Cable laying represents a significant portion of the capital cost of offshore wind projects, and this share is going to increase as project locations move increasingly farther from the shore. In addition, cable-lay vessels that are capable of installing high voltage export cables are currently in short supply globally. The limited availability of these vessels can cause project delays and cost overruns in future projects. The New Jersey offshore transmission link would reduce the need for these vessels considerably. However, the project's developers have not yet been able to quantify these cost benefits for future offshore wind projects in the New Jersey lease area. If the project passes the initial permitting and review process, then it may have a presumably positive impact on the expected rollout in the region.

Figure 12.The New Jersey Energy Link

NEW JERSEY OPTIONAL OFFSHORE STAGING PORTS

The selection of a New Jersey staging port takes into consideration the characteristics of each port with respect to offshore wind installation and service.

The selection criteria are based on four key critical factors and sub factors:

- Navigation access
- Port access
- Port operations
- Additional port operations

When considering all selection criteria, there are 16 ports suitable for consideration as an offshore staging port. The typical port selection criteria for New Jersey staging ports are provided in Table 8.

Table 8 -Typical Port Criteria Factors and Sub Factors for New Jersey Staging Ports

Factor	Sub Factor			
Navigational	Channel Depth	Overhead Clearance	Horizontal Clearance	Distance to OSW Farm & Open Sea
	Greater than 28 ft	No Obstructions	Allow a full turbine rotor (min. 400 ft)	As close as feasible.
Port Access	Berth Depth	Berth Length	Berth Width	Protected Harbor
	Greater than 22 ft	Two to three vessel lengths (720 ft)	Allow a full turbine rotor (min. 350 ft)	Protected
Primary Operational	Laydown Area Load Capacity	Open Storage Yard	Crane Load Capacity	24/7 Operations
	No OSW Terminals in NJ. Only breakbulk terminals (approx. 1,000 psf)	10 acres (min.)	750 to 1000 tons	24/7
Secondary Operational	Rail & Highway	Ice Breaking Services	Ship Repair and Services	Fuel Oil, Water & Other Supplies
	Direct Access	Yes	All	All

Based on the selection criteria sixteen New Jersey ports were evaluated to determine which would be the best staging port for OSW turbine installations.

The port ranking is based on overall grade indicating that Port Jersey (Global) is the best options and are ranked highest (98%)Table 9. For complete raning mathodology and analysis see extended report and appendices.

New Jersey Staging Port Vessel Navigation Considerations

Considerations of vessel operations within the region and their impact on operation timing is divided into the northern New Jersey ports and southern New Jersey ports.

Northern New Jersey Ports Navigation Considerations

New Jersey ports are subject to both the rise and fall of tide and current flow consisting of two high and two low water periods. Current flow changes approximately every six hours. The velocity of the flood current is about 1.7 knots. The ebb current is 2 knotsat the Narrows. Flood current runs north and ebb south. Ports located within a six-hour voyage to sea may carry a fair (ebb) current for the entire trip providing more speed, less fuel consumption, and quicker access. Ports located farther than a six-hour voyage decrease speed capacity and increase fuel consumption resulting in slower transits.

Table 9 -NJ Port – Offshore Wind Staging Port Ranking Summary

Port Name	Overall Grade	Rank
Port Jersey (Global)	98	A+
Port of Bayonne	93	A
Port Newark	90	A-
Beckett Street Terminal	85	B
Port of Paulsboro*	78	C+
Port Elizabeth	76	C
Gloucester Marine Terminal	66	D

* It should also be noted that the current ranking reflects the existing undeveloped condition of Port of Paulsboro. Once construction is complete, the Port of Paulsboro will rank similarly with Port Jersey, Port of Bayonne and Port Newark.

New York Harbor has a Vessel Traffic Service (VTS) (See 33 CFR 161.1 through 161.25) monitoring marine traffic (Table 10). The nautical miles to sea are between 15 and 22 with a potential sea transit at 8 knots of 1.8 to 2.75 hours.

Prevailing winds are from the Port of New York/New Jersey primarily sheltered except when winds are out of the East.

Navigation of the channels in the Port of New York and New Jersey is not restricted by ice.

Table 10 -New Jersey Ports Navigation Characteristic

Port	VTS	Berth Draft	Channel Draft	Air Draft	NM to Sea	Sea Transit (8 knots)
Port Jersey (Global)	Yes	45-50 FT	50 Feet	215 FT	16 NM	2 Hrs
Port of Bayonne	Yes	20-40 FT	50 Feet	215 FT	15 NM	1.8 Hrs
Port Newark	Yes	35-40 FT	50 Feet	151 FT	22 NM	2.75 Hrs
Beckett Street Terminal	No	39 FT	40 FT	150 FT	90 NM	11.25 Hrs
Port of Paulsboro	No	31 FT	40 FT	181 FT	81 NM	10.1 Hrs
Port Elizabeth	Yes	40-50 FT	50 Feet	151 FT	20 NM	2.5 Hrs
Gloucester Marine Terminal	No	32 FT	40 FT	150 FT	88 NM	11 Hrs

Southern New Jersey Ports Navigation Considerations

Southern Ports are sited on the Delaware River and based in the State of New Jersey. Delaware River ports are subject to both rise and fall of tide and current flow consisting of two high and two low water periods. As in the northern ports the current flow changes approximately every six hours and maximum velocity is approximately1.8 knots. Flood current runs north and ebb south. Ports located within a six-hour voyage to sea may carry a fair (ebb) current for the entire trip providing more speed, less fuel consumption, and quicker access. Ports located farther than a six-hour voyage decrease speed capacity and increase fuel consumption resulting in slower transits.

Delaware Bay and River Major ports are Wilmington, Chester, Philadelphia, Camden, and Trenton. Major facilities are located at Delaware City, Deepwater Point, and Marcus Hook.

The Delaware Bay is an open bay subject to confusing, and sometimes dangerous, sea and swell conditions due to a large fetch, strong currents, and numerous shoals and has no commercial port of refuge between the entrance and the C&D Canal. Vessels planning to navigate to sea are encouraged to monitor current weather conditions and forecast.

Unlike the northern ports, a voluntary vessel traffic information service (VTS) through the Delaware Pilot traffic tower on VHF-FM channel 14 is recommended for use by commercial vessels of the inbound vessel's entrance to the appropriate sea lane. Inbound towing traffic using the inshore route should contact the tower or when off of McCrie Shoal Lighted Gong Buoy 2 MS. Vessels outbound are requested to contact the traffic tower when they are passing the Brown Shoal or Tanker Anchorage Approach Lighted Buoy A if exiting Big Stone Beach anchorage. Additionally, outbound towing

traffic should report out of the entrance area while passing Delaware Bay Entrance Channel Lighted Buoy 8.

Strong north westerlies are prevalent from November through March and gales are encountered about 1 to 3 percent of the time. Seas build to 10 feet (3 m) or more about 1 percent of the time from November through March and average seas run 3 feet (0.9 m) from October through March. During the summer, prevailing southerlies are often reinforced by the sea breeze and afternoon wind speeds may reach 15 to 25 knots.

In ordinary winters there is usually sufficient ice in Delaware Bay and River to be of some concern to navigation. Thin ice forms early in December between Chester and Philadelphia, but the heavier ice usually does not begin to run before January. The tidal currents keep the ice in motion, except where it packs in the narrower parts of the river; tugs and larger vessels from Philadelphia keep these parts of the river open.

The number of nautical miles to sea of the six southern ports is between 45 and 94 with a potential sea transit at 8 knots of 5.6 to 11.75 hours.

Staging Ports Development Risks

In general the development of a staging port for an offshore wind farm has uncertainty as an investment. The development of an offshore wind farm is usually a project for a number of years. Thus, dedicating a port with permanent infrastructure investments as a staging port could be an impediment after the project is completed. Furthermore, an attempt to survey 11 potential OSW developers resulted in only one response that was discarded.

In Europe many ports are reluctant to commit to these types of projects. Obviously, it is not the case if a port management sees its long term mission of being a staging port for the northern East Coast of the US, assuming that offshore wind farms will be developed.

Similar to the northern European countries of the UK, Belgium, the Netherlands, Denmark and Germany, New Jersey has limited renewable options other than offshore wind. The onshore wind resource is unremarkable and open land to build wind farms is scarce; solar energy remains expensive and less competitive than in sunny, arid, southern states; and hydropower energy has reached its limits. The only true utility-scale renewable available on the east coast in general, and New Jersey in particular, is offshore wind. This resource is of exceptional quality and quantity, located in shallow to mid-depth waters near to shore and to major load centers. This operating environment is very similar to that of the northern European countries where the offshore wind industry and business is rooted.

VESSEL DEMAND BY VESSEL TYPE

Vessel demand is driven by two factors. The rollout scenarios developed for the Atlantic Coast region (North of Virginia) and New Jersey, combined with the three potential vessel strategies drive the anticipated vessel requirements for a range of vessel types.

The analysis comparing actual and modeled European vessel requirements indicate that the actual number of installation vessels required in the Atlantic Coast will likely be about 60% higher. This means that about 5 jack-ups or TIVs will likely have to be built to meet the vessel demand for 3 installation vessel equivalents in this particular scenario. In addition, another 5 to 6 jack-up vessels or TIVs may be employed as heavy maintenance vessels in the Atlantic Coast as a whole.

The critical shortage in US vessel capabilities lays in the installation vessel category, particularly in turbine installation vessels (jack-ups and TIVs). Today, the US has only one specialized turbine installation vessel, the RD MacDonald. There are no US-flagged cable-lay vessels. These are available globally, but cable-lay vessels have been in high demand recently. Other vessel types are assumed to be readily available or possible to construct in a short period of time. These include tugs, personnel transfer vessels and various supply and construction barges.

Our vessel demand forecast for the *High Growth* scenario, in which total Atlantic Coast offshore wind capacity will reach 12 GW by 2030, represents the high end of our estimates. In this scenario, the Atlantic Coast as a whole will require about 5 to 7 construction vessel equivalents, depending on the installation strategy chosen, and about 120 various surveys, service and maintenance vessel equivalents in the most active construction periods through 2030. Within the construction vessel category, the vast majority of the vessels will be turbine installation vessels (jack-up vessels and purpose-built TIVs); their combined number is expected to average 2-3 vessel equivalents through 2030 and reach 6 vessel equivalents in certain cases in peak construction years. Heavy lift and cable-lay vessels represent a minor portion in the construction vessel category throughout the forecast period.

In the *Medium Growth* scenario, where cumulative installed capacity ramps up to 6 GW in the Atlantic Coast through 2030, we anticipate the number of construction vessel equivalents to average 2 to 3 in the projection period, and reach 4 to 5 vessel equivalents in peak construction years in certain installation strategies. The support fleet, including survey, service and O&M vessels will gradually increase to over 70 vessel equivalents in this scenario.

In the *Low Growth* scenario, installation vessel requirements (jack-ups and TIVs combined) vary between 1 and 2 vessel equivalents through 2030, while demand for cable-lay and heavy lift vessels will not exceed one vessel equivalent at any time through 2030 in this scenario. Other supporting vessel types required in this scenario will ramp up to a total of 26 vessel equivalents by 2030. For complete analysis see extended report.

VESSEL REQUIREMENTS IN NEW JERSEY

New Jersey is well positioned to capture a large part of the entire Atlantic Coast offshore wind supply chain in any scenario, regardless of what the actual rate of installation is in New Jersey lease areas. Vessel requirements in New Jersey will vary in line with the actual installation activity around the state, but vessels based in New

Jersey can operate along the entire Atlantic Coast at times of slower installation activity within the New Jersey lease areas.

In the *High Growth* scenario, total cumulative installed capacity will reach 3 GW in New Jersey by 2030. In this scenario, the New Jersey offshore wind sector will require 1 or two construction vessel equivalents on average, but demand may go up to 3 to 4 construction vessel equivalents at times of strong installation activity, and depending on the installation strategy chosen. The vast majority of these vessels will be installation vessels (jack-ups or TIVs); New Jersey is not expected to fully utilize a cable-lay or a heavy lift vessel equivalent, even in the high case scenario. Demand for various supporting vessel types, such as survey, service and maintenance vessels, will go up to about 28 vessel equivalents in this scenario by 2030.

In the *Medium Growth* scenario, cumulative installed capacity ramps up to 2 GW in New Jersey by 2030. Our model indicates a construction vessel demand of between 1 and 3 vessel equivalents, depending on the pace of installation and the installation strategy chosen. The supporting vessel fleet (survey, service and O&M vessels) will gradually ramp up to 23 vessel equivalents in the medium case.

In the *Low Growth* scenario, which foresees 1 GW installed capacity in New Jersey by 2030, construction vessel requirements will remain below one vessel equivalent in most years through 2030.Only in the most installation vessel-intensive US TIV strategy it is expected to see up to 2 vessel equivalents working on New Jersey projects in peak construction years. Other support vessels required in this scenario will ramp up to a total of 9 vessel equivalents by 2030.

VESSEL TYPES AND FUNCTION

The phases of operation require a variety of vessels such as:

- Survey vessels
    - Environmental surveys
    - Geophysical survey
    - Geotechnical survey
- Jack-up vessels
- Turbine installation vessels
- Cable-lay vessels
- Heavy lift vessels
- Tugs
- Barges
- Offshore supply vessels
- Personnel transfer vessels
- Heavy maintenance vessels

These vessels come in different sizes and nationalities and are subject to regulations and restrictions.

VESSEL DEMAND BY VESSEL TYPE

Survey Vessels

Survey vessels are assumed to be widely available across the US, as these vessels are used for a wide range of activities, including for scientific and naval research as well as for seismic studies for the offshore oil and gas industry. Typically, three types of surveys are required before an offshore wind project can commence to the construction phase (Figure 13).

Figure 13.Geotechnical and Geophysical Survey Vessels

Bathymetric analysis, the assessment of water depth and conditions, as well as seabed assessment to approximately 1 meter (3 ft) depth, can be completed by various vessel types equipped with sensors or by autonomous underwater vehicles (AUVs). Such sensors and AUVs are comparatively affordable and readily available on the market.

Geotechnical surveys, that is, seismic surveys of the seabed to 100 meters (330 ft) depth or so can be conducted by the US geotechnical fleet. To the extent such a survey is necessary, the US geotechnical fleet, primarily used in oil and gas applications, is more than capable of meeting offshore wind needs.

Our modeling results indicate that one or two vessel equivalents of each survey vessel type will be sufficient to service the demands of the entire Atlantic Coast region, even in periods of the highest capacity installation rates.

Construction Vessels

Turbine installation vessels can be US- or foreign-flagged, but the US today has only one dedicated turbine installation vessel with modest capabilities, while the mobilization

of a foreign-flagged vessel would entail extra costs and operational difficulties. Cable-lay vessels are readily available in the global marketplace, although cable-lay capacity is increasingly tight, which may cause bottlenecks in offshore wind construction in the future. Heavy lift vessels are readily available in the Gulf Coast and can likely be mobilized for offshore wind operations along the Atlantic Coast as well.

Jack-up Vessels

Jack-up vessels are self-propelled or (more often) towed floating platforms that can be raised and lowered at an offshore location by means of mechanized jack-up legs Figure 14).

Figure 14.Jack-up Vessels in Operation

Turbine Installation Vessels

Over time, specialist turbine installation vessels (TIVs) have become the norm in offshore wind turbine installation. TIVs are self-powered vessels with jack-up capabilities, purpose-built for offshore wind farm installation and O&M activities. Modern TIVs are typically at least 90 meters (295 ft) in length, with a beam of 40 meters (130 ft) or more (Figure 15 and Figure 16).

Figure 15.Purpose-Built Turbine Installation Vessels in Operation

Figure 16.Pacific Orca Wind Farm Installation Vessel (New Generation)

The critical shortage in US vessel capabilities lays in the installation vessel category, particularly in turbine installation vessels (jack-ups and TIVs). Today, the US has only one dedicated turbine installation vessel, the RD MacDonald, which has relatively modest capabilities compared to a modern TIV. For example, the vessel can only operate in water depths not exceeding 72 ft and, while it can install 3.6 MW turbines, it is not clear whether it can also install larger 6 MW turbines. Foundation installation can be carried out by a wider variety of vessel types, such as crane barges or derrick

barges. Depending on the installation strategy chosen, the Atlantic Coast as a whole will see on average 2 or 3 installation vessel equivalents operating in the high case, but in certain cases, the number of installation vessel equivalents can go up to as high as 6 vessel equivalents in peak years. New Jersey will see on average one installation vessel equivalents operating on its wind farms, but the number can go up to 3 vessel equivalents in peak installation years in the high case. (For more vessel details see extended report and appendix.)

Cable-Lay Vessels

Cable-lay vessels are used to lay cables underwater for power transmission, telecommunications, or other purposes (Figure 17 and Figure 18). Most cable lay vessels are equipped with Dynamic Positioning (DP and DP2) and Dynamic Tracking (DT) systems. They are generally large vessels which cannot be used in shallow waters. A DP2 vessel provides faster set-up and installation time and can remain on station in higher sea states and wind conditions compared with a barge."[6]

Most vessels can lay one or two cables at a time. They are also capable of repairing and joining cables as needed. Some newer cable-lay vessels can maintain speeds of more than 14 knots while laying cable. Cable-lay barges are used in shallow waters near the shore, where large cable-lay vessels are not practical.

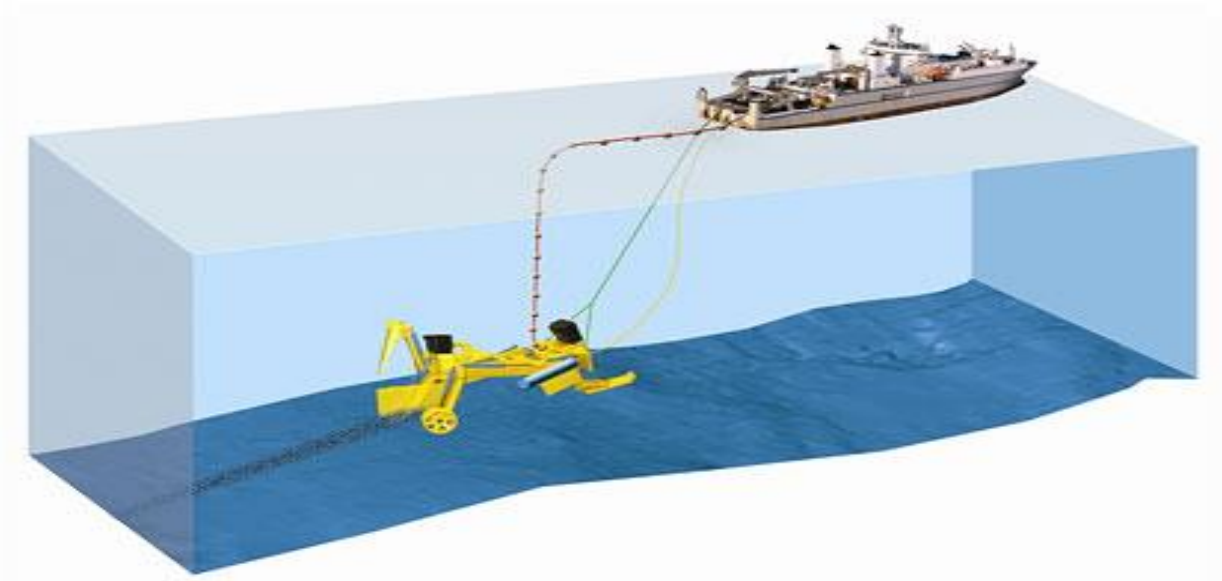


Figure 17.Schematic Overview of the Trenching and Burial Cable-Laying Method

[6] A Guide, pp. 59

Figure 18.Cable-laying Vessel (Horizontal Spool)

There are no US-flagged cable lay vessels in operation today. Foreign-flagged cable-lay vessels are generally considered exempt from the Jones Act. We assume that cable-lay vessels are readily available in the global marketplace, although cable-lay capacity is increasingly tight, which may cause bottlenecks in offshore wind construction in the future. One cable-lay vessel equivalent will likely be enough to service the entire Atlantic Coast through 2030, even in the High Growth scenario.

Heavy Lift Vessels

Heavy lift vessels are designed to transport and lift large, heavy or oddly shaped cargoes that cannot be handled by conventional transport vessels. Heavy lift vessels are widely used in the offshore oil & gas industry, and they are also extensively deployed to support offshore wind installation projects in Europe (Figure 19 and Figure 20).

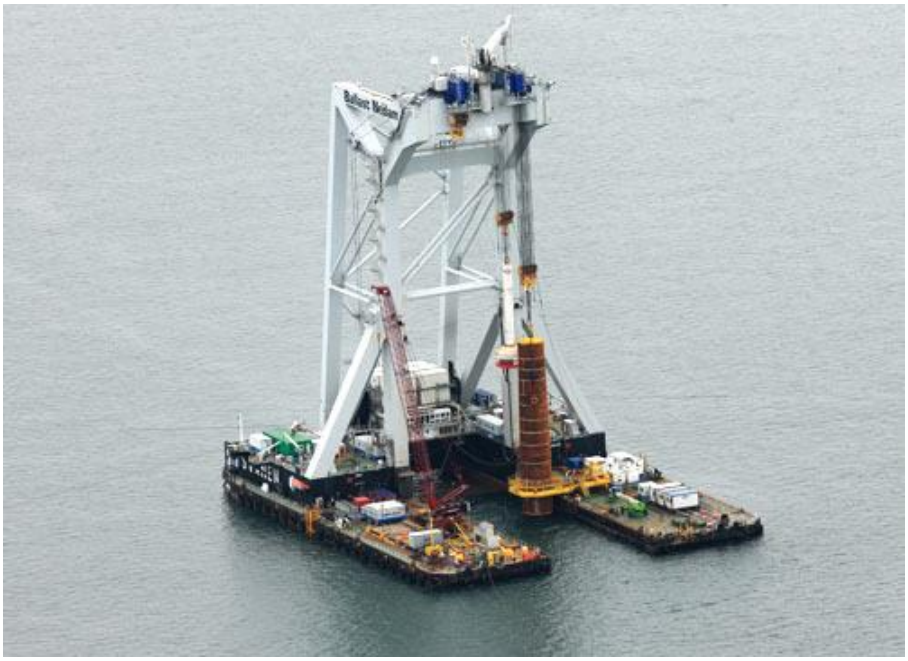


Figure 19.Heavy Lift Vessel *Svanen*During the Installation Of A Monopile Foundation

Figure 20.Heavy Lift Vessel *Stanislav Yudin*During the Installation of an Offshore Substation

We assume that heavy lift vessels are readily available in the Gulf Coast, currently servicing the offshore oil & gas industry. These vessels can, in all likelihood, be deployed to offshore wind installation projects as well, primarily for the installation of substations. Our model results indicate that one heavy lift vessel equivalent will be enough to service the entire Atlantic Coast region through 2030 in the high case.

Service Vessels

Service vessels will have to be US-built and US-crewed due to Jones Act requirements. Tugs, non-fixed barges and improvised PTV solutions are readily available. Jack-up barges will be needed for offshore wind construction; more optimized PTV solutions will likely develop over time.

Tugs

Tugs are required at several stages of the offshore wind supply chain. The main purpose of a tug is to tow vessels (barges, scows, or floatable items) and assist vessels. Tugs have powerful engines and are capable of towing weights many times their own weight (Figure 21). A tug's power is generally stated by its engine's horsepower and/or bollard pull. The term "bollard pull" refers to a towing vessel's pulling ability under static condition and is either measured or stated theoretically. Theoretic bollard pull is calculated based upon the vessel's theoretical horsepower divided by 100 and then multiplied by 1.3. Verified bollard pull is conducted under a static condition (secured to a bollard) and measured by a LOAD CELL. Bollard pull observed by a Class Society such as American Bureau of Shipping (ABS) is certified for X number of tones of bollard pull.

Figure 21.Oceangoing Tugs Towing a Floating Jacket-Mounted Turbine

Tugs are readily available in the US and they will be used in other applications when not employed in offshore wind work. As a result, there will be no exclusive offshore wind tug fleet in the US. Our model results indicate that roughly two tug vessel equivalents can service New Jersey's requirements in the peak installation years in the High Growth

scenario, and another four tug equivalents can cover the rest of the Atlantic Coast region through 2030.

Offshore Supply Vessels (Construction Support)

Platform supply vessels or offshore supply vessels (OSVs) are used to transport cargo, supplies, and crew from the staging port to an offshore oil platform or to a wind farm site (Figure 22).

Most supply vessel lengths range from 65 to 350 ft. Cargo is loaded both above and below deck for improved stability. Supply vessels are designed to maintain high speeds even in harsh weather conditions. Many supply vessels have deck cranes that increase loading and unloading efficiency.

Figure 22.Offshore Supply Vessels In Operation

A wide range of vessel types can be applied as PTVs, including some of the current fishing fleet and even certain pleasure craft. We assume that personnel and supply vessels of some sort will be available for Atlantic Coast wind operations. Initially, these will most likely be general purpose or multiuse vessels enlisted to support offshore projects. As the offshore wind industry matures in the US, purpose-built vessels optimized for wind installation are likely to emerge. PTV demand in New Jersey will average around 3 vessel equivalents in the High Growth scenario, and will reach nearly 7 vessel equivalents in peak installation years. The rest of the Atlantic Coast will demand 14 PTV equivalents to support installation activities by the time capacity addition reaches its highest level in 2030.

Barges

A barge is a flat bottom boat used to transport heavy bulk cargoes as well as in offshore construction. Barges are either ocean-going or river barges, and they are typically non-self-propelled vessels (Figure 23).

Barges are either construction or transport barges. Construction barges are used in offshore construction projects, including in offshore wind installation. These vessels typically have cranes on board, either permanently-mounted, or temporary ones that are loaded on board for a specific operation. Barges that house derrick cranes are often called derrick barges. Construction barges are often equipped with jack-up legs as well to ensure stability.

To the extent the turbine installation vessels remain in the field, they must be supported by feeder barges which ferry turbine components from the staging port to the wind farm site. Turbine manufacturers require that these vessels be stabilized prior to the removal of turbine components. This may be accomplished by using a jack-up barge. There are currently no suitable jack-up barges in the US; thus at least one would likely be required prior to the inception of any offshore wind projects. We anticipate that such barges will be constructed in timely fashion to support US wind industry. The transport of most foundation types does not require fixed barges. Such non-fixed vessels are readily available in the US. Our model estimates that 3 or 4 feeder barge equivalents will be needed to support the Atlantic Coast offshore wind industry. One or two vessel equivalents will be operating in New Jersey at times of strong installation activity, while 2 or 3 vessel equivalents will be operating in the rest of the region through 2030.

Figure 23.Transport Barges Loaded With Offshore Wind Turbine Components

O&M Vessels

O&M vessels will have to be US-built and US-crewed due to Jones Act requirements. Improvised PTVs are readily available and will increasingly specialize over time. Retired installation vessels will most likely be used for heavy maintenance work over time.

<u>Personnel Transfer Vessels (O&M support)</u>

Personnel transfer vessels (PTVs) are required during both the installation and the operation & maintenance phase of offshore wind projects. During the installation phase, PTVs supply crew changes and supplies to the installation vessels. During maintenance operations, PTVs transport maintenance crews and assist heavy maintenance vessels with personnel transfer and other supplies (Figure 24).

Figure 24.Personnel Transfer Vessels in Operation

PTVs used during the O&M phase are the same type of vessels used for construction support. PTVs are used to transport maintenance crews to the wind farm site for planned maintenance operations and to carry out smaller repairs. A wide range of vessel types can be applied as PTVs. We assume that personnel and supply vessels of some sort will be available in the Atlantic Coast for offshore wind O&M support. Initially, these will likely be general purpose or multiuse vessels enlisted to support offshore projects. As the offshore wind industry matures in the US, purpose-built vessels optimized for wind installation will likely appear. Demand for PTVs in O&M service will gradually increase with the growth of cumulative capacity. The O&M support of New Jersey's 3,000 MW of installed capacity in the High Growth scenario will employ approximately 20 PTV vessel equivalents by 2030. The entire Atlantic Coast can be expected to see about 79 PTV equivalents in service by 2030, if the cumulative installed capacity reaches 12,000 MW, as foreseen in the High Growth scenario.

Heavy Maintenance Vessels

Turbines require maintenance and repair subsequent to their installation. This can range from regular checks and the maintenance of the technical equipment to extensive repair work and upgrades, such as the replacement of blades or gear box parts.

Figure 25.Maintenance Crew Arriving At an Offshore Wind Farm Site

Wind farms will require access to maintenance vessels with the ability to replace heavier components, such as blades or gear box parts. No such vessels exist today in the US (Figure 25). In all likelihood, during the first several years of project deployment, existing wind farms will turn to the installation fleet when major maintenance must be conducted on operating turbines. As a consequence, downtime for certain outages may be prolonged, as installation vessels may be in short supply at any given time. Later on, as economies of scale are attained, a dedicated maintenance fleet is likely to emerge. Lower spec early generation installation vessels may be retired to maintenance duty over time, as larger and more capable vessels displace them from construction projects. We assume that maintenance vessels will be available as needed, with the caveat that installation vessels may play this role for some time. About one heavy maintenance vessel is required after each 1,000 MW of installed capacity. Thus the entire Atlantic Coast will require roughly 12 vessel equivalents in the High Growth scenario by 2030, whereas New Jersey alone will need about 3 vessel equivalents in 2030 in the high case. For more detail see chapter 12 in the extended report.

ECONOMIC IMPACT OF OSW

Economic growth requires additional energy. The supply of OSW energy supplements the existing energy sources supplied by traditional companies using other than wind sources of fuel in generating energy.

Utility companies' supply of energy together with the OSW energy should meet demand. However, the last should be modified due to uncertainty in generating electricity from the OSW farm. Therefore, given the uncertainty of OSW farm generating electricity, a level of OSW energy generating capacity should be determined so that, together with the utility companies' energy generating capacity, it would meet demand. Should the OSW industry provide more than the determined amounts, the OSW industry will become a substitute to the traditional utility companies.

The OSW industry supplying energy at levels that are substitutes for the traditional energy suppliers could initially lead to excess supply and lower rates. A continuation of this trend could eliminate some traditional utility companies or eliminate some OSW turbines/farms. The trend could also do both, lower rates and eliminate excess supply. The analysis below addresses some of these issues.

Economic Impact - Capturing the Supply Chain and Maritime Assets

As offshore wind requires substantial public support, related public policy places considerable emphasis on offsetting the burden on taxpayers or rate payers with increased economic activity. In other words, if ratepayers have to pay more for electricity generated by offshore wind power, it would be desirable that such expense would at least be directed to companies operating within New Jersey. Capturing the supply chain is an essential aspect of offshore wind policy.

The bulk of the supply chain consists of turbine, foundation, transition piece and cable manufacture. These are beyond the scope of our mandate. However, we do consider

vessel-related aspects in this section.

Broadly construed, the economic benefits related to offshore wind vessels can be placed in five categories:

- Vessel construction
- Vessel component and system manufacture
- Vessel kitting
- Vessel operation
- Vessel mobilization / demobilization

VESSEL CONSTRUCTION

Offshore wind installation vessels can cost from $40 - $300 million, depending on vessel size and complexity. The sorts of vessels used in offshore wind installation—jack-ups, lift boats, barges and offshore supply vessels (OSVs)—are constructed almost exclusively on the US Gulf Coast, notably in Florida (where the hull of the RD MacDonald was constructed), Alabama, Mississippi, Louisiana and Texas. Vessels constructed in these jurisdictions will, of course, provide no economic benefit to New Jersey.

The Aker Shipyard in Philadelphia is the only material shipyard of relevance for New Jersey. The yard has no experience with vessels employing jacking systems. Aker has estimated that it could build an offshore wind installation vessel for 60-200% more than a comparable Korean-built unit. For example, the Philadelphia Regional Port Authority (PRPA) applied for $135 Million in Tiger Grant funding to cover 30 percent of the anticipated cost ($450 Million) of constructing three TIVs at Aker Philadelphia. Furthermore, industry observers have expressed doubts whether Aker could successfully compete in the installation vessel market, as its primary focus and expertise resides in tankers.

Vessel Components and Systems Manufacture

Vessel components include jacking legs and jacking systems, engines, dynamic positioning controls and thrusters, cranes and heave compensation systems. Our analysis suggests that the Atlantic Coast as a whole might require 2-7 installation vessels through 2030. This small number of vessels suggests that vessel component suppliers would be unlikely to locate a facility in the New Jersey area simply to supply the offshore wind installation vessel market.

Vessel Kitting

Vessel kitting can be taken to include the installation of systems, associated construction, inspection and commissioning. The value of the kitting has been estimated by Weeks Marine at approximately 10% of the value of a vessel. In the case of the RD MacDonald, Weeks Marine’s wind installation jack-up, this would constitute a value of $4-6 million.

The hull of the RD MacDonald was constructed in Florida and the jack-up was brought to Camden with the intent to install legs, jacking systems, cranes and other systems (potentially, accommodation) in New Jersey. Notwithstanding, Weeks Marine has dispatched the RD MacDonald to Louisiana for final assembly and commissioning. This decision was made for a number of reasons:

- The project was taken over by a new project manager, who is based in Louisiana.
- The jacking system is physically located in Louisiana.
- The jacking system designer is based in Louisiana.
- Labor costs are materially lower on the Gulf Coast.
- Specialty steel fabrication skills for this sort of vessel are well established in Louisiana and not readily available in New Jersey.
- The classification and certification team from the American Bureau of Shipping (ABS) are headquartered in Houston.

Thus, as a practical matter, while kitting may be conducted in New Jersey, the realities of the business favor the Gulf Coast.

Mobilization / Demobilization

A vessel must be prepared prior to each engagement. In the case of the RD MacDonald, this is estimated to require 2 months of effort by perhaps 25 staff in Greeneville and Camden, New Jersey.

Including overhead (accountants, administrators, and managers), the spending captured by New Jersey might total $1,000 / employee per day, $50,000 per mobilization and $25,000 for demobilization. This is budgeted for approximately once per year in our model.

TURBINE AND FOUNDATION INSTALLATION

The RD MacDonald (Figure 26), and other offshore wind vessels, may well be operated in Paulsboro and Camden. A portion of the vessel crews are likely to be New Jersey residents.

A vessel of the class of the RD MacDonald would have a crew of 12, working in two shifts. This includes both vessel crew and the turbine installation team. The cost of such personnel, including associated personnel costs, is estimated at $1200 per day. Thus, the cost of personnel, which might be captured by New Jersey, would equal approximately $15,000 per day. For a larger TIV like the MPI Resolution, the crew would total 50-55, with daily wages and related costs of $60-70,000.

Assuming the TIV operated in “jack-up mode”, it would be accompanied by a logistics barge. A simple barge would be unmanned. A jack-up barge would have a crew of 3-4, representing a daily wage of $4,000-5,000. The RD MacDonald and an accompanying

barge would require a tug each, with a crew of 5 per tug. Thus, the crew cost of a tug might be estimated at $6,000 per day.

Personnel transfer vessels or crew boats would have only a captain and perhaps one other crew member, with a total cost of $1,000-2,000 per day. Thus, a vessel like the RD MacDonald, including its support vessels, might generate $35,000 of wages and related costs per day and $7-10 million per year. A modern TIV might generate twice as much, $15-20 million per year.

For a New Jersey-based vessel like the RD MacDonald, most of these outlays would tend to be captured by State residents. Depending on the scenario, the State might be expected to realize $150 – 400 million in wages and overhead spent through 2030 related to offshore installation.

Figure 26.The RD MacDonald

OPERATIONS AND MAINTENANCE

An O&M vessel might have a wage impact of $2,000-$5,000 per day. By 2030, the wage and overhead impact could reach $5-30 million per year, depending on the scenario. Importantly, the number of O&M vessels increases with the installed base of wind capacity, not with annual construction requirements. Therefore, the economic impact of O&M vessels will continue to rise over time, but this also means that the balance of the benefit is back-loaded to the second half of the 2020s.

TOTAL ECONOMIC BENEFIT FROM OFFSHORE WIND

The bulk of the economic benefit to New Jersey from offshore wind will likely arise from wages and onshore overhead related to turbine installation and operations and maintenance activities. For the 2013- 2030 period, in the better case, these could reach $250 – 500 million in total.

Proceeding towards the development of OSW farms should be carried out with caution. The European experience indicates that a determination should be made if the OSW farm would be supplemental to the existing energy supply or if it is designed to become a substitute to the existing energy supply system.

RECOMMENDATIONS

The uncertainty of OSW farm development on the East Coast of the U.S. contributes to slow investments in port development. A clear public policy of the role of OSW as complementary and/or substitute to the traditional sources of energy, together with budgets and scheduled development plans, would indicate a direction and time frame.

There are substantial benefits to be gained from the development of offshore wind power in New Jersey. Based on the European experience, the economic benefits are also derived from the first mover advantages. These advantages include:

- the creation of a new high-tech industrial sector in the economy
- increase of manufacturing employment
- increase of port infrastructure development
- the development of offshore wind power cluster
- value creation in the offshore wind power supply chain
- R&D and education
    - greener energy mix for New Jersey

OSW development requires 10 different types of vessels, such as:

- Survey vessels
    - Environmental surveys
    - Geophysical survey
    - Geotechnical survey
- Jack-up vessels
- Turbine installation vessels
- Cable-lay vessels
- Heavy lift vessels
- Tugs
- Barges
- Offshore supply vessels
- Personnel transfer vessels
- Heavy maintenance vessels

The number of vessels by category depends on the OSW farm size, turbine size, development duration and staging port distance from development site. Altogether, the estimates are from 12 to 28 vessels, depending on scenario choice (for more detail see report and extended report).

Every port on the short list has to invest in order to accommodate the OSW industry.

Some investments include infrastructure investments associated with accessibility from a highway or rail. The investments might be a combination of private and public sector investments. For detailed port by port needs, see report and extended report.

Specific issues that need attention include:

- Determine the OSW turbine generation that is planned for installation in order to be more specific about the equipment needed.
- Update the economic analysis prior to the project decision if it is delayed.
- Determine lead time for building vessels. Vessel building could take a one to two years once building starts.
- Determine and revisit the port preparation criteria and determine if access to the port complies with the selected OSW turbine components dimensions.
- Identify the suppliers of equipment and the supply chain they intend to use for delivery of components given the access characterisitcs of each port.
- In the long run identify benefits from getting into agreements with other States for OSW installation.
- Learn from other countries the time it takes from order to delivery.

Prior to and simultaneously with New Jersey's OSW development plans, there is a need for:

- Policy development: The following should be undertaken:
    - a comprehensive overall energy strategy policy incorporating offshore wind power
    - the role of offshore energy as a supplement, substitute or both to the traditional energy suppliers
    - opportunities and obstacles identified, and alternative solutions provided, including schedules and budgets
- Benefit–Cost Analysis: A benefit–cost (BCA) analysis should include both the economic and environmental benefits. Such analysis would provide guidelines to capture the benefits of OSW farm development.
- Development of OSW power industry cluster: Using the European experience New Jersey should promote the development of a competitive offshore wind power industry based on the establishment of close-knit clusters comprised of industry developers, component manufacturers, logistics service providers, education & research institutes, industry advocacy groups, and related government institutions. Once a cluster is established, it will become the new industrial base, attracting investment, R&D funding, infrastructure development, and economic development.
- Mapping of offshore wind power supply chain: The layout of the offshore wind power should include mapping the structure of the supply chain in New Jersey. Since there are five critical sub-sectors in the offshore wind power: turbine, foundation, vessel, port and infrastructure, and cable, it is important that the supply chain structure is clearly identified early in order to address potential issues in the development process and identify the State's benefits.

- Public-private partnership: It is recommended to establish a public-private sector partnership. Such partnership will enable New Jersey to bring in private sector expertise and needed investment.
- Offshore Oil & Gas industry participation: The offshore oil & gas industry has gained valuable experience in offshore development. The OSW industry can draw on the oil & gas industry skills, knowledge and technology all the way to partnering.
- Human Resources and R&D: Funding education and training for the industry is fundamental in order to provide the necessary OSW professionals. In addition, R&D will provide the intellectual capital to gain a competitive advantage in the market as several other states on the East Coast are also vying for a share in the offshore wind power development.

Similar to the northern European countries of the UK, Belgium, the Netherlands, Denmark and Germany, New Jersey has limited renewable options other than offshore wind. The onshore wind resource is remarkable and requires open land to build wind farms; solar energy remains expensive and less competitive than in sunny, southern states; and hydropower energy has reached its limits. The only true utility-scale renewable available on the east coast in general, and New Jersey in particular, is offshore wind. This resource is of exceptional quality and quantity, located in shallow to mid-depth waters near to shore and to major load centers. This operating environment is very similar to that of the northern European countries where the offshore wind industry and business are rooted. New Jersey would also benefit from being the first OSW developer developing a new industry to accommodate this industry in general.

IMPLEMENTATION AND TRAINING

An implementation and a maritime training package could be developed to advise individuals with different levels of skills in order to train them about the OSW farms. The training could include background based on the European examples and New Jersey energy policy and needs. A training package could include: OSW farm technology, installation process, vessel requirements, vessel characteristics, associated regulations, operations and maintenance aspects of OSW farms. A training program should be designed to accommodate agency plans as a part of the state and regional plan.

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