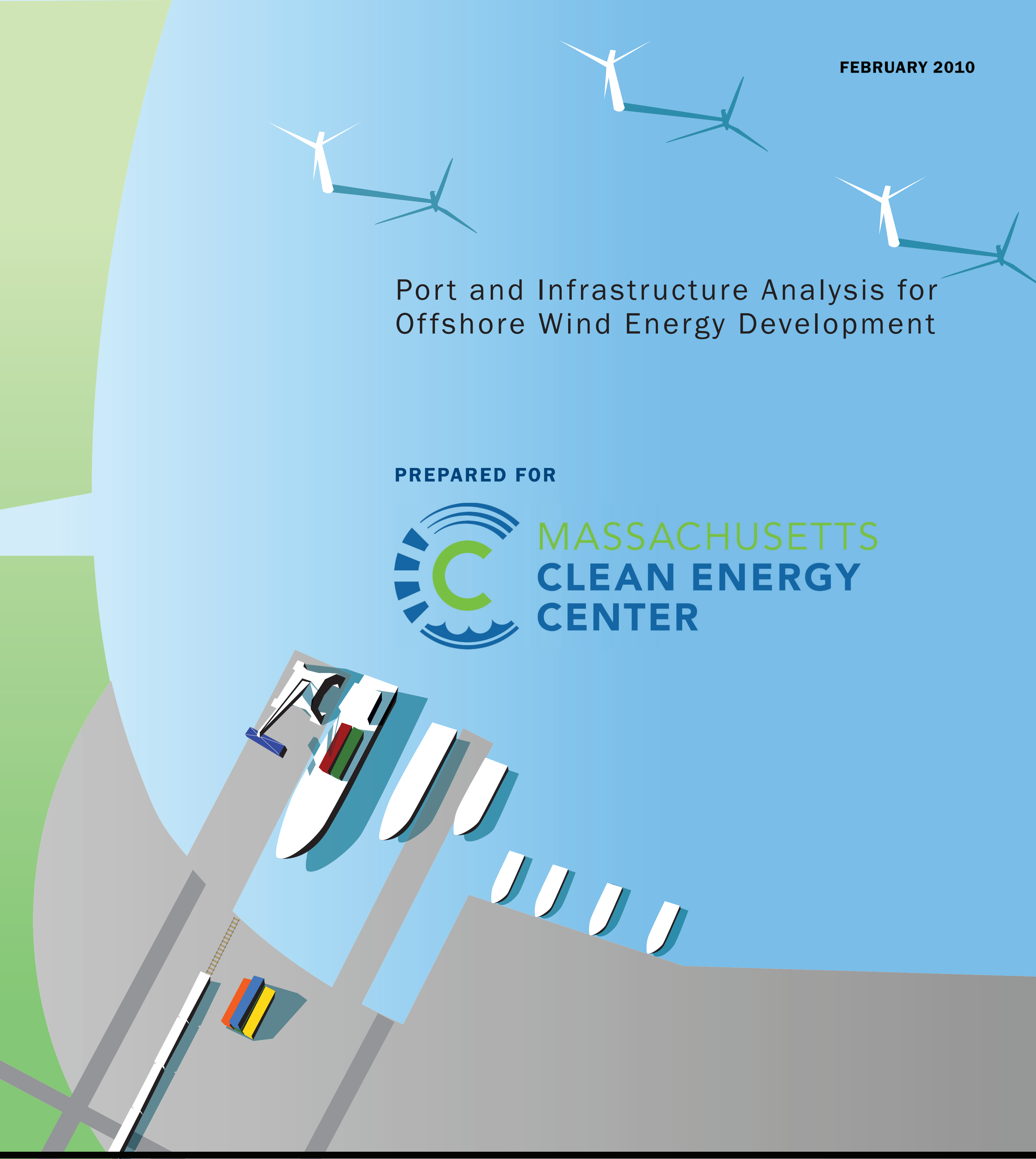
FEBRUARY 2010

Port and Infrastructure Analysis for Offshore Wind Energy Development



PREPARED FOR

MASSACHUSETTS CLEAN ENERGY CENTER

TETRA TECH EC, INC.

133 Federal Street, Boston, Massachusetts 02110

Port and Infrastructure Analysis for Offshore Wind Energy Development

Prepared by:

TETRA TECH EC, INC.

and

Advanced Offshore Solutions

Childs Engineering Corporation

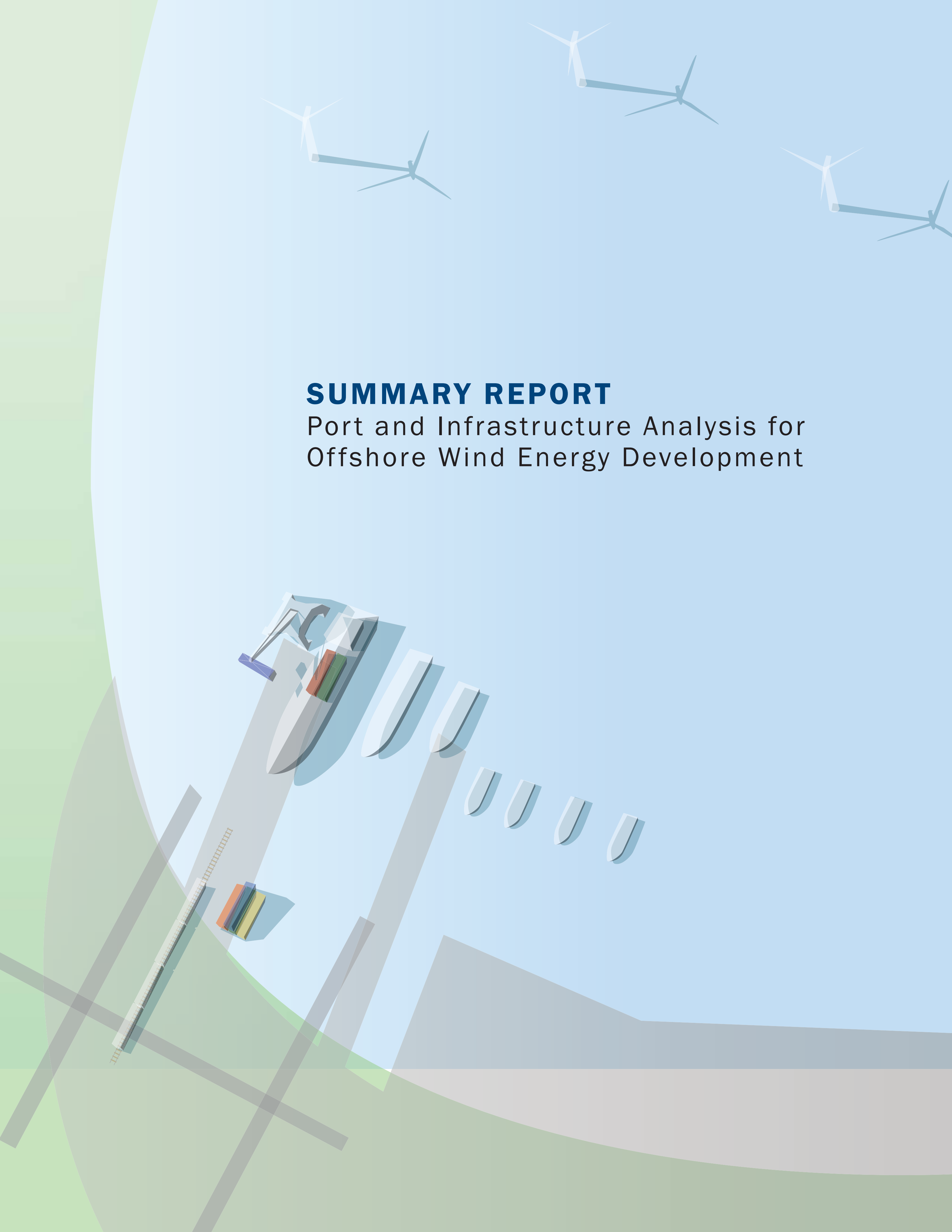
Durand & Anastas Environmental Strategies

FXM Associates

The Glosten Associates

MARPRO Associates International

February 2010



SUMMARY REPORT

Port and Infrastructure Analysis for Offshore Wind Energy Development

TABLE OF CONTENTS

1 Introduction ... 1
1.1 Background ... 1
1.2 Context ... 1

2 Assessment of Offshore Wind Energy Port Infrastructure Needs ... 4
2.1 Wind Farm Components ... 4
2.2 Wind Turbine Component Delivery and Deployment ... 6
2.3 Similar Offshore Activities ... 7

3 Industry Overview ... 9
3.1 Development of Port Criteria ... 9
3.2 Discussions with Developers ... 9
3.3 Key Parameters: Conditions at Ports and Wind Farm Locations ... 12
3.4 Key Parameters: Vessel Constraints and Requirements ... 13
3.5 Key Parameters: Navigational Access and Transit Distances ... 16
3.6 Key Parameters: Staging Port Facility Requirements ... 18
3.7 Key Parameters: Rail and Highway Access ... 21

4 Evaluation Criteria ... 22
4.1 1st Tier Hard Criteria ... 22
4.2 2nd Tier Hard Criteria ... 22
4.3 Soft Criteria ... 23
4.4 Screening and Short-Listing the Ports ... 23

5 Inventory of Massachusetts Ports ... 24
5.1 Overview of Massachusetts Port Facilities and Characteristics ... 24
5.2 U.S. East and Gulf Coast Shipyard Construction and Repair Capacity ... 25

6 Short-Listing Ports for Further Evaluation ... 27
6.1 Evaluation of Massachusetts Ports against Hard Criteria ... 28
6.2 Engineering Cost Analysis of Port Upgrades for Short-Listed Ports ... 29
6.3 Soft Criteria ... 30

7 Economic and Tax Effects of Construction and Operating Expenditures ... 33

8 Summary and Recommendation ... 35

9 Path Forward – Preliminary South Terminal Business Plan ... 38

10 References ... 40

LIST OF TABLES

Table 1 Dimensions of Turbine Components (Technical data for Vestas V112-3.0 MW) 6
Table 2 Planned Offshore Wind Projects 10
Table 3 Principal Dimensions for Turbine Installation or Transport Vessels 16
Table 4 Summary of Navigational Constraints at Selected Massachusetts Ports 16
Table 4 Summary of Navigational Constraints at Selected Massachusetts Ports (continued) 17
Table 5 Distances to Staging Port Locations from the OMP Wind Energy Areas 17
Table 6 Expected Through-Put at Staging Port, for Various Construction Scenarios 18
Table 7 Crane Requirements for 3.6 MW and 5 MW Turbines and Associated Monopile Foundations 20
Table 8 Massachusetts Port Criteria Analysis Matrix 27
Table 9 Comparison of the Two Short-Listed Ports (continued) 36
Table 10 South Terminal Operating Income and Expenses 39

LIST OF FIGURES

Figure 1 Primary Components of an Offshore Wind Turbine 4
Figure 2 Types of Foundation for Offshore Wind Turbines 5
Figure 3 Bunny Ear Configuration (Lateral) – End view looking forward 12
Figure 4 Bunny Ear Configuration (Fore-Aft) – End view looking forward 12
Figure 5 Star Configuration – End view looking forward 12
Figure 6 Loaded Barge in Transit 15
Figure 7 Barge on Site with Legs Down 15
Figure 8 New Bedford Harbor 33
Figure 9 Boston Harbor 33

ACRONYMS AND ABBREVIATIONS

DPAs	Designated Port Areas
EPA	Environmental Protection Agency
EWEA	European Wind Energy Association
FAA	Federal Aviation Administration
GDP	Gross Domestic Product
HDC	Harbor Development Commission
hp	horsepower
IBEW	International Brotherhood of Electrical Workers
LNG	liquid natural gas
MCEC	Massachusetts Clean Energy Center
MCZM	Massachusetts Coastal Zone Management
MDEP	Massachusetts Department of Environmental Protection
MDOT	Massachusetts Department of Transportation
MEPA	Massachusetts Environmental Policy Act
MIT	Massachusetts Institute of Technology
MREC	Marine Renewable Energy Center
mt	metric ton
MW	Megawatts
nm	nautical miles
NPDES	National Pollutant Discharge Elimination System
OCS	the Outer Continental Shelf
OMP	Ocean Management Plan
psf	per square foot
ROWEI	Representative Offshore Wind Energy Installation
USACE	U.S. Army Corps of Engineers
WHOI	Woods Hole Oceanographic Institute

1 Introduction

1.1 Background

In the context of a widespread interest in the potential of offshore wind to create clean energy jobs in Massachusetts, reduce the region's dependence on foreign oil, and reduce greenhouse gas emissions through the production of renewable energy, the Massachusetts Clean Energy Center (MCEC) commissioned this report ("Summary Report" or "report") to examine and identify port facilities in Massachusetts that have the ability to support commercial scale offshore renewable energy development. This report also seeks to explore the feasibility, as well as the economic development potential, of planned and potential port and landside facilities at Massachusetts ports identified as possible candidates for staging offshore wind farms. For this first-of-its-kind study of port infrastructure to support offshore wind, the MCEC contracted with Tetra Tech EC, Inc. and a team of specialized professionals (collectively "the Team") to conduct this study and issue a report on the findings.

As stated in the Request for Proposals solicitation for this study, "Offshore wind energy is the most viable option available for developing utility-scale renewable energy electric generating facilities to the densely populated states along the Eastern seaboard in the near term." Marine-based wind energy generation has the advantage as a renewable energy source because it is closer to commercial deployment than other marine-based electricity generation technologies, such as tidal and wave energy. Furthermore, the large scale of equipment and components required for offshore wind generation (i.e. the blades, foundations and towers) means that if a port can physically support offshore wind generation it most likely will meet the requirements for other marine based renewable energy technologies. Therefore, this study focused primarily on how Massachusetts ports can meet the requirements of commercial scale offshore wind energy generation projects.

This Summary Report has been distilled from the more detailed report ("Final Report"). The Final Report provides the approach, analysis, and recommendations that resulted in the identification of appropriate port facilities in New Bedford and Boston, which were subsequently evaluated in more depth. It also addresses the high level engineering requirements, associated costs, and economic potential of the proposed port improvements at the two short-listed ports, the South Terminal at the Port of New Bedford and Dry Dock #4 at the Port of Boston. The Final Report provides the key findings of the study and recommendations to the MCEC of the most effective investment in port facilities to support offshore wind energy generation construction, operation, and maintenance. Based on a thorough comparison between the ports in New Bedford and Boston, the Team concluded that the South Terminal at the Port of New Bedford is the port in the Commonwealth best able to meet the staging and operation requirements for offshore wind development.

1.2 Context

The Northeast Atlantic coastal waters, particularly those off Massachusetts, provide a combination of relatively shallow waters, favorable wind conditions, and proximity to population centers that makes this area uniquely attractive for offshore wind energy development. Those Massachusetts ports possessing the facilities, land area, and navigational characteristics necessary for the assembly and transport of wind turbine components, and for long-term operation and maintenance needs of offshore wind farms, are well-positioned to serve the emerging demands of the offshore wind energy industry.

In April 2009 the U.S. Department of the Interior Minerals Management Service issued final regulations on "Renewable Energy and Alternative Uses of Existing Facilities on the Outer Continental Shelf (Final Rule)," establishing a process for leasing submerged lands for renewable energy projects on the Outer Continental Shelf (OCS). The Final Rule outlines the requirements for limited (short-term – for testing and characterizing) and commercial (long-term – for power generation) leases and the bidding and regulatory procedures a wind developer must follow to obtain rights to a wind farm development site on the OCS.

Additionally, the Massachusetts Ocean Management Plan (OMP) was released on January 4, 2010 by the Commonwealth's Executive Office of Energy and Environmental Affairs (EOEEA OMP 2010). The OMP establishes new protections for environmental resources, and sets parameters for the development of community-scale and commercial-scale offshore wind energy as well as other infrastructure in State waters. The OMP designates which areas are prohibited from use and which may be used for wind energy farms and other renewable energy facilities. This new regulatory framework indicates interest in and expectation for future offshore development. Two renewable energy areas were identified based on the presence of suitable wind resource, water depth, and the absence of conflict with other uses or sensitive resources. These areas are located approximately one mile offshore in the vicinity of the southern end of the Elizabeth Islands and southwest of Nomans Land Island. These areas could accommodate approximately 150 3.6 megawatts (MW) turbines at full build-out (OMP pp 4-1). The Team recognized the potential for these sites to be developed for offshore wind energy and the implications for port and infrastructure to support offshore wind farms. Massachusetts ports with the potential to satisfy the infrastructure requirements of the offshore wind energy industry are well-positioned to support construction, as well as operation and maintenance in these areas.

Developers have yet to construct any offshore wind generation facilities in U.S. waters (to date only meteorological towers to test wind characteristics). In turn, U.S. port facilities have yet to stage construction for any offshore wind farms. Other than the import of landside wind farm components, East Coast ports have no experience in handling, storing or assembling the offshore wind generation components. Therefore, the current experience of European ports servicing offshore wind facilities and U.S. Gulf of Mexico ports staging construction for the offshore petroleum industry have formed the basis of the Team's analysis of the port infrastructure needed to support the East Coast offshore wind industry. The combination of the trend toward production of much larger components (such as blades with lengths approaching 90 meters) and the expectation that stateside developers intend to skip pilot scale offshore facilities (which would present learning opportunities) in favor of full-scale production projects, complicates the Commonwealth's preparation for this new industry. Also, the physical constraints in and around Massachusetts ports suggest that its ability to cost effectively stage such offshore construction will take both physical improvements and creative problem solving.

The focus of this port infrastructure analysis is to specifically determine:

- The required characteristics of a port facility to be considered an appropriate staging point for construction of offshore wind generation facilities;
- The difference between traditional port facility features and those required for delivery, storage, handling and deployment of large offshore wind farm components;
- The harborside (navigational) and landside (port facility) needs of purpose-built installation and component delivery vessels (now and in the future);

- Port facilities in the Commonwealth of Massachusetts that could be upgraded or expanded to be considered appropriate staging points;
- The costs for required upgrades or expansions at short-listed ports; and
- The ability of facility improvements to attract wind farm developers and government investment and to ensure a return on investment to the Commonwealth.

Construction staging depends on a number of variables, including number of turbines in a given development scenario, size and weight of the component pieces, schedule of material needs and their point of origination. Other factors include the degree of assembly prior to transport to the development site and the specialty equipment needed for final installation.

The following section provides an overview of offshore wind turbine components as an introduction, since each component has handling and care characteristics that need to be considered. The subsequent analysis characterizes navigation and port infrastructure requirements and identifies Massachusetts ports for further evaluation of the costs and economic impacts and benefits to upgrade port facilities to required standards.

2 Assessment of Offshore Wind Energy Port Infrastructure Needs

This section provides a description of wind farm components and the issues affecting their delivery and deployment and explains how other marine industries offer insight into navigational and port requirements for offshore wind deployment.

2.1 Wind Farm Components

Offshore wind turbine components include the turbine, tower, transition piece, and foundation (see Figure 1). The turbine consists of the nacelle, rotor (with blades) and hub. Most current large-scale turbines use a three-bladed rotor connected through the drive train to the generator, which is housed in the nacelle. Offshore wind turbines are typically larger than 2 MW in generation capacity because of the higher return on the construction investment in terms of power and revenue generation. In this analysis, the Team considered 3 MW or 3.6 MW turbines, as these are the current generation of turbines being installed. For the purposes of this study, a minimum offshore wind turbine array was assumed to consist of ten turbines. Based upon discussions with current and future developers, larger wind farm arrays would include from 60 to 150 turbines.

Various foundation structures can be used, depending on seabed geology, wind/wave conditions and water depth at the site. Four standard types of offshore foundation structures exist and are described below (see Figure 2).

- Monopile
- Gravity-Based
- Multi-Leg or Jacket
- Floating

Monopile and gravity foundations are commonly used in shallow and transitional water depths up to 90 feet. Multi-leg configurations with broader bases such as tripods, jackets, and suction bucket support structures are used for water depths of 180 feet or greater. Floating turbines may also become feasible long-term options for deep water (beyond 180 ft depth). These structures would be secured to the ocean floor via catenary guy wires, mooring lines, or tension legs, which in turn would be fastened to anchors or gravity-based platforms, according to a publication released by the U.S. Offshore Wind Collaborative in 2009.

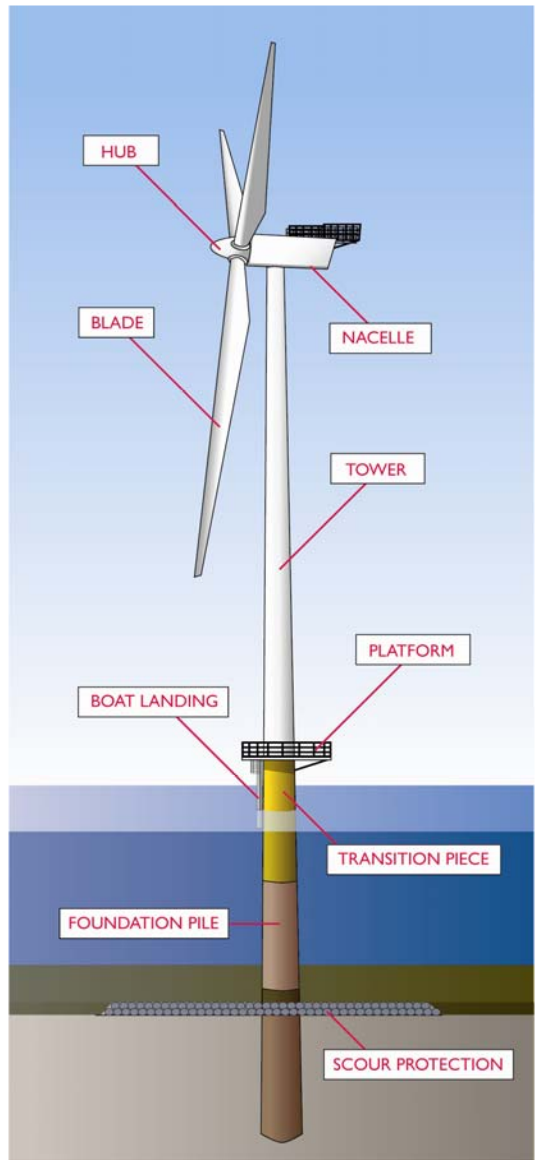


Figure 1 Primary Components of an Offshore Wind Turbine

Figure 2 shows five basic types of foundations. The illustration is not comprehensive as other pile type foundations exist. General depth ranges are shown in feet.

Dimensions of turbine components vary from make, model, and power rating. As stated above, most of the planned commercial-scale generation projects for the Northeast Atlantic coast expect to use turbines in the 3MW to 3.6MW range. Table 1 below provides an example of the magnitude of component dimensions.

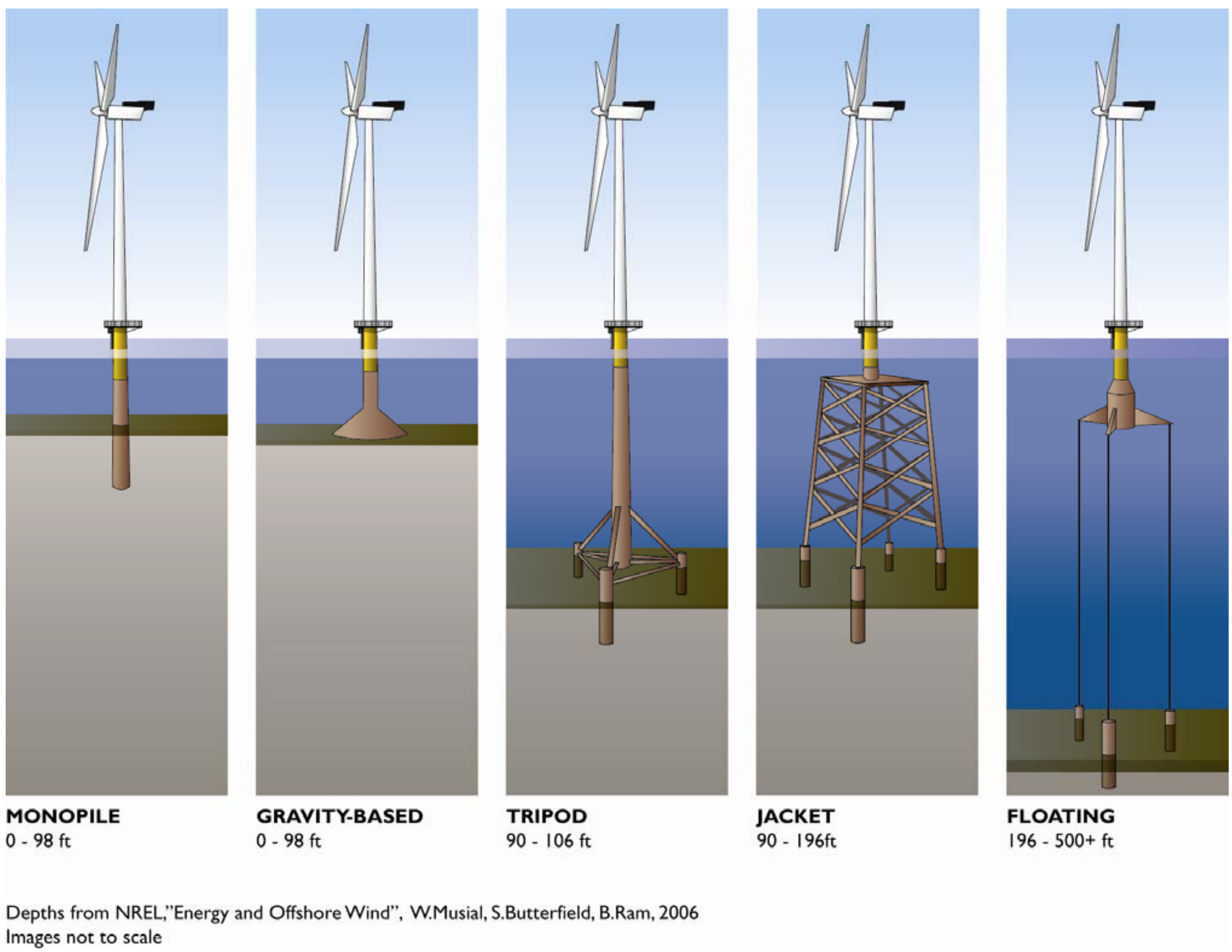


Figure 2 Types of Foundation for Offshore Wind Turbines

Table 1 Dimensions of Turbine Components (Technical data for Vestas V112-3.0 MW)

Dimensions				
Turbine Component	**Weight**	**Length**	**Height**	**Width/Diameter**
Monopile foundation	165 to 231 US ton (for 90 to 130 ft long monopile) 551 US tons (for 197 ft long monopile)	Varying 90 to 130 ft to up to 197 ft	N/A	D: 16.75 ft / 18 ft)
Transition piece	187 US tons	56 ft per unit	N/A	D: 13.8 ft
Nacelle (incl. hub)	138 to 165 US tons	46 ft	10.8 ft	w: 12.8 ft
One Blade	14 to < 20 US tons	179 ft	N/A	Max. w: 13.8 ft
Tower Section	Approximately 77 US tons	106.6 ft	197 ft assembled	d: 13 ft to 15 ft

(Source: Vestas 2008)

2.2 Wind Turbine Component Delivery and Deployment

Currently, very few offshore wind turbine components suitable for commercial-scale offshore wind farms are being manufactured in the U.S. that are of the size appropriate for a wind farm with 60 to 150 turbines. Manufacturers will have little incentive to set up large scale offshore wind component manufacturing operations in the United States until developers are ready to purchase components at a rate that makes the investment in a manufacturing facility financially attractive (based on Team discussions with manufacturers). Therefore the Team's analysis assumes that most, if not all turbine component pieces for the planned offshore wind farms would be manufactured and shipped from European facilities.

Foundations and transition pieces tend to be manufactured and delivered separately from the turbines, although there may be some manufacturing capacity overlap with towers. Currently, no operational rolled steel manufacturing facilities on the East Coast have been identified at a scale suitable for a large offshore wind farms. Like turbine manufacturers, foundation suppliers lack the incentive to set up an East Coast production facility, and therefore it is likely that foundation components would be shipped ready to be assembled on large barges from the Gulf of Mexico, Europe or Malaysia. Rail and truck delivery options are limited to aggregate for scour protection, or sectional pieces such as iron bars or flat sheets of steel for use in the foundations or transition pieces. Fully assembled foundations have dimensions which preclude shipping by rail or truck.

Developers do not necessarily have to stage foundations for offshore deployment out of the same port staging the turbine construction. The convenience of utilizing a common port facility generally would not outweigh the cost savings associated with improved logistics, less assembly, and minimizing storage space and handling needs. Barges also may be used for foundation storage in certain circumstances. Foundations can be delivered and stored on barges fully assembled and then tugged out to the installation site with less handling.

Turbine components may be transported from the staging port to the installation site in various stages of assembly (see Figures 3, 4, and 5 below). *Vessel Requirements for Offshore Wind Farm Construction and Maintenance* (The Glosten Associates 2009), which is Appendix A of the Final Report, provides more details on these transport options. The options range between offshore on-site assembly and installation at the wind farm site, and turbine assembly in the controlled environment of the staging port, with the fully assembled turbines transported to the installation site in an upright position. Assembly at the offshore installation site lessens the risk associated with fully assembled turbine transport, but entails risks associated with turbine assembly in the marine environment.

Turbine manufacturers and contractors experienced in European wind farm construction prefer specialized purpose-built vessels for turbine installation. Purpose-built vessels are not currently available in the U.S. and are not expected to be available for use in the U.S. in time for the initial construction of commercial-scale wind generation facilities on the East Coast. Construction costs for these vessels range from $40 million ($40M) to $80M for tugged vessels and $150M to $250M for self-propelled vessels (The Glosten Associates 2009). Similar to potential investment in manufacturing facilities, the incentive to build a purpose-built installation vessel will depend on actual demand and potential return on such investment. Existing U.S. built jack-up vessels are less than optimal for offshore wind turbine installation, but probably can be used for the initial deployments for East Coast offshore wind construction. However, the use of these existing vessels involves more risk and would require more installation time than purpose-built vessels. Rental rates for installation vessels are high and developers will attempt to maximize the utilization of the vessels when they have them. This factor, along with the ever present possibility of weather and seasonal delays, indicates that the staging port must be available 24 hours per day and 7 days per week. Both the availability of wind turbine components and delivery and construction vessels are critical elements of the offshore wind energy supply chain.

Future Trends

Proposed offshore wind projects in Europe and North America for 2015 are forecasted to reach 40 GW, of which the United States is expected to undertake projects totaling more than 2 GW (Infocast, U.S. Offshore Wind Report 2009, p. 6). The European Wind Energy Association (EWEA) has set a target for 2020 of 40 GW of offshore wind capacity. European offshore demand for 2010 is forecasted to reach 10 GW. This implies a European need for 30 GW or more over a 5-year span, which cannot be supported by current manufacturing capacity (EWEA, Oceans of Opportunity 2009, p. 44). However, the offshore wind industry will need to deploy upwards of 10,000 structures by 2020 to meet the minimum forecasted European demand. The current offshore manufacturing industry cannot deliver this number of structures due to insufficient capacity (EWEA, Oceans of Opportunity 2009, p. 49). Significant additional manufacturing facilities and related industrial capacity are needed to meet the forecasted European and North American demand.

2.3 Similar Offshore Activities

Offshore wind generation as a new marine industry on the U.S. East Coast will be added to a region that has historically been heavily dependant on maritime industry and commerce. As a new industry, however, offshore wind will require specialized equipment, services and labor not currently operating out of any U.S. ports. Understanding what will be needed to support both short-term construction activities and long-term operational and maintenance activities involves both learning from recent construction of European offshore wind projects, as well as identifying how similar services and activities already associated with existing marine industries here in the U.S are currently performed. There are a number of marine industries, each with its own port requirements, currently operating in the waters offshore of the U. S., including, but not limited to, petroleum extraction, liquid natural gas (LNG) ports, commercial shipping, and commercial fishing. The Final Report describes these existing U.S. marine industries in more detail and discusses potential similarities with the offshore wind industry.

Each marine industry is specialized, requiring differing shore-side support as well as equipment for conducting offshore operations. However, understanding the needs of these industries can help to identify the port-related requirements for offshore wind development and the potential utilization of the available marine equipment and facilities along the U.S. East Coast. In many ways, wind turbine foundations (and approach to installation) are comparable to offshore petroleum structures. Commercial fishing operation requirements are very comparable to offshore wind construction and operational needs. However, offshore wind generation support needs are much smaller in scale than the warehousing and wharf frontage needed for commercial shipping. Port and support vessel requirements for maintenance of offshore wind farms are similar to those for commercial fishing, offshore LNG ports, and petroleum platforms. Offshore wind turbine foundation technology has been developed based on structural foundations already in use in petroleum extraction, primarily the use of piles and jackets. As with wind turbine foundations, the foundation types for petroleum platforms vary greatly with water depth. Deep water technologies such as semi-submersible and floating platform equipment are being explored for the offshore wind industry as well as deep water LNG ports. Anchor systems similar to those used for petroleum and LNG ports could be modified for use as wind turbine foundations, anchoring floating turbine structures in deep water locations.

Petroleum extraction platforms are currently assembled using specialized heavy lift vessels. Vessels currently in the fleet (including jack-up cranes, tow boats, and large barges) have the potential to be modified for use as construction platforms for wind turbines. While such modifications can be made to existing vessels, the specialized construction techniques and heavy lift needs of offshore wind turbine construction may make the modification option expensive and potentially risky. The option of applying modified existing equipment may also be limited to smaller construction projects in near-shore environments. Purpose-built construction vessels for offshore wind turbine construction most likely, in the long run, would be more cost effective, less risky, and flexible in terms of operational capabilities. An offshore wind farm, once constructed, will need operational support in the form of routine maintenance. Maintenance vessels used during wind farm operations would likely be similar in size to those currently in use to support offshore LNG ports and petroleum extraction operations. Berthing space for support vessels will be vital for port facilities, as well as yard and warehousing space for components and other maintenance supplies.

3 Industry Overview

3.1 Development of Port Criteria

To determine the port-facility/land-based requirements for both the installation and long-term servicing of planned offshore wind projects, the Team:

- Held discussions with offshore developers and compiled relevant data;
- Conducted research and compiled data on manufacturer requirements;
- Determined key harborside and landside port parameters;
- Developed a list of evaluation criteria for harbors and port facilities; and
- Identified the most highly desirable characteristics of port facilities.

The following sections of this Summary Report describe some of the specific areas of analysis listed above.

3.2 Discussions with Developers

The Team identified and contacted several prospective U.S. East Coast offshore wind farm developers with the goal of compiling a detailed understanding of the requirements necessary to successfully support the construction, operation and maintenance of a commercial-scale offshore wind farm. The Team intended to use this developer input to identify an objective set of weighted criteria with which to compare and evaluate Massachusetts port facilities. Many developers have yet to specify or disclose in detail the key parameters and characteristics that were sought for this purpose; however, developers did identify and explain many aspects of the most important parameters, which helped the Team establish the basic port criteria. The Team's discussions with developers did provide a better understanding of offshore wind farm components and the logistics of importing, storing, assembling, scheduling, and deploying wind turbines and foundations to installation sites.

Some developers have already initiated permitting or applied for lease blocks for several wind generation sites along the East Coast. From the available information on these projects, the Team determined that port infrastructure must support projects of varying scale ranging from 60 to 150 turbines. These proposed projects formed the starting point for the Team's analysis of port requirements. Table 2 below provides a quick view of these proposed projects based on available public information. Projects are listed by developer with particulars such as location, water depth, generating capacity, number of turbines, and distance from shore. Because these projects are in various stages of development, not all information on every project is publicly available.

As the developer's needs were analyzed, the Team found that Massachusetts ports had clear, distinguishable differences relative to the offshore wind development requirements.

Table 2 Planned Offshore Wind Projects

Developer/Project	Project Location	Water Depth at Proposed Location	Project Generating Capacity	Number of Turbines (Scale)	Foundation Type	Estimated Cost of Construction	Port Staging Area
Cape Wind Associates							
Cape Wind	4.5 NM (5.2 miles) from coast of Cape Cod, MA, 7.8 NM (9 miles) from Martha's Vineyard, 12 NM (13.8 miles) from coast of Nantucket Island	3.7 m (12 ft) MLLW (mean low low water) minimum depth	468 MW	130 (3.6 MW per turbine)	Monopile	$700 million	Quonset Davisville Port and Commerce Park, Quonset, Rhode Island
NRG Bluewater Wind							
Bluewater Delaware	11.3 to 19.1 NM (13 to 22 mi) east of Rehoboth Beach, DE (wind park); 14.3 NM (16.5 mi) due east Rehoboth Beach (met tower)	12.2m to 18.3m (40 to 60 feet)	200 to 450 MW	Up to 150	Monopile	$800 million	Port of Wilmington, Delaware; Delaware Bay Launch in Milford Delaware for crew boat and small cargo barge launch
Bluewater New Jersey	14 NM (16 mi) southeast of Atlantic City, NJ	21.3m to 30.5m (70 to 100 feet)	350 MW	116	Monopile	$1.4 billion	Port of Wilmington, Delaware; Delaware Bay Launch in Milford Delaware for crew boat and small cargo barge launch
Deepwater Wind							
Garden State Offshore Energy (Deepwater with PSEG Renewables)	13.6 NM (15.6 mi) from shore, 17.4 NM (20 mi) due east of Avalon, NJ	24.4m to 27.4m (80 to 90 feet)	350 MW	96	Jacket	$1 billion	Atlantic City, New Jersey
Deepwater Wind Rhode Island	2.6 NM (3 miles) off Block Island, RI for Phase 1; Phase 2 located 13 to 17.4 NM (15 to 20 mi) off RI coast (location TBD upon completion of RI Ocean Special Area Management Plan in 2010	'deeper' waters	20 MW (Phase I) 400 MW (Phase II)	Phase 1: 8 turbines Phase 2: 106 turbines	Jacket	$1 billion	Quonset, Rhode Island

Table 2 Planned Offshore Wind Projects

Developer/Project	Project Location	Water Depth at Proposed Location	Project Generating Capacity	Number of Turbines (Scale)	Foundation Type	Estimated Cost of Construction	Port Staging Area
Fisherman's Energy							
Fisherman's Energy of New Jersey Project	Phase 1: 2.6 NM (3 miles) off the coast of Atlantic City Phase 2: 6.1 NM (7 miles) off the coast	18.3m to 21.3m (60 to 70 feet)	Total: 350 MW Phase 1: 20MW Phase 2: 330 MW	Total: 74 Phase 1: 8 turbines Phase 2: 66 turbines	Monopile	$100 million for Phase 1 $1 to 1.5 billion for Phase II	Dorchester, Atlantic City, and or Cape May, New Jersey
Fisherman's Energy of Rhode Island Independence 1 Project	2.6 NM (3 miles) south off the southern coast of Block Island, RI	20 m to 30 m (65.6 to 98.4 feet)	400 MW	80	TBD	$1.25 to $1.5 billion	TBD

3.3 Key Parameters: Conditions at Ports and Wind Farm Locations

Wave height, water depth and wind speed impose limitations on at-sea construction operations. The Team studied sea states, wind conditions, and water depths at a number of proposed wind farm sites along the U.S. East Coast, as well as transit distances between proposed wind farm sites and potential staging ports.

The base line transit routes for cargo in the region track around the east end of Cape Cod and the primary alternative route is via the Cape Cod Canal (MARPRO Associates International 2009). Air draft (i.e., the free space above the water line below an overhead obstruction) in the Cape Cod Canal is limited to approximately 135 feet. Vessels or barges transporting 5 MW turbines in the “bunny ear” configuration (especially the “fore-aft” configuration – See Figures 3 and 4) most likely cannot transit the Cape Cod Canal. Alternative turbine load-out configurations (e.g., the “star” configuration – See Figure 5) and/or smaller turbines (e.g., 3.6 MW turbines) in the “bunny ear” configuration probably could utilize the Cape Cod Canal.

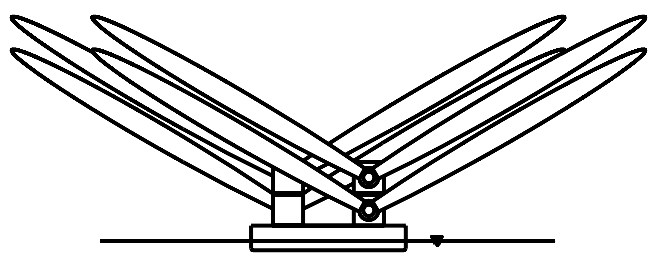


Figure 3 Bunny Ear Configuration (Lateral) – End view looking forward

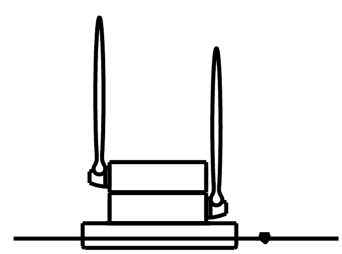


Figure 4 Bunny Ear Configuration (Fore-Aft) – End view looking forward

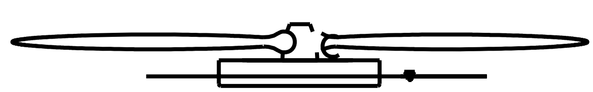


Figure 5 Star Configuration – End view looking forward
(Source of Figures 3-5: The Glosten Associates 2009)

3.4 Key Parameters: Vessel Constraints and Requirements

Characteristics of Available Vessels

The following sections discuss the basic characteristics, capabilities, limitations, and general availability of vessels that are currently available for use in the construction and maintenance of offshore wind farms. *Vessel Requirements for Offshore Wind Farm Construction and Maintenance* (The Glosten Associates 2009), which is Appendix A of the Final Report, provides further details.

Turbine Import/Delivery Vessels

The turbines used for the first round of U.S. offshore wind farms likely will be imported from Europe. Turbines are generally shipped in pieces (tower sections, nacelle, hub, individual blades) from the point of origin directly to the project site aboard open hatch cargo vessels.

Foundation Delivery and Installation Vessels

Foundations can be installed using either jack-up crane vessels or floating derrick barges. Jack-up crane vessels are described further below. Large floating derrick barges are in service on all three major U.S. coastlines and could be mobilized to serve the U.S. East Coast offshore wind energy market. Depending on the type of foundation being used (i.e., monopile, gravity-base, jacket, or tripod), a derrick barge could transport foundations between the staging port and the wind farm site on its own deck, or foundations could be transported using a separate barge.

Wind Turbine Installation Vessels

European offshore wind turbines have been installed using a variety of specialized equipment, which generally falls into one of three categories:

- Leg-Stabilized jack-up crane ships ("partial jack-ups");
- Jack-up crane barges; and
- Jack-up crane ships.

For all three vessel types, the limiting wind speed for at-sea crane operations is approximately 15 to 20 knots. For the leg-stabilized vessels, the limiting sea state for crane operations is approximately 1.7-foot seas, as the vessel's hull remains submerged and is subject to wave-induced motion. For the jack-up barges and ships, the process of jacking up and down is limited to approximately 5-foot seas. The crane can be operated in higher sea states once the vessel is jacked-up. Future wind turbine installation vessels are expected to focus on improving construction efficiency through faster transit speeds, larger payload capacity, and ability to erect turbines in higher wind speeds and larger sea states.

Maintenance Vessels

Regular, planned maintenance of offshore turbines requires personnel access to the wind farm facilities. Maintenance personnel are typically shuttled to the turbines by a crew boat or by helicopter. Major maintenance or repair of offshore wind turbines may require mobilization of a wind turbine installation vessel to reverse some or all of the installation process.

Vessel Requirements for Deployment and Maintenance

Understanding the marine vessel requirements for deploying and maintaining offshore wind farms along the U.S. East Coast is critical in the overall evaluation of ports' suitability as staging areas for offshore wind farm development. Vessel requirements are governed primarily by the following:

- Physical conditions in which vessels must operate at offshore wind farm sites;
- Size and weight of turbines being transported and installed; and
- Methodology for transporting and installing turbines.

The Team evaluated physical conditions, including wind speeds, wave regime, and water depth at proposed offshore wind farm installation sites along the U.S. East coast, as well as navigational constraints in and near existing Massachusetts port facilities. The Team reviewed demonstrated methodologies for transporting and installing offshore wind turbines.

Installation and Transport Vessel Requirements

For purposes of this study, it was assumed that the installation vessels discussed below would be subject to the Jones Act, which requires vessels engaged in the transport of passengers or cargo between U.S. places to be built and flagged in the United States, and owned and crewed by U.S. citizens.

The key dimensions of the turbine installation and turbine transport vessels are beam, length, draft, and vertical clearance (a.k.a. "air draft"). The beam of installation and transport vessels is largely dictated by vessel stability requirements during transit and, when applicable, the stability requirements and structural strength while elevated on legs (i.e., "jacked up"). The length of the vessel depends on functional and cargo requirements and structural considerations. The vessel's draft, or the required clearance between the waterline and sea bed, is dependant on the hull form and total weight, including cargo. Vertical clearance is dictated by three factors: length of legs (for a jackup barge or vessel), pre-assembly methodology, and crane height in the stowed position.

Figures 6 and 7 show a fully loaded 400-ft x 100-ft (length x beam) barge with jackup legs in transit and after installation configurations, respectively. Turbine tower sections are typically transported in the vertical orientation, with maximum height approximately even with the top of the blades in the bunny ear configuration.

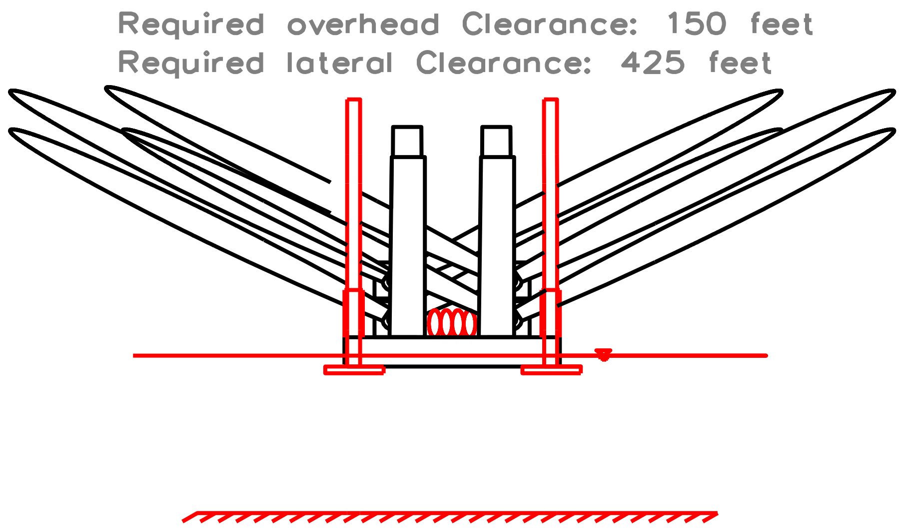


Figure 6 Loaded Barge in Transit

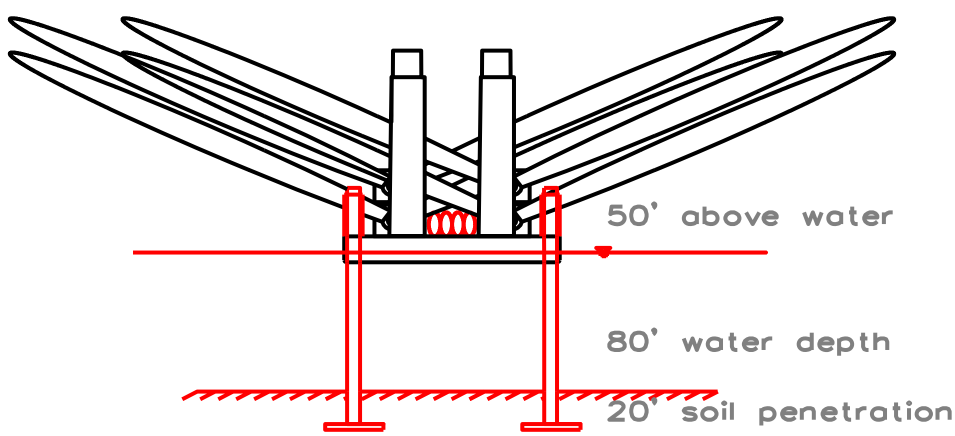


Figure 7 Barge on Site with Legs Down
(Source for Figures 6 and 7: The Glosten Associates 2009)

The required overhead clearance is approximately 150 ft. The star (Figure 5) and lateral bunny ear (Figure 3) configurations require a lateral clearance of approximately 425 ft. The lateral clearance for the fore-aft bunny ear (Figure 4) configuration is dictated by the barge or vessel beam, which is typically on the order of 100 to 125 ft. In the near future, it is expected that specialized installation vessels will transport multiple pre-assembled turbines on tower sections out to the installation sites, requiring overhead clearances in excess of 300 ft.

The principal dimensions and draft characteristics (navigational and air) of a typical installation or transport vessel are presented in Table 3.

Table 3 Principal Dimensions for Turbine Installation or Transport Vessels
(Source: The Glosten Associates 2009)

Length Overall	90 – 140 m (300' – 450')
Beam	30 – 40 m (100' to 130')
Navigation Draft	3.6 – 4.9 m (12' to 16')
Air Draft (legs in up position)	varies, approximately 46 m (150')
Air Draft (tower sections, bunny ears)	46 m (150')
Air Draft (crane in stowed position)	varies

Section 4.4.1 of the Final Report provides additional details of the principal dimensions of wind turbine installation vessels/barges and import vessels.

Tugboat and Auxiliary Vessels

Self-propelled wind turbine installation vessels likely will not require tug assistance, as they would be able to move and position themselves using their own propulsion and dynamic-positioning systems. Barges, on the other hand, would require at least one tug of approximately 4,000 to 5,000 horsepower (hp). In addition, a smaller tug of around 1,000 hp may be needed to help position the vessel for jacking operations. Additional necessary vessels include high-speed crew boats during wind farm construction and several auxiliary vessels to complete the marine fleet. These types of vessels are all readily available for hire throughout the Northeast U.S.

3.5 Key Parameters: Navigational Access and Transit Distances

The required navigational clearances for vessels involved in the construction and maintenance of offshore wind farms were presented. The key considerations for navigational access are:

- Vessel draft compared to navigable water depth;
- Vessel beam (including overhanging cargo) compared to channel width; and
- Vessel air draft compared to overhead clearance restrictions (bridges and aerial cables).

Table 4 summarizes the navigational restrictions associated with selected Massachusetts ports. Further details are given in *Vessel Requirements for Offshore Wind Farm Construction and Maintenance* (The Glosten Associates 2009), which is Appendix A of the Final Report.

Table 4 Summary of Navigational Constraints at Selected Massachusetts Ports

Staging Port	Potential Obstructions	Lateral Clearance	Overhead Clearance	Controlling Water Depth	Feasible Turbine Load-Out Configurations	Jack-Up Feasible?
New Bedford	Hurricane Barrier	45 m (150')	No Constraints	6.7-9.1 m (22'-30')	all	yes
Gloucester	water depth, channel width	61 m (200')	No Constraints	4.9-5.8 m (16'–19')	fore-aft bunny ear	Marginal (water depth)
Fall River	Mt. Hope Bridge	122 m (400')	41 m (135')	12.2 m (40')	star	Marginal (air draft)
Charlestown / East Boston (inner harbor)	Logan Airport	over 150 m (500')	Report air draft to airport traffic control	12.2 m (40')	all	yes

Table 4 Summary of Navigational Constraints at Selected Massachusetts Ports (continued)

Staging Port	Potential Obstructions	Lateral Clearance	Overhead Clearance	Controlling Water Depth	Feasible Turbine Load-Out Configurations	Jack-Up Feasible?
Mystic River	Tobin Memorial Bridge	over 150 m (500')	41 m (135')	7.6-10.7 m (25-35')	star	Marginal (air draft)
Chelsea River (West of Chelsea St. Bridge)	Andrew McArdle Bridge	53 m (175')	No Constraints	8.8-12.2 m (29-40')	fore-aft bunny ear	yes
Chelsea River (East of Chelsea St. Bridge)	Chelsea St. Bridge	28 m (93')	25 m (83')	8.8-12.2 m (29-40')	rotor disassembled	no

In selecting a support facility, distance to the wind farm must be considered in term of cost and effect on risk. Distance impacts fuel consumption, insurance and schedule costs. When turbine components are in transit from the staging port to the installation site, they are more vulnerable to risks associated with weather events and the ocean environment. The cost differential between a distant state-of-the-art facility and a closer facility with less than optimal component handling ability must be carefully evaluated. Table 5 provides transit distances to staging port locations from the Massachusetts OMP Wind Energy Areas located near the southern end of the Elizabeth Island and southwest of Nomans Land Island.

Table 5 Distances to Staging Port Locations from the OMP Wind Energy Areas

Staging Location	Primary Route Distance [nautical miles]	Alternate Route* Distance [nautical miles]
Boston, MA	260	100
Gloucester, MA	235	100
New Bedford, MA	35	n/a
Fall River, MA	50	n/a
Portland, ME	290	175
Quonset/Davisville, RI	40	n/a

* Alternative route is via the Cape Cod Canal

Staging Through-put Estimates

The Team examined the expected level of activity at a port serving as a staging area for offshore wind farm development and estimated the construction time for wind farm construction. Multiple wind farm construction scenarios were considered in order to develop upper and lower bounds of expected port activity. For this analysis the primary metric of port activity is the number of wind turbines deployed per month, which is referred to as "through-put."

The results of the desk top time line modeling of three different staging scenarios for New Bedford, MA were as follows:

- The time line modeling of the Baseline scenario for turbine staging and installation yielded an expected through-put of 15-18 turbines per month for 6-9 months.
- The time line modeling of the Optimistic scenario for turbine staging and installation yielded an expected through-put of 16-22 turbines per month for 12-15 months.

- The time line modeling of the Aggressive scenario for turbine staging and installation yielded an expected through-put of 15-20 turbines per month for 12-15 months and thereafter an expected through-put of 21-25 turbines per month for an additional 8-10 months.

Additional wind farm construction scenarios were evaluated to develop a better estimate of the potential ranges of through-put that may be required at regional staging ports. Each scenario was defined by a vessel type, a transit distance and a length of the construction season. The results of these multiple modeling runs are summarized in Table 6.

Table 6 Expected Through-Put at Staging Port, for Various Construction Scenarios

Transit Distance (staging port to wind farm site *)	Existing Vessels **		Future Vessels ***	
	Summer	Winter	Summer	Winter
50 nautical miles	20-22 turbines/month	16-18 turbines/month	30 turbines/month	30 turbines/month
150 nautical miles	18-20 turbines/month	15-17 turbines/month	21-25 turbines/month	21-25 turbines/month
250 nautical miles	15-17 turbines/month	12-15 turbines/month	16-20 turbines/month	16-20 turbines/month

Notes:

* The transit distance from New Bedford to the Cape Wind site is approximately 60 nautical miles (nm). The transit distance from Boston to Cape Wind is approximately 130 nm. The transit distance from New Bedford to the Deepwater sites near Delaware Bay is approximately 260 nm.

** Existing Vessels means jack-up vessels or barges with slewing cranes, typical of present European offshore wind farm construction practice.

*** Future Vessels means vessels or barges that transport and install fully assembled turbines.

(Source: The Glosten Associates 2009)

The through-put estimates are for turbine installation only. Foundation installation is typically completed in advance of turbine installation and can utilize a wider range of vessels and staging ports than turbine installation. For U.S. offshore wind farms, foundation installation can be completed using existing equipment, which is currently available.

Using a through-put of 18 to 22 turbines per month (based on the results of the time line modeling discussed above), the turbine manufacturer would want 20 nacelles stored at the staging port in advance of assembly and deployment. As workers assemble the turbines in preparation for loading onto the installation vessel, and bad weather hits the installation site, the assembled turbines would have to be stored at the port. Unassembled turbine components would continue to arrive from the manufacturer and require additional storage space for 20 more turbines. Throughput requirements translate into the laydown requirements discussed in Section 3.6 and may require multiple port facilities to support a given offshore wind development.

3.6 Key Parameters: Staging Port Facility Requirements

One developer we interviewed provided a description of the ideal port facility to support offshore wind; a port would have a 1000-ton crane on rolling tracks, which would carry components from a delivery vessel to a storage location; sufficient linear footage to efficiently load/unload one vessel at a time, with a preference for multiple deepwater berths to unload several vessels simultaneously; a secondary 80-ft berth; and about 200 acres for assembly and storage.

While no existing Massachusetts port facility has an assembly and staging area this large, the existing Commonwealth facilities could be repaired, upgraded, or expanded to provide sufficient area to meet the other requirements for staging offshore wind farm construction. If it is necessary to provide a larger area at these existing facilities, then a combination of properties at these marine parks, a combination of ports, or barge storage would have the ability to provide additional space.

Physical Considerations for Staging Turbines

There are a few minimum physical port characteristics that are necessary to stage offshore wind farm development. Based on a review of various European projects and available information from manufacturers, as well as discussions with potential U.S. offshore wind developers, the desirable (minimum) characteristics include:

1. Minimum 24-ft depth of water at low tide;
2. Minimum 450-ft berth;
3. Minimum horizontal channel clearance to harbor of 130 ft;
4. No restriction or air draft limitation on vertical clearance (in anticipation of a future need to transport fully assembled turbines to the installation site); and
5. Minimal distance in open water to project site (see Table 5 above).

<u>Harborside</u>

Water depth requirements relate directly to the vessel type, draft and function. The minimum water depth at mean low water applies to both the navigation channel and the berth. The deepest draft vessel used for transporting offshore wind components sets the navigation channel depth criteria. The vessel length of the largest expected vessel establishes the berth length. With visits from import vessels and transport/installation vessels overlapping, multiple berths or longer berths become more desirable.

Horizontal channel clearance not only depends on vessel beam, but also on component overhang during transport to the installation site. Unobstructed vertical clearance is highly recommended because of likely deployment methods in the future. Turbine manufacturers expect 197 foot-tall tower sections to be transported to the installation site in the upright position. If the turbines are fully assembled for transport, then the nacelle and blade would add significantly to this height. Furthermore, various installation tasks require jack up vessels (for stability at the site), the retracted legs of which would be in the 'up' position. There may be methods to work around vertical obstructions, such as placing a connector pin in the legs or utilizing a hydraulic leg that compresses within itself; however, these methods could add significant expense and complication. The salient point, however, is that vertical obstructions will limit assembly, transport, and vessel options. Further detail on vessel drafts and obstruction clearances can be found in Appendix A of the Final Report.

<u>Landside</u>

The port facility must have adequate laydown space for delivery, storage and assembly of turbine components. Among developers, manufacturers, and European staging facilities the estimated area varied widely, but a minimum of 10 acres was required with a 15- to 25-acre area desirable. If all components of a large development (110 turbines) were to be fully stored on land prior to installation, including both assembly and foundation components, the area required would be about 200 acres. In general, the logistics of manufacturing, assembly, and installation would not require all elements to be on the ground at one time.

To maximize the use of construction equipment, vessels and crews, turbine suppliers require storage based on two factors: (1) having a supply of turbine components ready for assembly and deployment; and (2) having an additional area ready for instances where weather precludes deployment to the installation site while import vessels continue to deliver components to the staging port. While turbine assembly continues, the newly arrived unassembled turbine components need storage. Based on a manufacturer's recommendations, and assuming storage of 20 or more turbines at any one time, the minimum space needed in this scenario is about 8.5 acres.

An additional accommodation for interior storage and/or fabrication space is necessary at the port facility. Developers, contractors and manufacturers also have a strong preference for office space on site. Worker accommodations at the staging port or on a 'hotel' ship at the installation site did not emerge as a major factor in port selection decisions. Construction workers at the installation site would travel on fast crew transport vessels from the construction site to various landing points.

Based on the weight of many of the components, the lay down space may require very high load bearing ground or deck capacity. Using a simple "footprint" analysis, these loads can reach well over 2,000 pounds per square foot (psf). As with many of the facility needs, the deck/ground capacity issue can be accommodated by using certain types of equipment or by placing "load spreading" mats or slabs. Various cranes and other types of material handling equipment will be needed, but it is anticipated that the fabrication or erection contractor would provide these items. Table 7 summarizes the key crane requirements for two representative turbines (a Siemens 3.6 MW Offshore Turbine and a REPower 5 MW Offshore Turbine) and typical monopile components. Load capacity was not used as a criterion to short list the ports, but rather was an issue further analyzed in the engineering review of the shortlisted facilities.

Table 7 Crane Requirements for 3.6 MW and 5 MW Turbines and Associated Monopile Foundations
(Source: The Glosten Associates 2009)

	Siemens 3.6 MW	REPower 5 MW	Monopiles
Max Pick Weight*	Nacelle: 125 mt (138 tons)	Nacelle: 290 mt (320 tons)	180 – 455 mt (200 – 500 tons)
Max Pick Height**	80 m (260 ')	85 – 95 m (280'-310')	Less than 30 m (100')

* 1 ton = 2000 pounds = 0.908 metric ton (mt);
** height above calm sea surface

As noise levels at operating landside facilities must comply with applicable regulatory limits, this factor was not viewed as a discriminator for short-listing ports.

Physical Considerations for Staging Foundation Transport

Harborside criteria established for turbine transport do not apply to foundations, which can be transported flat on barges. Barge transport of foundations would not have the same height, draft or clearance requirements as that for turbine transport; however, the foundation installation vessel may have similar characteristics as the turbine installation vessel. If the foundation installation jack-up vessel is at the construction site and barges are used to transport foundations to the site, then there would be more options for the staging facility. Port facilities with insufficient navigation access for turbine staging potentially could stage foundation deployment.

The staging requirements for foundations depend upon the stage of assembly phase upon arrival and the size and type of foundation. The size of the foundation depends on the size of the assembled turbine and tower, transition piece and blades and the maximum wind load imposed on them, as well as the geotechnical conditions and water depth at the installation site. The staging facility will need landside areas for loading and unloading, storage, and potentially for assembly of foundations components. Fully assembled foundations require a storage area. This area needs to be larger if foundation assembly is required. Shipping unassembled steel bars maximizes cargo space, which would lower shipping costs by reducing the number of shipments. However, the shipping of unassembled foundations or foundation parts would involve the labor cost associated with bar welding. In this case, foundation staging becomes a financial decision.

Manufacturing and Assembly Requirements

Monopile foundation manufacturing utilizes a series of specialized machines not currently available on the East Coast of the U. S. The industry views this potential market as lucrative enough to consider opening facilities in anticipation of offshore wind energy development. However, the investment risk remains similar to that of turbine and purpose-built vessel construction. Until the demand is sufficient for a profitable return on investment, monopiles for East Coast offshore wind farms will have to be manufactured elsewhere. However, a phased approach can reduce the initial investment risk. Monopile pieces can be shipped to a staging port as ‘cans’, or basically smaller sections of rolled steel. At the staging port the ‘cans’ would be welded together to form the monopiles.

3.7 Key Parameters: Rail and Highway Access

The ability to move component parts via rail is determined by rail corridor track curvatures, component weights, and loaded height on the rail car. In general, the weight and length of the proposed units can be handled by the nationwide system. Components can be designed to be transported on the national rail system. They can be broken down to insure they do not exceed rail system limitations on weight or clearance.

Overweight and large roadway shipment units are limited by State permitting requirements. Infrastructure is also considered in permit approvals including limitations from overhead utilities, road lighting, road curvatures and intersections.

Highway and rail delivery modes appear unlikely options for turbine or foundation delivery to port facilities. However, highway and rail access is desirable for delivery of related products such as aggregate for scour protection and component pieces.

4 Evaluation Criteria

The information presented in Section 3 above was reviewed to identify a broad set of direct requirements and highly desirable characteristics of port facilities relative to supporting offshore wind farm construction and operation. These requirements and characteristics were distilled down into a smaller set of criteria to be used more efficiently in the comparative evaluation of the candidate ports. In the distillation process, the Team distinguished a "hard" physical requirement that must be met from a "soft" requirement that reflects preferences and advantages that are more subjective to the developer. Two sets of "hard" requirements were identified for comparing the ports: (1) those related to harbor access (referred to as the 1st Tier Criteria) and (2) those required to meet specific developer and turbine supplier needs (referred to as the 2nd Tier Criteria). Also, a set of "soft" criteria was developed that is somewhat more subjective, but nevertheless allows ports to be distinguished from one another.

4.1 1st Tier Hard Criteria

The 1st Tier Hard Criteria identified relative to harbor access were:

- Sheltered harbor;
- Unobstructed vertical (overhead) clearance (e.g. no bridges);
- Minimum horizontal clearance greater than approximately 130 feet;
- Minimum low tide navigational channel depth of 24 feet; and
- 24 hour/day and 7 days/week operational availability; and
- Exclusive use of the staging facility.

Physical parameters for marine vessels to access a harbor emerge as critical criteria, while rail and trucking access were believed to be present or easily attainable at the set of ports being compared. Staging ports need to accommodate vessels shipping and handling the large components used for commercial scale wind farms. The greatest vessel draft (depth) establishes the criteria for the shipping or navigation channel depth. The widest vessel beam (width) along with the method of component transport, which may involve overhang, establishes horizontal clearances. Along with vessel height, the options for method of transport also contribute to vertical clearance criteria. The potential for bad weather interruptions and the need to maximize labor and equipment availability makes a sheltered harbor an essential criterion.

Implications of the cost of contractor mobilization, vessel and equipment usage combined with weather and seasonal limitations on the construction window result in developers and turbine suppliers requiring a port facility that allows operations 24 hours a day, seven days a week. Given that optimal operations would entail moving large components around the clock, the staging port must also provide exclusive use of the staging facility.

4.2 2nd Tier Hard Criteria

The 2nd Tier Hard Criteria identified relative to the port facilities were:

- Minimum berth length of approximately 450 feet;
- Minimum berth water depth of 24 feet;
- Lay down storage and assembly area larger than 10 acres;
- Proximity to likely offshore wind farm site.

Water depth at the berth must be sufficient to accommodate industry vessel drafts or must be attainable through routine dredging. Additionally, vessel length and the number of vessels operating simultaneously establish the parameters needed for length of the berth. The size of the backland area landside of the bulkhead for storage and assembly of the turbine components and the ability to handle the loads of the components and construction equipment are significant criteria. Proximity of the port to the construction site can affect operational logistics, risks, and costs. The distance from a port facility to wind farm sites, therefore, has significance, but becomes secondary to the parameters discussed above.

4.3 Soft Criteria

Soft criteria parameters, as noted above, are other port area attributes that may attract developers to consider one port over another. The Soft Criteria identified were:

- Workforce availability;
- Education and training facilities;
- Political climate/community acceptance; and
- Regulatory considerations.

The location of education or training facilities and work force availability, including various skilled labor trades, as well as political climate and potential regulatory requirements, are factors that could influence port selection.

4.4 Screening and Short-Listing the Ports

The larger set of ports considered in this study were analyzed using these criteria. Those that did not meet minimum thresholds were eliminated from further consideration by the Team. Section 5 provides an overview of Massachusetts ports that could support staging and installation of offshore wind farms, as well as other regional ports that could meet the assembly, construction, and/or servicing needs of the offshore wind industry. Section 6 describes the process that resulted in the two short-listed ports, the South Terminal in the Port of New Bedford Renewable Energy Marine Park and Dry Dock #4 in the Port of Boston Marine Industrial Park.

5 Inventory of Massachusetts Ports

5.1 Overview of Massachusetts Port Facilities and Characteristics

Our initial inventory of port facilities in Massachusetts is based on: (1) an assessment of each of the state's 11 Designated Port Areas (DPAs) and (2) a review of other properties or areas in other states currently used for industrial maritime activities. DPAs in Massachusetts include Gloucester Inner Harbor, Beverly Harbor, Salem Harbor, Lynn, Mystic River, East Boston, Chelsea Creek, South Boston, Weymouth Fore River, New Bedford-Fairhaven, and Mount Hope Bay. *Comparison of Selected Northeast Ports for Potential Handling of Wind Power Offshore Energy Installations* (MARPRO Associates International 2009) and *Road and Rail Access Ports of Massachusetts* (MARPRO Associates International 2009), Appendices F and G in the Final Report, provide more detail on these ports and modes of transportation to and from the ports.

Massachusetts has a number of ports that, because of their existing or proposed marine terminals, geographic location and surrounding market area, already have substantive marine activity including a wide range of freight activity. In addition to the ports discussed below, the Team contacted the municipalities of Beverly, Chelsea, Lynn, Everett, Somerset, Weymouth, and Falmouth to obtain information about their port facilities; those ports were removed from further consideration based on navigational and/or landside constraints. All of the ports in Massachusetts have some rail access; however, waterfront access to particular facilities varies in each area. No ports in Massachusetts have access to second generation rail with vertical clearances over 19 feet. From north to south, brief summaries of these six remaining Massachusetts candidate ports and their potential to stage a Representative Offshore Wind Energy Installation (ROWEI) 130-turbine wind farm follow:

Gloucester has sufficient land area for a new marine facility, a readily available skilled work force, and rail access. However, water depth and lateral clearance are the most significant constraints for the inner harbor at the Port of Gloucester and the rail service is limited to commuter rail. Turbine installation vessels should be able to navigate the Port of Gloucester, but turbine import vessels most likely would not be able to call at this port.

Salem has limited potential for substantial expanded marine industrial activities, with limited access by road and rail. The port's only deepwater commercial terminal is situated at the head of the harbor; however, the terminal is primarily used to supply the needs of the Salem Power Plant. There is also very little area outside of Salem Terminal where large vessels could handle offshore wind turbine or foundation components. The immediate area in and around the waterfront is congested and has poor capacity for high volume roadway traffic flow.

Boston is the largest and most prominent freight port in the Commonwealth. It has the most diversified port mix and handles the largest volume of containers in New England and the second largest amount of petroleum cargo. However, direct rail connections to the waterfront need improvements. The Boston Redevelopment Authority has 'shovel ready' plans to expand the existing rail from the Boston Marine Industrial Park to the North Jetty and to Dry Dock #4. Roadways are congested and direct street connections between the terminal and highway connectors are a weak link in the landside transportation connection. There are areas within the Port that might be available to support offshore wind deployment, but issues of height due to FAA requirements associated with Logan Airport must be considered.

Fore River (Ship Yard) has served as the Central Receiving Point for new car delivery to local dealerships. The site, which features rail and roadway access, is currently undergoing an initial planning process to determine all potential uses for the site including marine-related, residential, retail, office, and entertainment. The entrance to the Shipyard is restricted by the Fore River Bridge which has a 175 ft vertical clearance and a 175 ft horizontal clearance.

Fall River (Mount Hope Bay) is an active niche port serving several international markets. The port has the potential for industrial expansion at the State Pier, which has available storage and land area for operations but already is used for both industrial and tourism based activities. The State Pier can only handle small cargo ships and most of the critical infrastructure in the port is aging and in need of considerable repairs and improvements. Vertical clearance is the most significant navigational constraint for the Port of Fall River. The Braga Bridge and Mt. Hope Bridge each impose a height restriction of 135 feet. The port has good highway access and a rail corridor which requires additional infrastructure improvements.

New Bedford is an active freight seaport and a major logistical connection for agricultural products entering the New England market. Highway connections are good; the port would benefit from expanded and improved rail connections to meet freight needs. A request for TIGER Grant money was submitted to extend the rail line to the State Pier, but further rail extension to the proposed South Terminal expansion area is unrealistic. The port has sufficient deep water access for the size and type of vessel common to most break bulk and project cargo and has property available for expansion.

The Final Report contains more detailed data on each port, including location, facilities, harbor profile, advantages, disadvantages, and potential.

Other East Coast ports, including Portland Harbor (Maine), Portsmouth Harbor (New Hampshire), the Port of Providence (Rhode Island), the Port of Davisville (Rhode Island), New Haven Harbor (Connecticut), the Port of New York and New Jersey, the Port of Philadelphia (Pennsylvania), the Port of Baltimore (Maryland), the Port of Wilmington (Delaware), and the Port of Virginia, were evaluated to assess their suitability to support offshore wind projects. The Final Report describes these port facilities in more detail.

5.2 U.S. East and Gulf Coast Shipyard Construction and Repair Capacity

Declining domestic demand has reduced the number of available U.S. shipyards for new construction or repair of large vessels. In addition, existing shipyards' inability to comply with recent regulations, such as the "Jones Act," which requires vessels in domestic service or operating in domestic waters to be built and serviced in U.S. yards, has resulted in a decrease in yards available for new large vessel construction or repair. This is particularly evident in the Northeast U.S., including New England, where the ability to handle large tonnage vessels, such as deep water cargo ships, tankers, and specialty vessels for offshore delivery and support, has dramatically decreased in the past few decades. In other parts of the world, new shipyard capacity has replaced capacity lost in the U.S. However, in spite of the fact that the number of shipyards in the U.S. that handle large tonnage vessels has declined, the number of smaller yards has remained stable.

Specialty wind farm vessels have unique construction and servicing requirements. Smaller service vessels, including offshore supply vessels, tugs and barges, can be readily adapted to service offshore wind farm equipment. Installation and service vessels operating within the territorial waters of the U.S. most likely would be subject to the Jones Act, but import/delivery vessels could be foreign flagged if their operation is limited to equipment delivery at a single U.S. port. *US East and Gulf Coast Shipyard Construction and Repair Capacity and*

Availability Offshore Wind Turbine Delivery and Service Vessels (MARPRO Associates International 2009) provides detailed information on construction capacity and repair capacity at U.S. shipyards

Construction Demand and Capacity

In recent years, the U.S. small vessel construction industry has demonstrated growth. Stricter regulations and replacement requirements have increased demand for new small vessel construction, with the tug and barge industry emerging as the largest demand market. Tug and barge construction is of particular importance as the servicing and installation of offshore wind turbines may well be handled by tugs and barges in large part because of their lower operational costs.

Tank barge construction has had a major impact on shipyard capacity and delivery times. There are some new shipyards emerging to meet this demand for tank barges, and the major yards are ramping up production capabilities in anticipation of more tank barge orders. Increasing demand for tank barge construction is using up ship construction capacity in the yards where offshore specialty vessel construction could take place.

Shipyard Availability

The number of shipyards that have current capacity for large specialty vessel construction is limited within the U.S. Of the 350 active vessel construction companies in the U.S., only 52 have a history of significant vessel construction on the Atlantic and Gulf Coasts. A limited number are capable of handling large specialty vessels due to size limitations, but a number of them could handle smaller specialty vessels. The Final Report provides a list of the yards that can build offshore wind-related vessels on the Atlantic and Gulf Coasts.

Vessel Repair Capacity

In the Northeast, many of the yards have compressed operations due to increasing environmental concerns and gentrification of industrial areas. A number of yards confine activities to repair only and have refocused their efforts on small craft such as ferries, yachts and similar commercial watercraft. In the Gulf of Mexico, a number of the yards still have not fully restored operations to pre-Katrina levels primarily due to a shortage of qualified personnel and infrastructure that yards have chosen not to replace. Nevertheless, the Gulf of Mexico region still has the highest percentage of multi-purpose construction and repair yards in the country. Orders for vessels are averaging a 6 to 12 months delay to begin construction; however, there are several smaller yards in the Northeast and the Gulf that have no backlogs and can manage new vessel orders. Very few of these shipyards have multiple vessel capacity, and backlogs do not extend beyond 2011. Most of the shipyards on the Atlantic Coast that build vessels also have repair capacity; however, there is limited repair capacity in New England.

Shipyard Construction and Repair Capacity on the Atlantic Coast

Large vessel construction and small vessel construction most likely would be handled by different shipyards. Yard capacity varies from region to region. The industry can meet the demand for a phased-in cycle of new vessels on a limited basis up to approximately three units per year using multiple yards in various regions of the U.S. New England has new construction capability limited to smaller vessels, but has adequate repair capability for smaller vessels and some capacity for larger vessels. A developer should anticipate an 18-month lead time for design, contracting, construction and delivery of small vessels and up to 24 months for larger vessels. These projections along with the restrictions of the Jones Act will dictate time lines associated with the earliest offshore projects.

6 Short-Listing Ports for Further Evaluation

Based on the evaluation criteria developed for this report and further analysis, the Team concluded that the ports of New Bedford and Boston have the greatest potential to support the assembly and installation phases of planned and prospective offshore wind energy projects.

Of the Massachusetts ports described in Section 5 above, six ports (located in DPAs) were selected for further consideration. The Massachusetts Port Criteria Evaluation Matrix (see Table 8) clearly demonstrates how these six Massachusetts ports compare against each other with respect to the established “hard” criteria. Application of the identified “soft” criteria was reserved for only the short-listed ports.

Table 8 Massachusetts Port Criteria Analysis Matrix

PARAMETERS		PORTS					
Criteria	Recommended Values/Ranges	Boston	New Bedford	Fall River	Gloucester	Salem	Fore River
First Tier Harbor Navigational Access							
Protected Harbor	Sheltered from Weather Conditions	Yes	Yes	Yes	Yes	Yes	Yes
Shipping Vessel Channel Depth	Minimum 7.3 m (24’)	12.2 – 13.7 m (40' - 45')	9.1 m (30')	10.7 m (40')	4.9 – 5.8 m (16' - 19')	9.4 m (31')	9.8 m (32')
Overhead Clearance	No Vertical Obstruction (NVO)	NVO, but FAA approval required	NVO	41 m (135')	NVO	NVO	53.3 m (175')
Horizontal Clearance	40 m (130') (beam plus overhang)	131 m (430')	45.7 m (150')	122 m (400')	61 m (200')	85.3 m (280')	53.3 m (175')
24/7 Operational Ability	24/7 operations	Yes	Yes	Yes	No	Yes	Yes
Exclusive Use of Port Facility	Ability to Offer Exclusive Use	Yes	Yes	No	No	No	Yes
Comments				Mt Hope Bridge height restriction	Navigational constraints	Salem DPA in full use by power plant	Fore River Bridge height restriction
Second Tier Port Facilities							
Berth Length	Minimum 138 m (450’)	549 m (1,800')	488 m (1,600')	189 m (620')	427 m (1,400')	177 m (580')	244 m (800')
Shipping Vessel Water Depth	Minimum 7.3 m (24’)	12.2 – 13.7 m (40' - 45')	9.1 m (30')	10.7 m (40')	4.9 – 5.8 m (16' - 19')	9.4 m (31')	9.8 m (32')
Total Wharf and Yard Upland Area	4.0 ha (10 ac)	5.7 – 6.9 ha (14-17 ac)	4.0+ ha (10+ ac)	2.8 ha (7.0 ac)	3.2 ha (7.8 ac)	NA	44.9 ha (111 ac)
Rail Access	Rail Access	Limited	Limited	Yes	Yes	No	Yes
Highway Access	Highway Access	Yes	Yes	Yes	Yes	No	No
Comments				State Pier can only accommodate small cargo vessels.	Limited adaptable area	Insufficient work area; additional focus on tourism	Multiple berths/ rough estimate; plans for mixed-use waterfront development

Legend NVO = No vertical obstruction
[grey box] = Criteria not met
NA = Not available for ROWEI staging

6.1 Evaluation of Massachusetts Ports against Hard Criteria

Protected Harbor: All of the six Massachusetts ports are in protected harbors. The hurricane barrier in New Bedford adds an additional layer of protection for portside operations during inclement weather.

Shipping Channel Depth and Overhead Clearance: Navigational access to Fall River and Fore River is constrained by the overhead height restrictions of existing bridges, and the Port of Gloucester does not meet the minimum shipping channel depth of 24 feet (indicated by the shaded cells in Table 8). On the other hand, the shipping channels of New Bedford and Boston Harbors meet the minimum depth criterion. Both New Bedford and Boston Harbor have unobstructed overhead clearance. There are no vertical obstructions, such as bridges and/or power lines, which would prohibit offshore wind component delivery and installation vessels, including jack-up vessels, from accessing either harbor. However, FAA approval may be required in Boston Harbor because of the harbor's proximity to Logan International Airport.

Horizontal Clearance: None of the selected ports are restricted by horizontal (lateral) clearances less than 130 feet. The minimum horizontal clearance criterion eliminated facilities in New Bedford upstream of the New Bedford-Fairhaven Bridge (92 feet of lateral clearance). However, the South Terminal at New Bedford Harbor is downstream of the New Bedford-Fairhaven Bridge and upstream of the Hurricane Barrier.

24/7 Operational Ability and Exclusive Use of Port Facility: All ports being evaluated, with the exception of the Port of Gloucester, can operate round the clock and all year. The Ports of Gloucester and Salem also did not have the ability to offer exclusive use of their facilities.

Berth Length and Shipping Vessel Water Depth: The established berth length and channel and portside depth criteria reflect minimum requirements for accommodating berthing operations. The Port of Gloucester failed to meet the depth criterion. All other ports had sufficient length and depth.

Total Wharf and Yard Upland Area: Landside (upland) port facilities provide storage, staging and assembly work areas to facilitate offshore wind farm installation. The Team determined that given sufficient land area, storage, assembly, and load bearing issues could be addressed with improvements to the port. Neither Fall River, Gloucester, or Salem has sufficient adaptable space for the work area required to support offshore wind farm staging.

Rail Access: None of the Massachusetts ports evaluated for this study has second generation rail access. Existing rail lines could be used primarily for delivery of aggregate and related products rather than turbine or foundation components. Whereas Fall River, Gloucester, and Fore River have existing freight rail lines to the waterfront, Boston and New Bedford currently have limited rail access, and Salem has none. Boston and New Bedford submitted TIGER applications for rail extensions; however, the New Bedford rail line will connect the existing tracks to the State Pier, but not the South Terminal.

Highway Access: Road connections are important for transport of ancillary material and equipment, as well as personnel. Neither Salem Harbor nor the Fore River Shipyard has sufficient highway access due to roadway congestion. There is no highway access within the City of Salem; the nearest highway access to Route 128 is along Route 114 in neighboring Peabody. Fore River's access to the interstate highway network is via Route 3, a limited-access roadway that is about two miles away from the Shipyard.

Based on the hard criteria established in Section 4 and displayed in Table 8 above, the ports of Fall River, Gloucester, Salem, and Fore River fell short of the minimum requirements for navigational access and port infrastructure to support offshore wind development activities. The ports of New Bedford and Boston emerged as the two short-listed ports.

6.2 Engineering Cost Analysis of Port Upgrades for Short-Listed Ports

New Bedford Harbor

The project team identified two possible locations in New Bedford Harbor that could reasonably meet the established criteria, the South Terminal area and the State Pier facility. However, both facilities failed to meet all of the criteria and demonstrated deficiencies in their current physical condition. Cost estimates for facility improvements were provided by Childs Engineering Corporation.

South Terminal

The City of New Bedford has identified the expansion of the South Terminal as a major priority. The City applied for a TIGER grant to support its proposed plan to expand the berth by approximately 800 ft and dredge a 30-ft deep channel from the main channel to the new berth. The new facility would have significant backland load bearing capacity. There are between 14 and 20 acres of land adjacent to the berth. The cost of the new bulkhead and dredging is estimated to be approximately $20 million (see the cost analysis conducted for this study, which resulted in a comparable estimate), in the Final Report. Additional improvements, including paving, utilities and site equipment (such as a large crane), could add an additional $15 million and would provide a “future” life as a general cargo or container handling facility.

State Pier

The State Pier is constructed with a solid fill core surrounded by a marginal wharf. This construction is typical of many old New England ports. The wharf structure is in poor condition according to recent inspections and must be replaced or modified. The rebuild options include a repair/replace in kind, which would result in a reasonably low deck capacity. The preferred alternative would replace the wharf structure with solid fill behind a new bulkhead. A recent study suggested rebuild costs could be from about $12.1 million to more than $52 million. The immediate backland is about 7 to 8 acres, which does not meet the landside criterion. This lack of space would probably result in material rehandling costs, which would not occur on a larger site. The State Pier would best be described as a short-term, but an immediately available site. This solution also anticipates that no repairs would be performed and a larger land-based unloading crane would be employed inshore of the wharf structure.

The Team believes the preferred option for New Bedford is the South Terminal. The site is the most ideal in terms of meeting the port criteria established by the Team. The expansion cost is similar to the repair cost for the State Pier. However, the South Terminal has significantly more laydown area, which offsets any potential cost savings from the State Pier repair/rebuild.

Boston Harbor

The project Team identified three possible locations in Boston Harbor that reasonably meet the criteria. These include the North Jetty, Dry Dock #4 in the Boston Marine Industrial Park, and the former Coastal Oil site adjacent to Conley Terminal on the Reserved Channel. None of these facilities meet all of the defined criteria and each has deficiencies in their current physical conditions. . Cost estimates for facility improvements were provided by Childs Engineering Corporation.

North Jetty

The North Jetty is constructed with a solid fill core supported by a steel sheet pile bulkhead fronted by a marginal wharf. The marginal wharf is comprised of steel h-piles supporting a reinforced concrete super structure. The wharf structure is in poor condition and must be replaced or rebuilt to be a viable staging port. The immediate backland is about 7 to 8 acres, with an additional 10 or more acres immediately adjacent. A 1996 design suggested rebuild costs (in 2010 dollars) would be about $15 million.

The City included the North Jetty rebuild in its application for a TIGER grant. Although the rebuild will correct current deficiencies, it will still leave the wharf with a deck capacity of 600 lb/ft^2, which is insufficient for unit loading under certain situations.

Dry Dock #4

The existing Dry Dock is in very poor condition but could be rebuilt to provide a two sided solid fill pier with almost 1800 feet of berthing. The Dry Dock would be filled with gravel and new steel sheet piling would be installed around the deteriorated bulkheads. The estimated cost to rebuild the site is approximately $20 million. This site would provide nominal laydown space, but the solid fill pier has very high ground capacity and the berth has "bonus" length. Although the site does not have covered space, there are such structures and warehouses in the Boston Marine Industrial Park.

Dry Dock #4 could accommodate the staging of offshore development with improvements at a reasonable cost. However, from a planning perspective, there are potential permitting issues associated with these improvements due to Dry Dock #4's proximity to Logan Airport. Tall equipment, such as cranes, likely will require approvals from the FAA. Furthermore, the potential wind farm locations are much closer to New Bedford Harbor than Boston Harbor.

Coastal Oil Site

The Massachusetts Port Authority owns the former Coastal Oil terminal in South Boston. The site is approximately 35 acres and has a former oil tanker berth with a water depth in excess of 34 ft. The facility would require a new steel sheet pile bulkhead to be adequate for laydown. It also would need re-grading and paving to "cap" any environmental issues. The estimated cost for the repairs is approximately $20 million. The site does not have any covered space, and there is no covered space on the immediately adjacent parcel.

The Team believes the preferred option for Boston is Dry Dock #4, which meets most of the established criteria. The rebuild cost is similar to the cost of repairs for the North Jetty; however, Dry Dock #4 has significantly more berthing space, which offsets any potential repair/rebuild cost savings.

6.3 Soft Criteria

The Team examined education and training needs required to support the offshore wind energy industry in Massachusetts. We conducted interviews with various educational and training institutions to ascertain the status of programs designed specifically for the offshore wind industry.

More effective state support for renewable energy has encouraged investment in workforce training at many levels. The Massachusetts Maritime Academy is nationally known for its mariner training programs, and a regional Marine Renewable Energy Center (MREC) at the University of Massachusetts/ Dartmouth joins the resources of some of the region's leading academic institutions, community colleges, and trade unions to coordinate and plan appropriate training for this emerging industry. Several public and private academic institutions, including the Amherst and Dartmouth campuses of the University of Massachusetts system, Harvard, the Massachusetts Institute of Technology (MIT), the Massachusetts Maritime Academy, and the Woods Hole Oceanographic Institute (WHOI), have examined and will continue to explore numerous issues related to offshore renewable energy generation, including energy production, facility design, transmission issues, and maritime training.

Understanding that the ocean energy industry is evolving within the U.S. and specifically New England, MREC joined forces with Cape Wind, Resolute Marine Energy, Ocean Renewable Power Company, Local 56 Pile Drivers Union, the Massachusetts Maritime Academy, the New Bedford Department of Workforce Development, and the community college system to form the Ocean Energy Training Task Force. The Task Force meets regularly to identify issues and to discuss how best to meet the needs of offshore energy developers, and draws on the expertise of each of its members. Significant education and training programs related to offshore renewable energy are being developed, and some are currently being offered.

Massachusetts trade unions have been very active in identifying offshore energy construction needs and developing appropriate training courses. For example, Local 56 of the Massachusetts Pile Drivers is a statewide organization that has been at the forefront of training workers for offshore energy. Similarly, the International Brotherhood of Electrical Workers (“IBEW”) Local 103 has demonstrated its leadership in support and training for the renewable energy industry through the erection of a publicly visible 100kW wind turbine and the installation of a 5.4kW solar roof at its headquarters and Apprentice Training Facility in Dorchester.

With the state aggressively supporting the development of offshore wind energy through policy initiatives, expertise, and financial support, and with academic institutions and trade unions actively developing and improving training opportunities, Massachusetts is well situated to respond to a wide variety of technologies used to harness renewable energy in offshore waters. Perhaps more relevant, Massachusetts is in a unique position to successfully meet the needs of the offshore wind energy industry because of its broad geographic coverage, extensive research facilities, in-depth industry expertise, and a trained, flexible work force.

Soft criteria also include regulatory considerations. Port facility upgrades may require Massachusetts environmental review if the project meets or exceeds certain thresholds established by the Massachusetts Environmental Policy Act (MEPA). A variety of federal, state and local permits also may be required, including, but not limited to:

- U.S. Army Corps of Engineers (USACE) Section 10 permit for structures in navigable waters,
- USACE Section 404 permit for discharge of dredged or fill materials into waters of the U.S.,
- Federal Aviation Administration (FAA) Determination of No Hazard,
- Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) permit,

- EPA Air Emission permit,
- Massachusetts Coastal Zone Management (MCZM) Consistency Determination,
- Massachusetts Department of Environmental Protection (MDEP) Water Quality Certificate,
- MDEP Chapter 91 License for work in, under, or over flowed or filled tidelands,
- Massachusetts Department of Transportation (MDOT) Oversize/overweight vehicle permit,
- Conservation Commission Order of Conditions for alteration of “any bank, fresh water wetland, coastal wetland, beach, dune, flat, marsh, meadow, or swamp bordering on the ocean or on any estuary (a broad mouth of a river into which the tide flows.), creek, river, stream, pond, or lake, or any land under said waters or any land subject to tidal action, coastal storm flowage, or flooding,” and
- Local zoning, building or utility permits.

7 Economic and Tax Effects of Construction and Operating Expenditures

Based on the criteria and cost analysis presented above, the South Terminal in the Port of New Bedford Renewable Energy Marine Park (Figure 8) and Dry Dock #4 in the Port of Boston Marine Industrial Park (Figure 9) were selected for further evaluation and discussion. More detailed information about how the team arrived at this conclusion can be found in *Economic Effects of Offshore Wind Energy and Related Construction and Operating Expenditures* (FXM Associates 2009), which is Appendix J of the Final Report.

Figure 8 New Bedford Harbor

Figure 9 Boston Harbor

This section summarizes the economic and fiscal effects of construction and operation of these ports to support a ROWEI 130-turbine wind farm.

Construction and Operating Periods- Economic Effects

The measures of economic effects are:

- Output – which comprises business sales less the costs of materials and equipment produced outside Massachusetts;
- Employment – the full-time equivalent jobs expected to be held by Massachusetts residents;
- Income – the payroll and self-employment earnings of households; and
- GDP (Gross Domestic Product) – which measures the value added to the Massachusetts economy in terms of labor and proprietors' income, corporate profits, dividends, interest, rent and taxes.

Expenditures for the assembly and installation of the ROWEI are estimated to increase business output by more than $457 million in Massachusetts over the anticipated three-year projected period of construction, provide over 1700 person years of employment, and generate nearly $163 million in household income statewide. Construction of the Port of Boston Dry Dock #4 facility is expected to increase business output by nearly $19 million, provide over 100 person years of employment and $9.1 million of additional household income in Suffolk County. Construction of the South Terminal project in New Bedford Harbor is estimated to expand business output by more than $44 million, provide nearly 400 person years of employment, and $19.2 million of additional household income in Bristol County over its estimated 2-year construction period.

Each year following completion of the ROWEI, expenditures for servicing and maintaining the wind turbines is estimated to expand business output in Massachusetts by $27.5 million, provide 110 permanent jobs, and generate $6.8 million in household income annually. New Bedford South Terminal port facility operations, specifically the handling, storage, and transshipment of prospective new container, break bulk, and bulk cargoes, are estimated to expand business output in Bristol County by $15.6 million, provide over 130 permanent jobs, and generate $5.9 million in additional household income each year.

Construction and Operating Periods- Fiscal Effects

The total direct, indirect, and induced tax effects correspond to the economic effects discussed above. Local taxes include property and excise taxes paid to municipalities by workers in the jobs generated by construction and operating period employment effects, as well as property and other local taxes paid by the companies employing those individuals. State taxes include income and sales taxes paid by individuals as well as payroll, income, and other taxes paid by the companies that employ those individuals.

During the assembly and installation phase of the ROWEI nearly $9 million in taxes to municipalities throughout Massachusetts are estimated to be attributable to the direct, indirect and induced economic effects discussed above over the projected 3-year construction period of the ROWEI. More than $10 million in taxes paid to the Commonwealth of Massachusetts over this 3- year period would be attributable to the economic effects of construction, and almost $46 million in federal taxes would be stimulated by the construction period economic effects. Some additional local, state, and federal taxes would be generated by activity at the staging ports. Servicing and maintaining the exemplified offshore wind energy project would generate an annually recurring amount of $390,000 in municipal tax receipts throughout Massachusetts, $433,000 in state taxes annually, and $2.2 million in new federal taxes each year.

As can be seen from these projections, the economic and fiscal effects of port development and use are roughly comparable for both ports. Therefore, the selection of one port over the other is more likely to be determined by the balancing of the soft criteria.

8 Summary and Recommendation

In Massachusetts there are no port facilities ready for turnkey support of offshore wind energy facility development at this point in time. However, the opportunity to attract offshore wind deployment exists if appropriate investment in relevant port upgrades is made. The Team performed a side-by-side comparison of the two short-listed ports and has concluded that the expansion of the South Terminal in the Port of New Bedford represents the best opportunity for a Massachusetts port facility to accommodate assembly and installation of offshore wind energy projects. Table 9 summarizes the comparison between Dry Dock #4 at the Port of Boston and the South Terminal at the Port of New Bedford relative to the hard and soft evaluation criteria developed for this study.

Table 9 Comparison of the Two Short-Listed Ports

	Port of Boston Dry Dock #4	New Bedford Harbor South Terminal	Comments
1st TIER HARD CRITERIA			
Protected Harbor	●	●	Both ports are acceptable.
Shipping Channel Depth	●	●	Both ports are acceptable.
Overhead Clearance	●	●	Both ports are acceptable.
Horizontal Clearance	●	●	Both ports are acceptable.
24/7 Operational Ability	●	●	Both ports are acceptable.
Exclusive Use of Port Facility	●	●	Both ports are acceptable.
2nd TIER HARD CRITERIA			
Berth Length	●	●	Both ports are acceptable.
Shipping Vessel Water Depth	●	●	Both ports are acceptable.
Total Wharf and Yard Upland Area	●	●	Both ports are acceptable.
Rail Access	●	⊙	BRA has a design to expand rail access to Dry Dock #4. New Bedford submitted TIGER application to extend rail line to State Pier, but not to South Terminal.
Highway Access	⊙	●	Despite adequate highway access to port area, the Boston Haul Road currently has vertical/ horizontal limitations; however, a new freight roadway system is planned.
Proximity to Construction Site	⊙	●	South Terminal is closer to the planned offshore sites than Dry Dock #4 (as of January 2010).
SOFT CRITERIA			
Workforce Availability	●	●	
Education and Training Facilities	⊙	⊙	In U.S., education and training programs are now being developed for nascent offshore renewable energy industry. Given extensive research facilities, in-depth industry expertise, and trained, flexible work force, Massachusetts will be able to successfully meet education and training needs.

Table 9 Comparison of the Two Short-Listed Ports (continued)

	Port of Boston Dry Dock #4	New Bedford Harbor South Terminal	Comments
Political Climate/Community Acceptance	⦿	●	New Bedford has a Green Port initiative in place, has done study on South Terminal development, has submitted various proposals for infrastructure grants, and has the goal of strengthening its economy by focusing on renewable energy such as offshore wind. The BRA has emphasized a commitment to sustainability but may not be focused on the seaport. Dry Dock #4 currently has a tenant.
Regulatory Considerations	⦿	●	Required permits could include, but are not limited to: MEPA review; CZM Consistency Certification; USACE Section 404 and 10 Permits, FAA approval; Chapter 91 License/Permit; Water Quality Certification; NPDES Permit; Order of Conditions. Certain circumstances at each port may eliminate or reduce regulatory process. FAA approval at Dry Dock #4 may be problematic.

LEGEND:
- ● Acceptable / Most Supportive of offshore wind farm development
- ⦿ Qualified Acceptability / Degree of Supportiveness of offshore wind farm development
- ○ Unacceptable / Not Supportive of offshore wind farm development

With specifically targeted upgrades, both Dry Dock #4 and the South Terminal would have acceptable harbor access and the navigational parameters needed to accommodate wind turbine delivery and installation vessels (1^{st} Tier Hard Criteria), and both ports are capable of accommodating the assembly and installation of offshore wind turbines and foundations (2^{nd} Tier Hard Criteria). An exception at the present time may be Rail and Highway Access; however, it is unlikely that rail and highway delivery would be used for large offshore wind generation components due to weight and dimensional constraints. Based on available public information as of January 2010 regarding proposed offshore wind farm sites, the South Terminal at New Bedford Harbor is closer to these potential installation sites than is Dry Dock #4 at the Port of Boston.

With regard to soft criteria, the City of New Bedford is moving ahead with its goal of strengthening its economy by focusing on supporting the renewable energy industry at the Port of New Bedford. In Boston, the BRA has demonstrated its commitment to environmental sustainability by launching a pilot program to help small businesses improve their energy efficiency and sustainability practices. However, this initiative is not focused specifically on the seaport.

Another soft criterion, Regulatory Considerations, involves the environmental review and permitting processes that may be required for the port projects. Work in and around Massachusetts waters may require state environmental review, if one or more MEPA review thresholds is met or exceeded. Installing and operating an offshore wind farm also will require obtaining a number of federal, state, and local permits. MEPA review of a major port improvements project could take between six months and one year, depending on the type of MEPA review triggered and the amount and intensity of political and community support for the project. Permitting such a project may require a similar amount of time, depending on (among other factors) the complexities of the project, the number and length of public comment periods, and the duration of mitigation negotiations that must be conducted between the project proponent and the regulatory agencies.

Since some of the environmental impacts of the South Terminal site have already been assessed by the Commonwealth as part of the Superfund cleanup response for the site, MEPA review of the South Terminal expansion may be streamlined or limited. The permits required for this project are contingent on its projected impacts on regulated resources. The dredging component of the port expansion project may be covered under the State Enhanced Remedy CAD Cell Dredge Disposal Approval for the cleanup. However, other permits/approvals may still be required.

If the required upgrades to Dry Dock #4 at the Port of Boston can be defined as maintenance activities authorized under existing permits, the regulatory process may be circumvented or limited. Nevertheless, because of its proximity to Logan International Airport, obtaining FAA approval of crane heights at Dry Dock #4 could prove to be a lengthy process. The level of MEPA review required for the Dry Dock #4 improvements also would depend on which thresholds were exceeded, if any. Other permits/approvals may be required.

Determining the permits applicable to either project was not within the scope of this report. Additional research would be required to verify which, if any, permits would be needed. If support of renewable energy and immediate job creation are important political objectives in the Commonwealth, it would follow that the port project with the shortest regulatory track and the greatest political and community support would emerge as the best project to meet those objectives.

Based on this comprehensive side-by-side comparison, the Team has concluded that the expansion of the South Terminal at the Port of New Bedford represents the best opportunity for a Massachusetts port facility to accommodate assembly and installation of offshore wind energy projects. In addition, the new facility will provide sufficient economic and fiscal benefits to Bristol County and the Commonwealth of Massachusetts to make the investment attractive and worthwhile. The political support, advanced planning effort, proximity to offshore sites, and absence of FAA obstacles have led the Team to recommend the South Terminal expansion.

9 Path Forward – Preliminary South Terminal Business Plan

As a follow-up to the recommendation presented above, the Team prepared portions of a preliminary business plan for an offshore wind deployment/multi-use cargo facility at the South Terminal at the Port of New Bedford (see *Port of New Bedford South Terminal Business Plan* [FXM Associates 2009], which is Appendix K of the Final Report). Specific objectives of this effort were to (1) identify potential cargoes and revenues for the South Terminal facility, in addition to those associated with a ROWEI; (2) identify an appropriate governance model for multi-use terminal ownership and management; and (3) prepare a preliminary terminal business plan with operating pro forma. In addition to the economic and tax effects discussed in Section 7 above, the Team made the following findings:

- A new multi-use cargo facility at the South Terminal site represents the best option in the Port of New Bedford for servicing offshore wind energy development projects during the assembly and installation phases;
- A new multi-use port facility at the South Terminal can capture container, break bulk, and bulk cargoes not now handled in New Bedford or other Massachusetts ports and can generate income for the Harbor Development Commission (HDC) with or without offshore wind energy development projects;
- The optimal model for governance of a new facility at the South Terminal would be ownership by the New Bedford HDC, which would lease offshore wind energy staging and other cargo handling, storage, and related facility operations to a qualified private operator.
- Capital costs for a new multi-use port facility at the South Terminal are estimated to total about $44 million (in 2009 dollars). Approximately $32 million of this total investment is for land acquisition, bulkhead construction and dredging, buildings and site improvements to support offshore wind energy installation projects, with an additional $5 million in capital expenditures ($37 million total) functionally necessary to attract and support new bulk, break bulk, and container cargoes;
- Average net operating income to the HDC from the fully-developed South Terminal port facility would total about $1.2 million per year during a projected 3-year ROWEI and about $622,000 per year with full cargo operations. Potential operating revenues and costs are shown in Table 10; and
- The South Terminal can cover all of its operating expenses during the ROWEI use of the facility and annually thereafter based on non-ROWEI cargo operations. Approximately $12 million of the capital costs for the new facility can be supported by annual net operating income combined with income from the 3-year ROWEI use of the facility. This leaves $32 million of debt that would require financing from other sources.

These components of a "path forward" relative to the development of an expanded multi-use cargo facility at the South Terminal address the key findings of a preliminary business plan for port expansion. This study demonstrated that the South Terminal at the Port of New Bedford meets the necessary requirements and possesses a number of the advantageous characteristics needed to successfully support a developing offshore commercial wind farm. The study also identified some areas where this port could make modifications and improvements to its harbor or wharf facilities that would further enhance the port's ability to support offshore wind energy. The path forward would continue the process outlined here, more fully develop the elements that were addressed in this study, and consider other important aspects of the port's development that were not considered to be critical to the scope of this study.

Table 10 South Terminal Operating Income and Expenses

SOUTH TERMINAL OPERATING INCOME & EXPENSES	Offshore Wind Installation	Non-Offshore Wind Cargoes
Average Year Annual Operating Income		
Offshore Wind Energy Development (ROWEI)	$ 1,500,000	
Container Service		$ 280,000
Break Bulk Program		$ 240,000
Bulk Cargo		$ 432,500
Total Non-ROWEI Cargo		$ 952,500
Average Year Annual Operating Expenses		
HDC Personnel (contract/lessee management)	$ 140,000	$ 140,000
HDC Capital/maintenance reserve at 20% income	$ 190,500	$ 190,500
Average Year Annual Expenses	$ 330,500	$ 330,500
Average Year NET Operating Income		
Offshore Wind Energy Development (ROWEI)	$ 1,169,500	
Total Non-ROWEI Cargo		$ 622,000

Source: FXM Associates, RECON™ Input Output Model

Section 9 of the Final Report provides details of the Team's findings as a result of our preliminary business plan for a multi-use cargo facility at the South Terminal at the Port of New Bedford.

These components of a "path forward" relative to the development of an expanded multi-use cargo facility at the South Terminal address only a few of the key elements of a comprehensive, fully developed business plan for port expansion. Additional information relative to these components can be found in the Final Report and a number of its appendices. This study demonstrated that the South Terminal at the Port of New Bedford meets the necessary requirements and possesses a number of the advantageous characteristics needed to successfully support a developing offshore commercial wind farm. The study also identified some areas where this port could make modifications and improvements to its harbor or wharf facilities that would further enhance the port's ability to support offshore wind energy. The path forward would continue the process outlined here, more fully develop the elements that were addressed in this study, and consider other important aspects of the port's development that were not considered to be critical to the scope of this study.

10 References

Advanced Offshore Solutions. June 26, 2009. Crew Transfer Vessel Specification

Advanced Offshore Solutions. 26 June 2009. Installation Vessel Specification.

Childs Engineering Corporation. 2009. South Terminal Capital and Maintenance Costs Spreadsheets.

Durand & Anastas Environmental Strategies Inc. 2009. Profiles of East Coast Ports Outside of Massachusetts.

FXM Associates. 2009. Economic Effects of Offshore Wind Energy and Related Construction and Operating Expenditures.

FXM Associates. 2009. Port of New Bedford South Terminal Business Plan.

MARPRO Associates International. 2009. Potential Wind Turbine Delivery Ships.

MARPRO Associates International. 2009. Comparison of Selected Northeast ports for potential handling of Wind Power Offshore Energy Installations

MARPRO Associates International. 2009. Road ad Rail Access Ports of Massachusetts.

MARPRO Associates International. 2009. US East and Gulf Coast Shipyard Construction an Repair Capacity And Availability Offshore Wind Turbine Delivery and Service Vessels.

Massachusetts Executive Office of Energy and Environmental Affairs. Draft Ocean Management Plan. 2010.

National Renewable Energy Laboratory, U.S. Department of Energy. April 2009. Economic Development Impacts in Colorado from Four Vestas Manufacturing Facilities. Wind Powering America Fact Sheet Series.

The Glosten Associates. 2009. Vessel Requirements for Offshore Wind Farm Construction and Maintenance.

The Glosten Associates. 2009. Marine Vessels for Construction and Maintenance of Offshore Wind Farms.

Vestas. Offshore A/S. Functional Specification. 2008. Harbor Storage, Pre-Assembly and Load Out for Offshore Wind Turbine Installation.

FINAL REPORT

Port and Infrastructure Analysis for Offshore Wind Energy Development

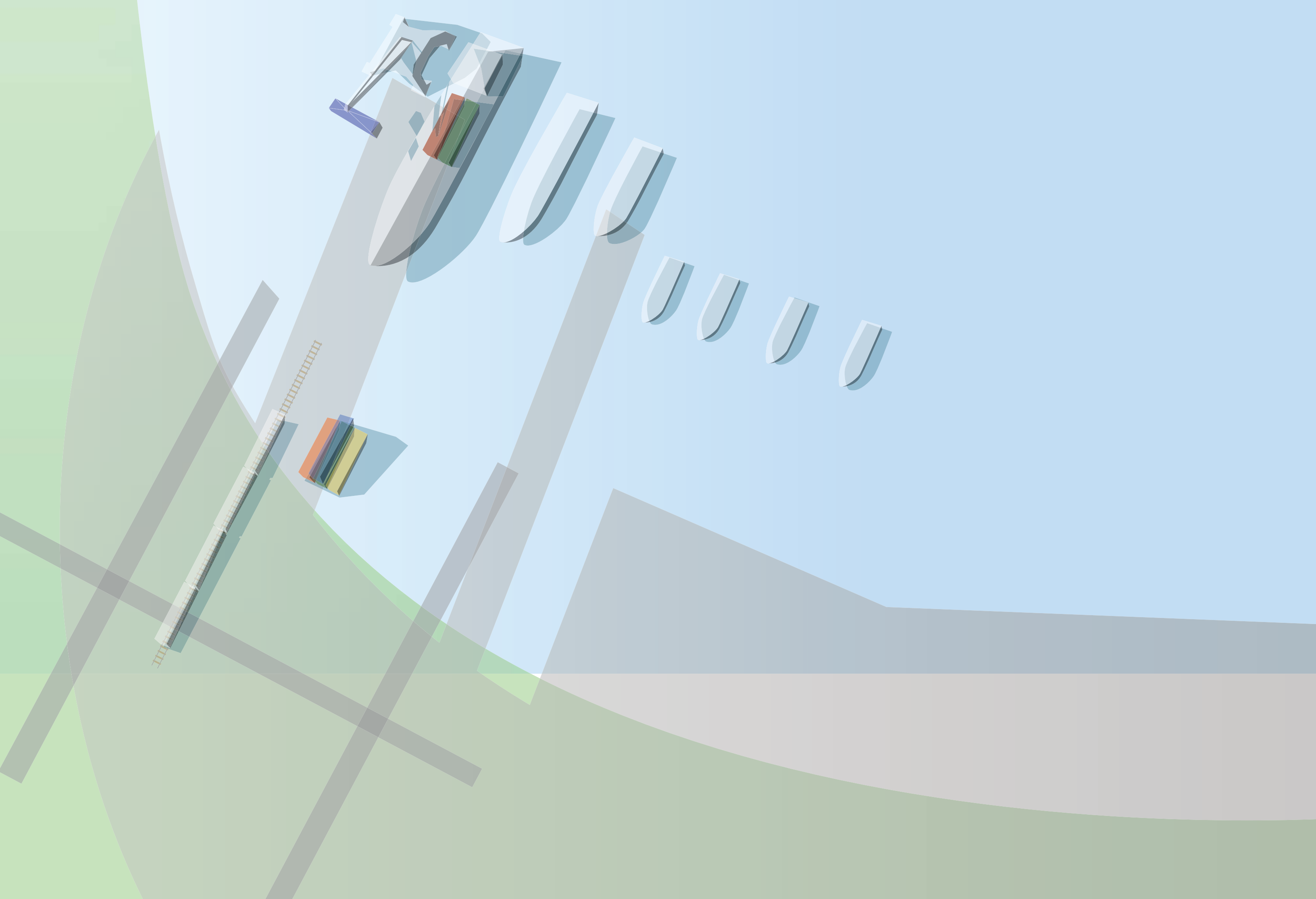


TABLE OF CONTENTS

1.0 INTRODUCTION 1-1

2.0 BACKGROUND AND CONTEXT 2-1

3.0 ASSESSMENT OF OFFSHORE WIND ENERGY PORT INFRASTRUCTURE NEEDS 3-1

3.1 Introduction to Offshore Wind Energy and Similar Offshore Activities 3-1
3.1.1 Wind Farm Components 3-1
3.1.2 Wind Turbine Component Delivery and Deployment 3-3
3.1.3 General Sequence of Offshore Construction and Installation Activities 3-5
3.1.4 Forecasts and Future Trends in Offshore Wind Energy Affecting Port Requirements 3-6
3.1.5 Similar Offshore Activities 3-7
3.1.5.1 Offshore Energy Industry in the US 3-7
3.1.5.2 Commercial Shipping 3-8
3.1.5.3 Commercial Fishing Factory Vessels 3-9
3.1.5.4 Submarine Transmission Cables 3-9
3.1.5.5 Implications 3-9
3.2 Industry Overview 3-11
3.2.1 Development of the Port Criteria 3-11
3.2.2 Interviews with Developers 3-11
3.2.3 Conditions at Ports and Wind Farm Locations 3-13
3.2.3.1 Nantucket Sound 3-14
3.2.3.2 Rhode Island 3-15
3.2.3.3 Delaware Bay 3-17
3.2.3.4 Other Areas 3-17
3.3 Characteristics of Available Vessels 3-20
3.3.1 Turbine Import/Delivery Vessels 3-20
3.3.2 Foundation Delivery and Installation Vessels 3-21
3.3.3 Wind Turbine Installation Vessels 3-22
3.3.4 Maintenance Vessels 3-24
3.4 Overview of Vessel Constraints and Requirements 3-24
3.4.1 Installation and Transport Vessel Requirements 3-24
3.4.1.1 Flag and Class 3-24
3.4.1.2 Principal Dimensions 3-25
3.4.1.3 Propulsion 3-27
3.4.1.4 Crane Requirements 3-28
3.4.1.5 Jacking System Requirements 3-28
3.4.1.6 Limiting Weather Conditions for Pile Driving and Crane Operation 3-28
3.4.1.7 Requirements for Accommodations 3-29
3.4.1.8 Power Requirements 3-29
3.4.1.9 Deck Load Requirements 3-29
3.4.1.10 Safety Equipment 3-30
3.4.1.11 Requirements Associated with Alternative and Future Vessel Uses 3-30
3.4.1.12 Parametric Cost Estimate 3-30
3.4.2 Tugboat and Auxiliary Vessel Requirements 3-30

TABLE OF CONTENTS - Continued

3.4.2.1 Tug Boat Requirements........3-30
3.4.2.2 Crew Boat Requirements........3-30
3.4.2.3 Other Auxiliary Vessel Requirements........3-31
3.5 Navigational Access and Transit Distances........3-31
3.6 Staging Port Through-Put Estimates........3-33
3.6.1 Methodology and Assumptions........3-34
3.6.2 Analysis........3-34
3.6.3 Results........3-35
3.6.4 Near-Term and Long-Term Demands on Staging Port Support Infrastructure........3-36
3.7 Staging Port Support Facility Requirements........3-37
3.7.1 Physical Considerations Relative to Staging Turbines........3-37
3.7.1.1 Harborside Area........3-37
3.7.1.2 Landside or Lay Down Area........3-38
3.7.1.3 Onshore Construction Area........3-39
3.7.1.4 Inside Storage / Assembly Space........3-41
3.7.1.5 Load Capacity........3-41
3.7.2 Physical Considerations Relative to Staging Foundations........3-42
3.7.2.1 Manufacturing and Assembly Requirements........3-43
3.7.2.2 Storage Requirements........3-43
3.8 Rail and Road Access........3-43
3.8.1 Overview of Rail........3-44
3.8.2 Overview of Road Transport Requirements........3-46
3.9 Implications of Distance........3-46

4.0 EVALUATION CRITERIA........4-1
4.1 Summary of Requirements and Desirable Characteristics........4-1
4.2 Criteria Development........4-2
4.2.1 1st Tier Hard Criteria Relating to Harbor Access........4-2
4.2.2 2nd Tier Hard Criteria Relating to Port Facilities........4-3
4.2.3 Soft Criteria........4-4
4.2.4 Screening and Short-Listing the Ports........4-4

5.0 INVENTORY OF PORTS........5-1
5.1 Profiles of Port Facilities in Massachusetts........5-1
5.1.1 Gloucester, Massachusetts........5-1
5.1.2 Salem, Massachusetts........5-4
5.1.3 Boston, Massachusetts........5-7
5.1.4 Fore River Shipyard........5-13
5.1.5 Fall River, Massachusetts........5-15
5.1.6 New Bedford, Massachusetts........5-19
5.2 Profiles of East Coast Ports Outside of Massachusetts........5-25
5.2.1 Portland, Maine........5-25
5.2.2 Portsmouth, New Hampshire........5-26
5.2.3 Providence, Rhode Island........5-27
5.2.4 Quonset Point / Davisville, Rhode Island........5-28
5.2.5 New Haven, Connecticut........5-30
5.2.6 New York and New Jersey........5-31
5.2.7 Philadelphia, Pennsylvania........5-32
5.2.8 Baltimore, Maryland........5-33

TABLE OF CONTENTS - Continued

5.2.9 Wilmington, Delaware 5-34
5.2.10 Virginia Port Authority 5-35
5.3 U.S. East and Gulf Coast Shipyard Construction and Repair Capacity 5-37
5.3.1 Construction Demand and Capacity 5-38
5.3.2 Shipyard Availability 5-40
5.3.3 Capacity and Delivery Estimations 5-42
5.3.4 Vessel Repair Capacity 5-42
5.3.5 Conclusions Relative to Construction and Repair Capacities on the Atlantic Coast 5-43

6.0 SHORT-LISTING OF PORTS FOR FURTHER EVALUATION 6-1
6.1 Massachusetts Port Criteria Evaluation Matrix 6-1
6.2 Implications of Applying the Hard Criteria Relating to Navigational Access and Port Facilities 6-2
6.2.1 Evaluation of Each Hard Criterion 6-2
6.2.2 Results of the Evaluations 6-4
6.3 Engineering Cost Analysis of Port Upgrades at Short-Listed Ports 6-4
6.3.1 New Bedford Harbor 6-4
6.3.1.1 South Terminal 6-4
6.3.1.2 State Pier 6-7
6.3.2 Boston Harbor 6-12
6.3.2.1 North Jetty 6-12
6.3.2.2 Dry Dock #4 6-14
6.3.2.3 Coastal Oil Site 6-17
6.4 Implications of Applying the Soft Criteria 6-20

7.0 ECONOMIC AND TAX EFFECTS OF CONSTRUCTION AND OPERATING EXPENDITURES 7-1
7.1 Construction and Operating Period Economic Effects 7-1
7.2 Construction and Operating Period Fiscal Effects 7-2
7.3 Summary 7-3

8.0 SUMMARY AND RECOMMENDATION 8-1

9.0 PATH FORWARD – HIGH-LEVEL SOUTH TERMINAL BUSINESS PLAN 9-1

10.0 REFERENCES 10-1

TABLES

Table 3-1 Planned Offshore Wind Projects 3-12
Table 3-2 Distances to Staging Port Locations from the Proposed Cape Wind Site 3-15
Table 3-3 Distances to Staging Port Locations from the Proposed Deepwater Site 3-16
Table 3-4 Rhode Island Climatology Data 3-17
Table 3-5 Distances to Port Staging Locations from the Proposed Bluewater/Deepwater Sites 3-19
Table 3-6 Delaware/New Jersey Climatology Data 3-19
Table 3-7 Distances to Staging Port Locations from the OMP Designated Sites 3-20
Table 3-8 Principal Dimensions for Turbine Import Vessels 3-20
Table 3-9 Principal Dimensions for Turbine Installation Vessels 3-23

TABLE OF CONTENTS - Continued

Table 3-10 Principal Dimensions of Specific Turbine Import Vessels 3-27
Table 3-11 Typical Dimensions of Turbine Installation or Transport Vessels.....................3-27
Table 3-12 Crane Requirements for 3.6 MW and 5 MW Turbines and Associated Monopile Foundations 3-28
Table 3-13 Summary of Navigational Constraints at Selected Massachusetts Ports.........3-31
Table 3-14 Distances from Regional Ports to Proposed Wind Farms 3-32
Table 3-15 Excerpt from Time Line Model Illustrating the Typical Work Breakdown Structure..3-33
Table 3-16 Expected Through-Put at Staging Port for Various Construction Scenarios 3-36
Table 3-17 Indoor/Outdoor Storage Requirements 3-39
Table 3-18 Dimensions and Weights of Turbine Components Technical Data for Vestas V112-3.0 MW 3-44
Table 4-1 Groupings of Port Characteristics...4-1
Table 5-1 Summary of Navigational Constraints in Boston 5-12
Table 5-2 Nine Year Tug and Barge Construction Demand-U.S. Shipyards....................5-38
Table 5-3 Recent Shipyard Contracts as of 2009...5-39
Table 5-4 Active East Coast and Gulf Coast Shipyards with Significant Construction Records 5-40
Table 5-5 Listing of Shipyards on the Atlantic Coast with Build and/or Repair Capacity 5-42
Table 6-1 Massachusetts Port Criteria Evaluation Matrix...6-1
Table 6-2 Cost Estimate for South Terminal Expansion..6-7
Table 6-3 Cost Estimate for Improvements to State Pier at New Bedford Harbor..............6-8
Table 6-4 Cost Estimate for Improvements to Dry Dock #4 at the Port of Boston............6-15
Table 6-5 Cost Estimate for Improvements to the Coastal Oil Site at the Port of Boston 6-18
Table 6-6 Workers Required for Typical 80-Turbine Offshore Wind Energy Project........6-21
Table 7-1 Total Direct, Indirect, and Induced Economic Effects of Offshore Wind Installation and Related Port Facilities Construction and Operation 7-2
Table 7-2 Total Direct, Indirect, and Induced Tax Effects of Offshore Wind Installation and Related Port Facilities Construction and Operation....................................7-3
Table 8-1 Comparison of the Two Short-Listed Ports..8-1
Table 9-1 South Terminal Capital Costs...9-2
Table 9-2 South Terminal Operating Income and Expenses...9-2
Table 9-3 Construction and Annual Direct, Indirect and Induced Economic Effects Associated with South Terminal Construction 9-3
Table 9-4 Construction and Annual Direct, Indirect and Induced Tax Effects 9-4

FIGURES

Figure 1-1 Installed Nysted Windfarm (Denmark)..1-2
Figure 2-1 Massachusetts Ocean Management Plan Offshore Wind Energy Areas 2-2
Figure 3-1 Primary Components of an Offshore Wind Turbine...3-1
Figure 3-2 Types of Foundation for Offshore Wind Turbines...3-2
Figure 3-3 Monopiles are driven in with the Menck 3-5
Figure 3-4 Bunny Ear Configuration (Lateral) – End view looking forward 3-14
Figure 3-5 Bunny Ear Configuration (Fore-Aft) – End view looking forward 3-14
Figure 3-6 Star Configuration – End view looking forward..3-14
Figure 3-7 Cape Wind Proposed Horseshoe Shoal Site...3-15

TABLE OF CONTENTS - Continued

Figure 3-8 Deepwater Wind Proposed Rhode Island Site 3-16
Figure 3-9 Cumulative Probability Graphs of Wind Speed and Wave Height for Coastal Rhode Island 3-17
Figure 3-10 Bluewater Wind and Deepwater Wind Proposed Sites 3-18
Figure 3-11 Cumulative Probability Graphs of Wind Speed and Wave Height for the Delaware/New Jersey Area 3-19
Figure 3-12 BBC KONAN Transiting With Turbine Components with Nacelles Stowed Below Deck 3-21
Figure 3-13 Self-Propelled Crane Barge with 250 Ton Lifting Capacity 3-21
Figure 3-14 Leg-Stabilized Crane Ship 3-22
Figure 3-15 Jack-Up Crane Barge 3-22
Figure 3-16 Jack-Up Crane Ship 3-22
Figure 3-17 The Dixie Class Lift Boat Represents a Near-Term Option for U.S. Offshore Wind Turbine Installation 3-22
Figure 3-18 Glosten Vessel Concept 3-23
Figure 3-19 Loaded Barge in Transit 3-26
Figure 3-20 Barge Onsite with Legs Down 3-27
Figure 3-21 Rail Trucks 3-45
Figure 3-22 Broken Down Wind Components on Rail Cars....................3-45
Figure 5-1 Layout of the Inner Harbor at the Port of Gloucester....................5-2
Figure 5-2 Gloucester Harbor and Shoreline Areas....................5-4
Figure 5-3 Aerial View of Salem Harbor 5-5
Figure 5-4 Salem Harbor and Shoreline Areas....................5-6
Figure 5-5 Aerial View of Boston Harbor 5-8
Figure 5-6 Massport Facilities....................5-9
Figure 5-7 Aerial View of Fore River Shipyard....................5-14
Figure 5-8 Aerial View of Fall River Harbor 5-17
Figure 5-9 Aerial View of New Bedford Harbor....................5-19
Figure 5-10 Navigational Map of New Bedford Harbor....................5-21
Figure 5-11 Portland Harbor and Shoreline Areas 5-25
Figure 5-12 Portsmouth Harbor and Shoreline Areas....................5-26
Figure 5-13 Port of Providence....................5-28
Figure 5-14 Quonset Business Park....................5-29
Figure 5-15 Aerial View of New Haven Harbor....................5-30
Figure 5-16 Terminal Areas at the Port of New York and New Jersey 5-32
Figure 5-17 Port of Philadelphia 5-33
Figure 5-18 Port of Baltimore....................5-34
Figure 5-19 Terminal Areas at the Port of Wilmington....................5-35
Figure 5-20 Port of Virginia....................5-36
Figure 6-1 South Terminal Port of New Bedford....................6-5
Figure 6-2 State Pier Port of New Bedford 6-6
Figure 6-3 North Jetty Port of Boston 6-13
Figure 6-4 Dry Dock #4 at the Port of Boston....................6-14
Figure 6-5 Coastal Oil Terminal Port of Boston 6-18

TABLE OF CONTENTS - Continued

APPENDICES

Appendix A	Marine Vessels for Construction and Maintenance of Offshore Wind Farms
Appendix B	Developer Questionnaire: Massachusetts Coastal Infrastructure Needs to Support Offshore Wind Farms
Appendix C	Cape Cod Canal Transit Analysis for Nantucket Cape Wind Location
Appendix D	Potential Wind Turbine Delivery Ships
Appendix E	Designated Port Area Figures
Appendix F	Comparison of Selected Northeast Ports for Potential Handling of Wind Power Offshore Energy Installation
Appendix G	Road and Rail Access: Ports of Massachusetts
Appendix H	U.S. East and Gulf Coast Shipyard Construction and Repair Capacity and Availability
Appendix I	Offshore Renewable Energy Port Infrastructure Education Survey
Appendix J	Economic Effects of Offshore Wind Energy and Related Construction and Operating Expenditures
Appendix K	Port of New Bedford South Terminal Business Plan

ACRONYMS AND ABBREVIATIONS

ABS	American Bureau of Shipping
ATR	above the rail
BRA	Boston Redevelopment Authority
DP	dynamic-positioning
DPA	Designated Port Area
Dry Dock #4	Boston Port Facility
EOEEA	Energy and Environmental Affairs
EEZ	Exclusive Economic Zone
EMEC	European Marine Energy Center
EPA	Environmental Protection Agency
EWEA	European Wind Energy Association
FAA	Federal Aviation Administration
GDP	Gross Domestic Product
GW	gigawatt
HDC	Harbor Development Commission
hp	horsepower
H_S	wave height
Hz	hertz
IBEW	International Brotherhood of Electrical Workers
km	kilometers
KTH	KTH Royal Institute of Technology (Sweden)
kV	kilovolt
kW	kilowatt
LNB	Lighted Whistle Buoy N
LNG	liquified natural gas
LOA	length overall
M	million
MassDEP	Massachusetts Department of Environmental Protection
Massport	Massachusetts Port Authority
MBTA	Massachusetts Bay Transportation Authority
MBTA	Massachusetts Bay Transportation Authority
MCEC	Mass Clean Energy Center
MCZM	Massachusetts Coastal Zone Management
MDOT	Massachusetts Department of Transportation
MEPA	Massachusetts Environmental Policy Act
MIT	Massachusetts Institute of Technology
MLW	mean low water
MMA	Massachusetts Maritime Academy
MMS	Minerals Management Service
MREC	Marine Renewable Energy Center
MRET	Massachusetts Renewable Energy Trust
mt	metric tons
MTC	Massachusetts Technology Collaborative
MW	megawatt

NaREC	New and Renewable Energy Center
NEG	Northeast Gateway
NOREIZ	National Offshore Renewable Energy Innovation Zone
NPDES	National Pollutant Discharge Elimination System
nm	Nautical mile
O&M	Operation and Maintenance
OCS	Outer Continental Shelf
OMP	Ocean Management Plan
OSHA	Occupational Safety and Hazards Administration
OSV	offshore support vessel
P&W	Providence & Worcester
PCB	polychlorinated biphenyls
psf	pounds/square foot
QDC	Quonset Development Corporation
RFI	Requests for Information
RFP	Request for Proposal
ROWEI	Representative Offshore Wind Energy Installation
RWU	Roger Williams University
SMAST	School for Marine Science and Technology
TEU	twenty-foot equivalent units
TIGER	Transportation Investment Generating Economic Recovery
TIVs	turbine installation vessels
U.S.	United States
UMaine	University of Maine
UMass/Dartmouth	University of Massachusetts/Dartmouth
UNH	University of New Hampshire
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
V AC	volts alternating current
V_W	average wind speed
WHOI	Woods Hole Oceanographic Institution
WTTC	Wind Technology Testing Center

1.0 INTRODUCTION

In January, 2009, the Massachusetts Clean Energy Center (MCEC)[1], formerly Massachusetts Renewable Energy Trust (MRET), issued a Request for Proposals for Port and Support Infrastructure Analysis for Offshore Energy Development No. 2009-IId-01 ("RFP"). This RFP stated, "Offshore wind energy is the most viable option available for developing utility-scale renewable energy electric generating facilities to the densely populated states along the Eastern Seaboard in the near term." In recognition of a widespread, growing interest in reversing the climate effects of fossil fuels and federal and state policies and programs that promote growth in the use of renewables for electricity generation, the overall goal of this study is to identify port facilities in Massachusetts that have the ability to support offshore renewable energy development. This study also seeks to explore the feasibility and economic development potential, as well as the economic impacts, of planned and potential port and landside facilities at candidate Massachusetts ports.

For this first-of-its-kind study of infrastructure to support offshore wind in the United States, the MCEC contracted with Tetra Tech EC, Inc. and a team of specialized professionals (collectively "the Team") to analyze the ability of Massachusetts port facilities to support the anticipated development of commercial scale offshore wind generation facilities along the northeast Atlantic coast. This study provides the results of the Team's efforts to analyze and integrate information from current industry participants, such as potential developers and turbine manufacturers, with information from ongoing European offshore energy developments (see Figure 1-1) to characterize ports and associated facilities. These characterization parameters for existing ports and facilities in Massachusetts were then compared to determine which facilities may best be able to support commercial offshore wind development and what specific improvements may be required to better support offshore wind and other marine energy projects. This report presents the approach, analysis, and findings of the study that resulted in the identification of two Massachusetts port facilities, which were subsequently evaluated in more depth. This report further provides the MCEC with recommendations for direct port investment in support of offshore wind energy generation.

Marine-based wind energy generation has an advantage as a renewable energy source because it is closer to commercial deployment than other marine-based renewable energy generation approaches, such as tidal and wave technology. Furthermore, the large scale of equipment and components required for wind generation (i.e., the blades, foundations and towers) means that if a port can physically support offshore wind generation it also will likely meet the requirements for other marine-based renewable energy technologies. Therefore, this study focused primarily on how Massachusetts ports can meet the requirements of offshore wind energy generation projects. The needs related to transmission line construction and interconnection to the power grid are outside the scope of this report. Integrating power from offshore wind generation into the Massachusetts power transmission system raises other issues of concern in terms of who should invest in such construction and how the costs of such investments might be allocated. A separate report administered by MCEC analyzes the issues related to offshore wind power transmission investment. *The 2009 Summary Report - Strategic*

[1] The RFP was originally advertised and the selection process administered by the Massachusetts Technology Collaborative (MTC); MTC subsequently transferred staff and the project to the MCEC.

Options for Investments in Transmission in Support of Offshore Wind Development in Massachusetts provides an analysis of the transmission investment issues (The Analysis Group, Inc. et al. 2009).

Figure 1-1 Installed Nysted Windfarm (Denmark)
(Source: A2Sea)

The focus of this analysis was to specifically determine:

- The required characteristics of a port facility to be considered an appropriate staging point for construction of offshore wind generation facilities;
- The primary differences between traditional port facility features and those required for delivery, storage, handling and deployment of very large wind farm components;
- The harborside and landside needs of purpose-built installation and component delivery vessels (now and in the future);
- The set of port facilities in the Commonwealth of Massachusetts that could be upgraded or expanded to be considered relevant staging points;
- The estimated costs for required upgrades or expansions at the ports that are the leading candidates for supporting offshore wind development; and
- The ability of facility improvements to attract wind farm developers, government investment, and ensure an appropriate return on investment.

2.0 BACKGROUND AND CONTEXT

The Northeast Atlantic coastal waters, including those off Massachusetts, are a national focus of the offshore wind industry. This interest is based primarily on the relatively shallow water of the continental shelf, favorable wind characteristics, and relative proximity to large electrical load centers. Those Massachusetts ports possessing the facilities, land area, and navigational characteristics necessary for the assembly and transport of wind turbine components, and for long-term operation and maintenance needs, are well-positioned to serve the emerging demands of the offshore wind energy industry.

In April 2009 the United States (U.S.) Department of the Interior, Minerals Management Service (MMS) issued final regulations on “Renewable Energy and Alternative Uses of Existing Facilities on the Outer Continental Shelf (Final Rule),” establishing a process for leasing submerged lands for renewable energy projects on the Outer Continental Shelf (OCS). The Final Rule outlines the requirements for limited (short-term – for testing and characterizing) and commercial (long-term – for power generation) leases and the bidding and regulatory procedures a wind developer must follow to obtain rights to a wind farm development site on the OCS. Current and future activities of potential developers of offshore wind generation facilities and MMS’s Final Rule provide a context within which to evaluate offshore wind energy development in waters off the Massachusetts Coast and along the Atlantic Seaboard.

The Massachusetts Ocean Management Plan (OMP) was released on January 4, 2010 by the Commonwealth’s Executive Office of Energy and Environmental Affairs (EEA OMP 2009). The OMP establishes new protections for environmental resources and sets parameters for the development of community-scale and commercial-scale offshore wind energy and other infrastructure in Commonwealth waters.

OMP identifies and designates areas such as:

- Prohibited Areas;
- Renewable Energy Areas; and
- Multi-Use Areas.

Offshore Wind Energy Areas identified in the OMP are specifically designated for commercial wind energy facilities, which are defined as eleven or more turbines. This designation recognizes the need to provide opportunity for renewable energy generation at a meaningful scale while being cognizant of potential environmental impacts. Two Offshore Wind Energy Areas were identified in the OMP based on the presence of suitable wind resource and water depth and the absence of conflict with other uses or sensitive resources. These areas are located approximately one nautical mile offshore in the vicinity of the southern end of the Elizabeth Islands and southwest of Nomans Land Island (located just southwest of Martha’s Vineyard) (see Figure 2-1). These areas could accommodate approximately 150 3.6 MW turbines at full build-out (EOEEA OMP pp 2-2). Commercial scale wind farms are restricted to the Wind Energy Areas.

This study considered the OMP Offshore Wind Energy Areas as possible offshore wind construction sites. Distances to the these sites (measured in nautical miles) were calculated from the ports of Gloucester, Salem, Boston, Fore River, Fall River, and New Bedford, MA, and from Portland, ME, Quonset/Davisville, RI, Philadelphia, PA, New York, NY, and Norfolk, VA.

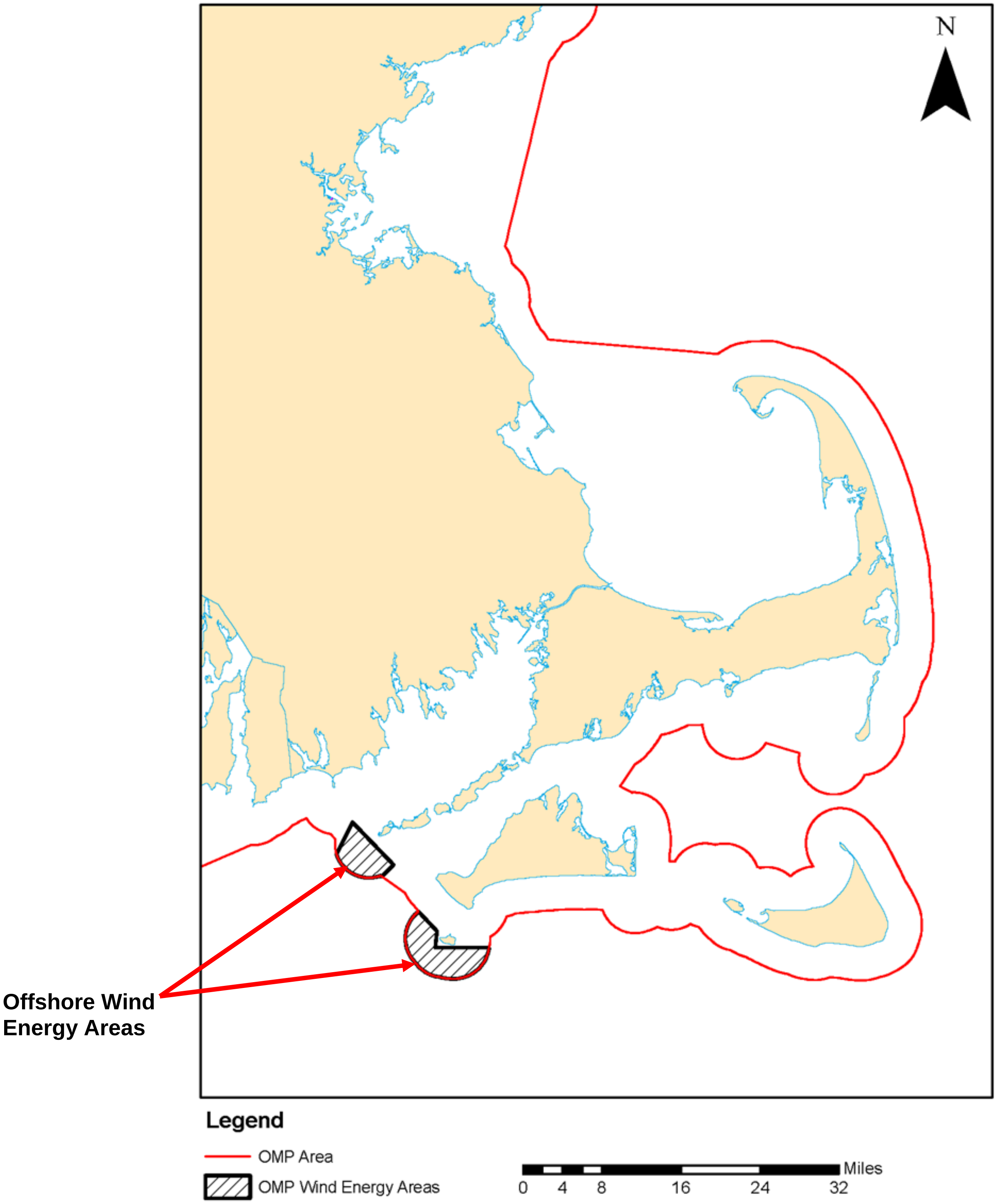


Figure 2-1 Massachusetts Ocean Management Plan Offshore Wind Energy Areas
(Source: Based on EOEEA OMP, 2009)

The Team recognized the potential for these sites to be developed for offshore wind energy and the implications of that development on the demand for port and offshore support infrastructure. Massachusetts ports with the potential to satisfy the infrastructure requirements of the offshore wind energy industry would be well-positioned to support construction in the Offshore Wind Energy Areas.

Developers have yet to construct any offshore wind commercial generation facilities in U.S. waters (so far only meteorological towers have been constructed to test wind characteristics). As such, U.S. port facilities have yet to stage construction for any offshore wind farms. Other than the import of landside wind farm components, East Coast ports have no experience in handling, storing or assembling offshore wind generation components. Therefore, the experience gained at European ports that are servicing offshore wind facilities and at the U.S. Gulf of Mexico ports staging construction for the offshore petroleum industry have formed the basis of the Team's analysis of the port infrastructure needed to support the East Coast offshore wind industry. The combination of massive turbine component sizes, the trend toward production of much larger components (such as blades with lengths approaching 90 meters), and the expectation that stateside developers intend to skip pilot scale offshore facilities (which would present learning opportunities) in favor of full-scale production projects, complicates the Commonwealth's preparation for this new industry. The physical constraints in and around Massachusetts ports also suggest that their ability to cost-effectively stage such offshore construction will take both physical improvements and attentive problem solving.

The Team's approach to addressing these questions and specific needs of the industry involved a sequential approach that considered:

- Assessment of Offshore Wind Energy Port Infrastructure Needs – Section 3.0 of this study provides an overview of the current industry, site conditions along the eastern U.S. coastline, and vessel characteristics and constraints for transport, installation and maintenance of offshore wind farms.
- Evaluation Criteria – Section 4.0 describes the "hard" and "soft" criteria that were used to evaluate specific port facilities. These criteria include port utilization, staging requirements, navigational access, distance to the installation site, and rail/highway access for component delivery to port facilities.
- Inventory of Port Facilities in the Commonwealth of Massachusetts – Section 5.0 outlines the general characteristics of six port facilities, along with their navigational constraints and rail and highway access. This section also provides the distance from each port to a Representative Offshore Wind Energy Installation (ROWEI) 130-turbine wind farm.
- Short-listing of Ports for Further Evaluation – Section 6.0 considers the information developed in the needs assessment and the port inventory against the evaluation criteria to short-list two ports for further consideration. Section 6.0 also includes an engineering cost analysis of port upgrades, along with a description of educational, training and research organizations that will support offshore wind energy activities in the Commonwealth of Massachusetts.
- Economic and Tax Effects of Construction and Operating Expenditures – Section 7 provides an analysis of the estimated costs for required upgrades at the two short-listed

ports, in addition to the economic and tax effects of these activities on the Commonwealth.

- Summary and Recommendation – Section 8.0 contains a summary of the Team's findings, along with a final comparison of the two short-listed port facilities to the evaluation criteria developed for this study.
- Path Forward – Section 9.0 contains a preliminary high-level business plan for the recommended port and suggests a path forward that would consider other important aspects of the port's development that were not within the scope of this study.
- References cited in this report are listed in Section 10.0.

3.0 ASSESSMENT OF OFFSHORE WIND ENERGY PORT INFRASTRUCTURE NEEDS

Any port to be used to support offshore wind energy development must be capable of meeting a number of physical and operational requirements relating to navigation, scale of operations, physical space, ancillary support facilities, and other considerations. This section reviews a number of the key features and characteristics of commercial offshore wind farm development to provide a basis for identifying port criteria that would be either required or highly desirable for supporting that development.

3.1 Introduction to Offshore Wind Energy and Similar Offshore Activities

This section provides a description of wind farm components and the issues affecting their delivery and deployment, explains how other offshore industries offer insight into navigational and port requirements for offshore wind development, discusses proposed offshore wind projects and site conditions at these locations, provides an overview of currently available vessels, and discusses the constraints and requirements of installation, import and auxiliary vessels for the offshore wind industry.

3.1.1 Wind Farm Components

A wind energy system transforms the kinetic energy of the wind into mechanical or electrical energy that can be harnessed for practical use. Mechanical energy is most commonly used for pumping water in rural or remote locations. The "farm windmill" that is still seen in many rural areas of the United States is a wind-powered water pumper, but it can also be used for many other purposes (e.g., grinding grain, sawing). If this mechanical energy is converted into electricity, the machine is called a wind turbine. Wind electric turbines generate electricity for homes and businesses and for sale to utilities. Wind turbines, including offshore wind turbines, primarily consist of a rotor (with blades on a hub), a nacelle, tower, foundation and associated electronic equipment (see Figure 3-1). Most turbines use a three-bladed rotor that is connected through the drive train to the electrical generator that is housed in the nacelle. Offshore wind turbines are typically designed to also have extra space within the nacelle to allow access for maintenance. The associated electronic controls for the system are housed in the nacelle and in land-based control buildings. The cylindrical, self-supporting, tubular tower supports the turbine rotor and nacelle

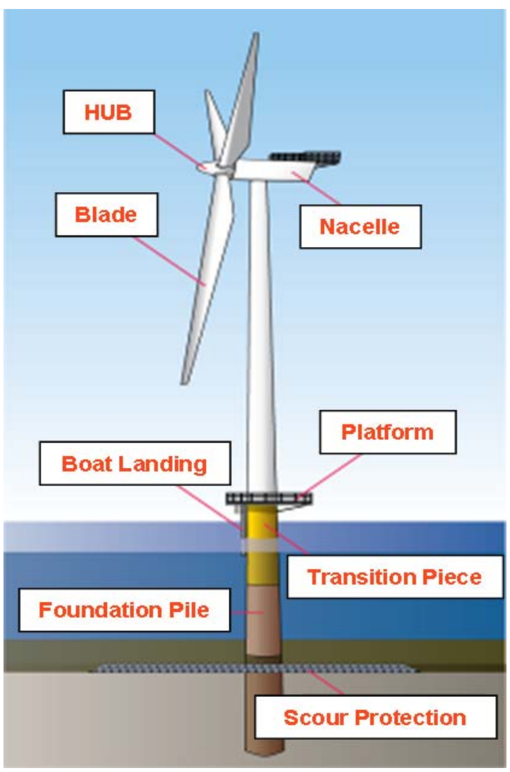


Figure 3-1 Primary Components of an Offshore Wind Turbine

and provides a sheltered interior for the cables, controls and access way to the nacelle for maintenance and repairs. Cabling, transformers, interconnect equipment, meteorological tower(s) and a substation are the major components of any wind turbine system.

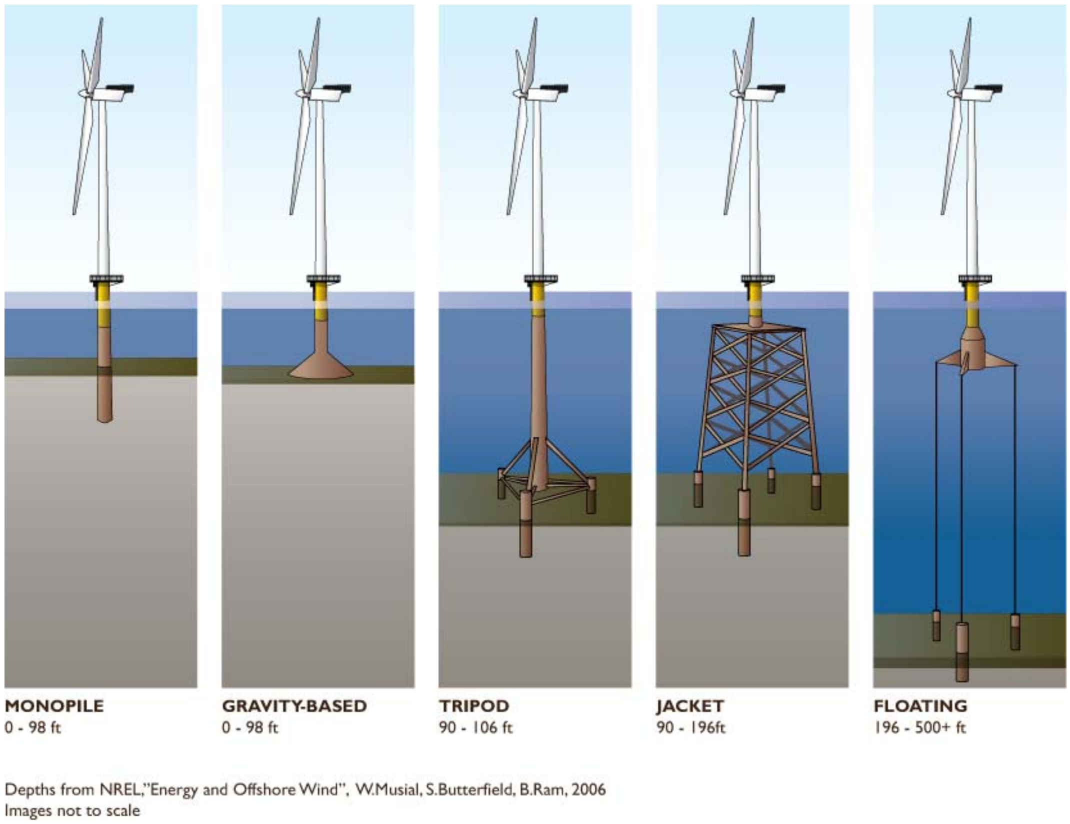


Figure 3-2 Types of Foundation for Offshore Wind Turbines

Offshore wind turbines are typically larger than 2 MW in generation capacity. In this analysis, the Team primarily considered 3 MW or 3.6 MW turbines, as these are typical of the sizes currently being deployed. Examples of current wind turbines in this range are the Siemens SWT-3.6-107 turbine or the Vestas V112- 3MW turbine. Next generation wind turbines for offshore deployment are expected to be 5 MW and greater in generation capacity. For the purposes of this study, a minimum offshore wind turbine array was assumed to consist of ten turbines. Based upon discussions with current and future developers, larger wind farm arrays would include from 60 to 150 turbines.

Various foundation structures can be used depending on the seabed geology, the wind/wave conditions, and water depth at the site. Four standard types of offshore foundations currently exist (see Figure 3-2):

- Monopile;
- Gravity-Based;
- Multi-Leg – Tripod or Jacket; and
- Floating.

Offshore wind turbine foundation technology is being developed from the structural foundations already in use in the offshore petroleum extraction industry, mainly from the use of piles and jackets. Foundation types for wind turbines, like those for petroleum extraction platforms, vary with water depth. Deep water technologies, such as semi-submersible and floating platform technologies, are being explored for the offshore wind industry. However, there are differences between stabilization requirements of petroleum extraction platforms and wind turbine towers. The torque of the rotating blades of the wind turbine adds stresses to the structure that makes stabilization of the towers more difficult. The State of Maine is currently exploring the use of floating turbine technology, specifically because of the deep water environment found in the Gulf of Maine (University of Maine 2009). The technology used for floating and anchored structures has also been modified for new applications such as deep water Liquified Natural Gas (LNG) ports. Anchor systems used for petroleum and LNG ports could also be adapted for wind turbine applications to anchor structures at deep water locations.

Monopiles and gravity-based foundations are commonly used in shallow and transitional water with water depths up to 30 m (approximately 100 feet). Monopile foundations are already heavily used for offshore wind in Europe. Multi-pile configurations with broader bases (such as tripods, jackets, mono-towers and suction bucket support structures) are used where the water depth is 30 to 60 m (approximately 100 to 200 feet). Floating turbines may also become feasible long-term options for deep water installations greater than 60 m (200 feet) deep. These floating turbine structures would be secured to the ocean floor via guy wires, mooring lines, or taut tension legs, which in turn would be fastened to anchors or gravity-based platforms (U.S. Offshore Wind Collaborative 2009, p. 23). Most of the developers that were interviewed for this study indicated they plan to use monopiles for their currently proposed offshore wind farms. Deepwater Wind expects to use monopiles for its proposed Block Island project and jacket foundations for its deeper water Delaware project (Tetra Tech 2009b).

3.1.2 Wind Turbine Component Delivery and Deployment

Port infrastructure needs must consider the logistics of wind turbine component delivery and the sequencing of installation and construction. Currently, very few offshore wind turbine components are manufactured in the United States that are large enough to be suitable for a commercial offshore wind farm. Manufacturers such as Siemens, Vestas, REPower, Clipper Windpower, General Electric, Northern Power Systems, and Multibrid currently have little incentive to set up large scale offshore wind component manufacturing operations for offshore wind development in the United States until developers are ready to place orders and purchase components at a rate that makes the investment in a manufacturing facility financially attractive (based on Team discussions with manufacturers). Vestas has been manufacturing turbine components in the United States for a couple of years and Siemens and General Electric (among other manufacturers) are currently developing domestic manufacturing facilities for wind turbine towers and nacelles in the United States. Some of these new facilities are expected to become operational in 2010. However, these facilities will likely focus on landside wind turbines in the short term. Therefore, this analysis assumes that almost all turbine component pieces for offshore wind farms in the near future would be delivered from Europe.

Suppliers are expected to ship turbines from European manufacturing facilities to the United States in pieces (e.g., the tower sections, nacelle, hub, individual blades) aboard crane-equipped, open hatch cargo vessels. These vessels can accommodate from four to eight nacelles, hubs and blades depending on the size of the vessel. As discussed below, the draft and beam of these vessels (referred to as either “import” or “delivery” vessels) must be accommodated by the port of delivery (see Appendix A, Vessel Requirements for Offshore Wind Farm Construction and Maintenance). Component pieces will be offloaded upon delivery and placed in a storage area. Onshore assembly of the wind turbine parts makes use of land-based cranes. Turbine towers have their own storage requirements, including specific brackets. Components assembled in the storage areas require relocation to the quayside via onshore cranes before being loaded onto the installation vessels. Smaller wind turbine component pieces and scour protection aggregate could be transported to the onshore staging port by existing rail or truck.

Foundations and transition pieces tend to be manufactured and delivered separately from the turbines, although there may be some manufacturing overlap with towers. Currently, no operational rolled steel manufacturing facilities on the East Coast have been identified that operate at a scale suitable for manufacturing the towers and structural components of a large offshore wind farm. Since there is still no firm demand for the number and size of monopiles necessary to construct a 60 to 150 turbine wind farm, foundation suppliers also currently lack an incentive to set up an East Coast production facility.

Existing domestic and foreign suppliers may deliver foundations fully assembled or ready for assembly. These sections or components would be shipped in on large barges from the Gulf of Mexico, Europe, or Malaysia. A potential scenario for monopiles delivery would include shipping ‘cans’ or small sections of rolled steel from Europe or Malaysia by barge for welding and assembly at the staging port. Similarly, jacket piles could be shipped as unassembled bars from the Gulf of Mexico to the staging port to save cargo space and be welded together there. Depending on the type and point of origin, foundation component delivery to the staging port may also be performed using more traditional means such as barges, rail, or truck. Rail and truck options are limited to bulk concrete components, or sectional pieces such as iron bars or flat sheets of steel. Fully assembled foundations have dimensions that preclude their delivery by rail and truck.

Developers do not necessarily have to stage foundations for offshore deployment out of the same port that is staging the turbine construction. The value of the convenience of utilizing a common port or port facility generally would not outweigh the cost savings associated with improved logistics, less assembly, and minimizing storage space and handling needs. Barges may also be used conveniently for foundation storage in certain situations. Foundations can be delivered and/or stored on barges fully assembled, then tugged out to the installation site with less handling.

Ample storage at the staging port is needed to support routine logistical inventories. For example, Vestas stated that it would generally require 20 turbines to be assembled ahead of time before transport to the installation site (Tetra Tech EC 2009-2010a). Weather conditions at the installation site, including wind and wave action, can disrupt deployment and installation activity. This possibility translates into a need for increased landside storage capacity to accommodate a backlog of turbine and foundation component deliveries.

3.1.3 General Sequence of Offshore Construction and Installation Activities

The sequence of offshore wind turbine construction begins with the installation of foundations. Foundations can be delivered from the staging port by either a standard barge or on the installation vessel. A jack-up barge with a crane creates a stable work platform for the placement. Traditionally, these vessels have been used in the U.S. marine construction industry in contrast to the specialized vessels that are generally preferred by European offshore wind developers for turbine installation. The foundation installation methodology depends on the foundation type. Each type of foundation requires tailored installation procedures and equipment. A monopile foundation, for example, would require pile drivers (see Figure 3-3). After foundation installation, the transition piece gets attached to the top of the foundation, creating a level connection surface for the towers. See Appendix A for details of other installation types.

Figure 3-3 Monopile Being Driven In with a Menck Hammer
(Source: Courtesy of A2Sea)

As previously noted, turbine components may be transported from the staging port to the installation site in various stages of assembly. Appendix A provides more details of these transport options. In general, options are defined by the capabilities of the particular installation vessel, preferences of the manufacturer for sub-assembly configurations, and site-specific navigation constraints. On-site assembly cuts down on transport risk, but entails other risks associated with assembly in the marine environment. Similarly, assembly in the controlled environment of the staging port results in more difficult and risky transport, but less risk at the installation site. Turbine manufacturers and contractors with experience in European wind farm construction prefer to use specialized vessels for turbine installation. Installation vessels need to be stabilized (i.e., with jack-up legs) and have a crane or cranes able to lift a 3 MW or 3.6 MW nacelle (which weighs approximately 135 to 185 metric tons (mt) (approximately 150 to 200 tons)) into place so that the blades can be attached. Delivering and installing fully assembled turbines on towers requires greater lifting capabilities of up to 275 mt (approximately 300 tons). It should be noted that a 5 MW nacelle, which may be employed in future systems, weighs 360 to 390 mt (approximately 400 to 430 tons).

The unassembled deployed wind turbine components are then assembled at the offshore site. The foundations are installed first, followed by the transition piece, the tower, the hub, and the nacelle. Next the blades are attached to the hub and the assembled rotor is hoisted and attached to the nacelle. However, as was noted, the turbine components also can be transported partially or fully assembled to the site.

Purpose-built vessels (vessels designed specifically for the offshore wind industry) for wind turbine installation are not currently available in the United States. Additionally, it is not expected that a U.S. purpose-built vessel will exist in time for the initial construction of utility scale wind generation facilities on the East Coast. Construction costs for these vessels range from $40 million ($40M) to $80M for tugged vessels and $150M to $250M for self-propelled vessels (see Appendix A). Like other offshore wind turbine components, the incentive to build a purpose-built installation vessel will depend on the amount of actual demand for their use and the potential return on such investment. Existing U.S. built jack-up vessels were built for the oil and gas industry and are less than optimal for offshore wind turbine installation, but they could be used for the initial deployments for East Coast offshore wind construction. However, the use of these existing vessels involves more risk and would require more installation time than purpose-built vessels. Rental rates for installation vessels are high and developers will attempt to maximize the utilization of the vessels when leased. This factor, along with the ever present possibility of weather and seasonal delays, indicates that the staging port must be available 24 hours per day and 7 days per week. Both the availability of wind turbine components and delivery and construction vessels are critical elements of the offshore wind energy supply chain.

3.1.4 Forecasts and Future Trends in Offshore Wind Energy Affecting Port Requirements

Proposed offshore wind projects in Europe and North America for 2015 are forecasted to reach 40 gigawatt (GW), of which the United States is expected to undertake projects totaling more than 2 GW (Infocast, U.S. Offshore Wind Report 2009, p. 6). The European Wind Energy Association (EWEA) has set a target for 2020 of 40 GW of offshore wind capacity. European offshore demand for 2010 is forecasted to reach 10 GW. This implies a European need for 30 GW or more over a 5-year span, which cannot be supported by current manufacturing capacity (EWEA, Oceans of Opportunity 2009, p. 44). However, the offshore wind industry will need to deploy upwards of 10,000 structures by 2020 to meet the minimum forecasted European demand. The current offshore manufacturing industry cannot deliver this number of structures due to insufficient capacity. (EWEA, Oceans of Opportunity 2009, p. 49). Additional manufacturing facilities and related industrial capacity are needed to meet the forecasted European and North American demand.

Offshore development costs depend significantly on the price of the substructures. For example, foundations represent 25 percent and 34 percent of total investment costs for 5 MW and 2 MW systems installed in 25 m of water, respectively (Papalexandrou 2008, Economic analysis of offshore wind farms, KTH Royal Institute of Technology [Sweden] (KTH) School of Energy and Environment, in partnership with Ecofys). The economics of offshore wind development tend to favor larger machines (potentially in the range of 5 MW to 10 MW in the future, with less emphasis on design features (such as aesthetics and sound emission level) than for onshore wind turbines (EWEA, Oceans of Opportunity 2009, p. 44). Current technology suggests that increases in turbine power rating are commensurate with incremental increases in turbine size.

3.1.5 Similar Offshore Activities

Offshore wind generation is a new marine industry on the Eastern Seaboard and will be added into a region that has historically been heavily dependent on maritime industry and commerce. As a new industry, however, offshore wind will require specialized equipment, services and labor not currently available in any U.S. ports. Understanding what will be needed to support both short-term construction and long-term operational and maintenance activities involves learning from the recent experience of European offshore wind projects, as well as identifying similar services and activities already associated with existing marine industries here in the United States.

There are a number of marine industries currently in operation in the waters offshore of the United States, each with its own specialized port requirements. These industries include, but are not limited to, petroleum extraction, LNG off loading or storage, commercial shipping, and commercial fishing. Each marine industry is specialized, requiring differing shore-side support as well as different configurations for the appropriate offshore environment. However, comparing and contrasting the needs of these industries with European experience can increase our understanding of the port-related requirements for offshore wind development and the potential utilization of the available marine industrial capabilities in the US. For instance, wind turbine foundations are comparable to offshore petroleum structures. Shore-side infrastructure for construction and maintenance of offshore wind farms is similar to that needed for commercial shipping and large-scale commercial fishing operations. Additionally, port requirements for maintenance and support of offshore wind farms would be similar to those for offshore LNG ports and petroleum platforms.

3.1.5.1 Offshore Energy Industry in the US

Petroleum Extraction

Petroleum extraction is well established in the United States, especially in the Gulf of Mexico. There is a broad range of off shore platform designs, and their structural design has evolved over time. In general, the petroleum extraction platforms in the Gulf of Mexico are designed for water depths of 60 to 190 m (approximately 200 to 600 feet) (MMS 2009). However, platforms in deeper water up to 2,450 m (approximately 8,000 feet) also exist (MMS 2009). These deep water platforms are built using pre-fabricated modules. The super-structure is pre-assembled on land and transported to the field site for final assembly. These structures are comprised of different modules, typically partitioned into crew housing and process or control functions. Petroleum platforms are often built in clusters, centered on a developed well. Assembly is intensive due to the multiple connections required between modules, clustered platforms, and the well. Steel construction is preferred for the platform superstructure while concrete is limited to the platform foundations. Shallow foundations are commonly constructed using piles that anchor the superstructure or jack-up platforms on the seabed. Deeper platforms require semi-submersible elements or floating devices anchored to the seabed to fix the position of the platform. Platform assembly is generally accomplished using specialty vessels, including jack-up cranes, tow boats, and large barges. Special heavy lift vessels are needed to transport the large assemblies, such as the pre-fabricated modules. Jack-up cranes or crane vessels lift the pre-fabricated modules into place. Platform modules are purposefully designed to have a minimum number of tie-ins to minimize field assembly efforts.

Large ports play an important role in the operation and maintenance of these petroleum extraction platforms. Major petroleum companies with a number of offshore platforms maintain permanent access to their own shore-side terminals that are capable of berthing vessels from 90 to over 185 m (approximately 300 to over 600 feet) in length with drafts that can exceed 11 m (36 feet). The accessibility and use of onshore facilities is critical to supporting petroleum extraction. Considering the premium that is placed on the space available on offshore platforms, activities aboard are typically minimized to assure operational efficiency and safety. All other materials are supplied from storage facilities at nearby ports, ready to be shipped out when and as needed. Because of this, ports receiving and delivering large petroleum extraction components and platform modules require large areas for yard storage, large dock heavy lift capability, and berthing for other construction and maintenance vessels. These requirements are similar to those for supporting offshore wind development on a commercial scale.

LNG Ports

The importation of LNG into U.S. markets has recently begun to favor fixed locations in deepwater offshore locations. These deepwater ports offer easy access, improved safety and reduced visibility to coastal residents. Deepwater LNG ports typically consist of re-gasification equipment, LNG vessel anchorage, and pipeline delivery systems to shore-based storage and distribution pipelines. Many technologies have been proposed for re-gasification, including barged equipment, modified petroleum platforms, island structures, and underwater riser assemblies. Northeast Gateway (NEG) Deepwater LNG Port is currently operating off the Massachusetts coast. Another similar deepwater LNG port facility is being planned in the area by Neptune LNG. Both of these facilities are located approximately 8.7 nm (10 miles) due east of Boston. The technology used for the NEG port is an underwater riser assembly that acts as anchorage and gas delivery system to a sub-sea delivery pipeline. Two such riser assemblies were constructed, and are anchored in place much like anchored floating petroleum platforms. Construction of the NEG Port required a large 110 m (approximately 350 foot) pipeline lay barge for offshore pipeline construction, anchoring vessels, and diver support vessels. Crew vessels provided provisions, material and transit for the 150 to 300 person crew throughout the construction operations. Specialized 275 m (900 feet) long LNG re-gasification vessels moor to the riser/mooring assembly during gas delivery operation. Support and security vessels for the NEG Port are based out of Boston, and are deployed to provide safety and security. Shore-based facilities are minimal for operation of the NEG Deepwater Port. However, construction of the deepwater port required layout, staging areas, and crew deployment from multiple ports.

3.1.5.2 Commercial Shipping

Commercial shipping requires large, mobile vessels exporting and importing bulk cargo to ports throughout the world. Vessels range from under 215 to over 300 m (approximately 700 to over

1,000 feet) in length. Ports that receive and deliver cargo require large areas for yard storage and wharf frontage. Vessels calling on commercial shipping ports must also be able of pass under vertical obstructions such as bridges. In the United States, vertical obstructions are typically standardized by the U.S. Coast Guard (USCG) to maintain a minimum clearance of approximately 41 m (135 feet) (Coast Pilot specification).

Commercial shipping ports such as Boston require distribution and warehousing facilities for the handling of roughly 1.2 million mt (1.3M tons) of general cargo, 1.4 million mt (1.5M tons) of non-fuels bulk cargo, and 11.6 million mt (12.8M tons) of bulk fuel cargo per year (Massachusetts Port Authority 2009). The Port of New York and New Jersey handles 5.3 million loaded and unloaded twenty-foot equivalent units (TEUs) per year (Port Authority of New York and New Jersey 2009). Trucking and rail access facilitate shipment of cargo over land. The Port of New York and New Jersey also boasts 54 container cranes that can handle all types of cargo, 135 to 320 mt (approximately 150 to 350 ton) capacity cranes, and the largest heavy-lift crane on the East Coast (an approximately 900 mt (1,000 ton) rated-capacity Chesapeake 1000). Donjon Marine Co. Inc. cranes have handled large bulk cargo including 365 mt (400 ton) General Electric Co. and Siemens generator units that were transported to the port via oceangoing vessels (Port Authority of New York and New Jersey 2009).

3.1.5.3 Commercial Fishing Factory Vessels

Commercial fishing is conducted by vessels ranging from very small, 1 or 2 man crew ships to large factory vessels. Shore-based support for these operations varies widely considering the large diversity of vessel types. Large factory vessels have similar shore-side requirements as commercial shipping. Consequently, commercial fishing operation requirements are very comparable to offshore wind operational and maintenance needs. However, offshore wind generation support needs are much smaller in scale than the warehousing and wharf frontage needed for commercial shipping. Frozen fish products also require freezer containment for offloaded cargo. In Rhode Island, Seafreeze Ltd. utilizes berthing space for two 45 m (approximately 150 feet) processing vessels, warehousing cold storage capacity of approximately 10.4 million kg (23 million pounds), offloading cranes, and truck and rail access (Seafreeze Ltd. 2009).

3.1.5.4 Submarine Transmission Cables

Additionally, technologies and construction techniques used for submarine pipeline installation may have similarities, in terms of lay-down area and construction vessel size, to those needed for high-capacity submarine transmission cable installation required for the offshore wind industry.

3.1.5.5 Implications

Offshore wind power generation will require specialized labor and equipment for construction and operation. Specialized training will be required to successfully construct and operate safely and efficiently in the marine environment. The basic skill-set exists, to a certain extent, within the maritime industry and Merchant Marine. Local universities (including the Massachusetts Maritime Academy) and labor unions could modify existing training courses to create and maintain a qualified labor force specifically geared to service a growing offshore wind industry. But establishing programs in anticipation of the offshore wind industry is unlikely.

Petroleum extraction platforms are currently assembled using specialized heavy lift vessels. Similar vessels will be required for the construction of wind turbines. Vessels currently in the fleet (including jack-up cranes, tow boats, and large barges) have the potential to be modified for use as construction platforms for wind turbines (especially for initial installations). While such modifications can be made to existing vessels, the specialized construction techniques and heavy lift needs of offshore wind turbine construction may make the modification option expensive and potentially risky as compared to purpose-built vessels. The option of applying modified existing equipment may also be limited to smaller construction projects in near-shore environments. Purpose-built construction vessels for offshore wind turbine construction would most likely, be more cost effective, less risky, and flexible in terms of operational capabilities.

As with petroleum extraction, commercial shipping and factory fishing port facilities, offshore wind construction lay down and port requirements are fairly significant. To support the offshore wind industry, significant lay down areas will be required for the assembly and storage of large wind turbine components. It is estimated based on discussions with major offshore wind turbine manufacturers in Europe that a minimum of 8.1 hectares (approximately 20 acres) would be needed for assembly and storage of these components assuming component delivery is scheduled so that the portside assembly area only needs capacity for a fraction of the total wind farm components at any given time (based on interviews with developers). Large-capacity cranes will also be needed to move turbine components such as nacelles and tower pieces. Yard and wharf facilities will need to be sufficiently large to store, move and assemble turbine components with weights up to approximately 290 mt (320 tons). The large vessels needed for receiving and delivering such components require navigation channels of particular depth and clearance (both horizontal and vertical) to allow passage through/beneath obstructions such as bridges. Recent developments in offshore wind turbine size, coupled with evolving construction and component delivery techniques, may exceed the current 41 m (135 feet) vertical clearance of local, large fixed bridges.

An offshore wind farm, once constructed, will need routine maintenance and occasional component replacement, including major components such as a blade or nacelle. Maintenance vessels used during wind farm operations would be similar in size to those currently in use to support offshore LNG ports and petroleum extraction operations and, on rare occasion, would require the same or similar vessels to those used during construction for major maintenance. Berthing space for support vessels would be vital for these port facilities, as well as sufficient yard and warehousing space for components and other maintenance supplies and activities. The NEG Deepwater LNG Port operating off the coast of Massachusetts currently utilizes a 33 to 49 m (approximately 110 to 160 feet) long offshore support vessel (OSV) that makes roughly 65 round trips to the port site each year (U.S. Coast Guard 2006). For comparison, Cape Wind estimates that three maintenance vessels will be required each day, 252 days per year, for routine maintenance, resulting in an estimated 756 vessel trips per year. Commercial shipping and fishing vessel activity is similarly constant with vessels arriving and departing port facilities on a daily basis. Vessel activity during offshore wind project construction also would be constant, but short in duration during the one to two year long construction phase of a project (depending upon the size of the wind farm). Larger vessel activity would drop off considerably during operation and maintenance of offshore wind projects. However, major repair work would likely require a large vessel like the ones used during wind park construction. Vessels currently in the fleet, including jack-up cranes, tow boats, and large barges, can be modified for use as construction/maintenance platforms. However, the availability of purpose-built construction vessels would be the preferred option in the long run.

3.2 Industry Overview

3.2.1 Development of the Port Criteria

To determine the port facility/land-based requirements for offshore wind development, the Team interviewed developers, obtained turbine manufacturer information, and had discussions with consultants with offshore wind farm construction experience in Europe. Through this information gathering, the Team identified:

- specific port- and land-based needs related to vessel requirements;
- component, materials and equipment storage and assembly requirements;
- preliminary estimates of potential through-put of wind turbines (e.g., the number of wind turbines deployed); and
- skilled labor needs and trades requirements.

The Team identified “hard” and “soft” criteria based on the stated requirements (see Section 4.0). These criteria were used to create a Criteria Evaluation Matrix as a tool for comparing and ranking Massachusetts port facilities (see Section 6.0) on the ability to serve as offshore wind construction and deployment ports.

3.2.2 Interviews with Developers

The Team contacted most of the current and prospective offshore wind farm developers on the East Coast to gain a deeper understanding of the requirements for supporting the construction, operation and maintenance of a utility scale offshore wind farm. The Team intended to use this developer input to identify an objective set of weighted criteria with which to compare and evaluate Massachusetts port facilities. However, many developers have yet to specify or disclose in detail the key parameters and characteristics of the port and other supply chain requirements. While cognizant of the need to solve logistical issues, negotiations between developers and various manufacturers and material suppliers are ongoing. Actual component manufacturing sites and delivery methods will be determined on a project- and item-specific basis. As a result, many of the detailed questions contained in the customized developer questionnaires were left unanswered (see Appendix B for the questionnaire). However, developers did identify and explain many aspects of the most important parameters that helped the Team establish the basic criteria. Developers identified general port staging needs against the characteristics of which current ports could be compared and ranked. Developers also were questioned about what would make one port more attractive than another. Cost control and risk avoidance emerged as key factors.

The Team’s interviews with developers provided insight into the principal issues concerning commercial offshore wind energy development off the Northeast Atlantic Coast. These insights provided a better understanding of wind farm components and the associated logistics of importing, storing, assembling and deployment to and installation at the project site. Table 3-1 below provides a quick summary of these proposed projects based on available public information. Projects are listed by developer with project particulars such as location, water depth, generating capacity, number of turbines, and distance from shore. Because these projects are in various stages of development, not all information on every project is publicly available.

As the developer's needs were analyzed, the Team found that Massachusetts ports had clear, distinguishable differences relative to offshore wind development requirements, and that the ports could be compared in a straightforward manner relative to these parameters. Development of a more complex framework for the evaluation that made use of multi-variable, weighted criteria was unnecessary.

Table 3-1
Planned Offshore Wind Projects

Developer/ Project	Project Location	Water Depth at Proposed Location	Project Generating Capacity	Number of Turbines (Scale)	Foundation Type	Estimated Cost of Construction	Port Staging Area
Cape Wind Associates							
Cape Wind	4.5 NM (5.2 miles) from coast of Cape Cod, MA, 7.8 NM (9 miles) from Martha's Vineyard, 12 NM (13.8 miles) from coast of Nantucket Island	3.7 m (12 ft) MLLW (mean low low water) minimum depth	468 MW	130 (3.6 MW per turbine)	Monopile	$700 million	Quonset Davisville Port and Commerce Park, Quonset, Rhode Island
NRG Bluewater Wind							
Bluewater Delaware	11.3 to 19.1 NM (13 to 22 mi) east of Rehoboth Beach, DE (wind park); 14.3 NM (16.5 mi) due east Rehoboth Beach (met tower)	12.2m to 18.3m (40 to 60 feet)	200 to 450 MW	Up to 150	Monopile	$800 million	Port of Wilmington, Delaware; Delaware Bay Launch in Milford Delaware for crew boat and small cargo barge launch
Bluewater New Jersey	14 NM (16 mi) southeast of Atlantic City, NJ	21.3m to 30.5m (70 to 100 feet)	350 MW	116	Monopile	$1.4 billion	Port of Wilmington, Delaware; Delaware Bay Launch in Milford Delaware for crew boat and small cargo barge launch
Deepwater Wind							
Garden State Offshore Energy (Deepwater with PSEG Renewables)	13.6 NM (15.6 mi) from shore, 17.4 NM (20 mi) due east of Avalon, NJ	24.4m to 27.4m (80 to 90 feet)	350 MW	96	Jacket	$1 billion	Atlantic City, New Jersey

Table 3-1
Planned Offshore Wind Projects (continued)

Developer/ Project	Project Location	Water Depth at Proposed Location	Project Generating Capacity	Number of Turbines (Scale)	Foundation Type	Estimated Cost of Construction	Port Staging Area
Deepwater Wind Rhode Island	2.6 NM (3 miles) off Block Island, RI for Phase 1; Phase 2 located 13 to 17.4 NM (15 to 20 mi) off RI coast (location TBD upon completion of RI Ocean Special Area Management Plan in 2010	'deeper' waters	20 MW (Phase I) 400 MW (Phase II)	Phase 1: 8 turbines Phase 2: 106 turbines	Jacket	$1 billion	Quonset, Rhode Island
Fisherman's Energy							
Fisherman's Energy of New Jersey Project	Phase 1: 2.6 NM (3 miles) off the coast of Atlantic City Phase 2: 6.1 NM (7 miles) off the coast	18.3m to 21.3m (60 to 70 feet)	Total: 350 MW Phase 1: 20MW Phase 2: 330 MW	Total: 74 Phase 1: 8 turbines Phase 2: 66 turbines	Monopile	$100 million for Phase 1 $1 to 1.5 billion for Phase II	Dorchester, Atlantic City, and or Cape May, New Jersey
Fisherman's Energy of Rhode Island Indepen-dence 1 Project	2.6 NM (3 miles) south off the southern coast of Block Island, RI	20 m to 30 m (65.6 to 98.4 feet)	400 MW	80	TBD	$1.25 to $1.5 billion	TBD

3.2.3 Conditions at Ports and Wind Farm Locations

Wave height, water depth and wind speed impose limitations on at-sea construction operations. The following subsections describe sea states, wind conditions, and water depths at a number of proposed wind farm sites along the U.S. East Coast. Transit distances[2] between proposed wind farm sites and potential staging ports also are evaluated.

Sea states are typically characterized by the significant wave height (H_S), which is the average of the largest one-third of the observed waves. H_S correlates very well to the sea state as observed by mariners. Wind is characterized by the 10-minute average wind speed (V_W).

The base line transit routes for cargo in the region track around the east end of Cape Cod. The primary alternative route is via the Cape Cod Canal (see Appendix C). Air draft (i.e., the free space above the water line below an overhead obstruction) in the Cape Cod Canal is limited to approximately 41 m (135 feet). In practice, this means vessels or barges transporting 5 MW turbines in the "bunny ear" configuration (especially the "fore-aft" configuration – see Figures 3-4 and 3-5) probably cannot expect to transit the Cape Cod Canal. Alternative turbine load-out

[2] Transit distances are in nautical miles and are based on typical shipping routes.

configurations (e.g., the “star” configuration – see Figure 3-6) and/or smaller turbines (e.g., 3.6 MW turbines) in the “bunny ear” configuration could probably utilize the Cape Cod Canal.

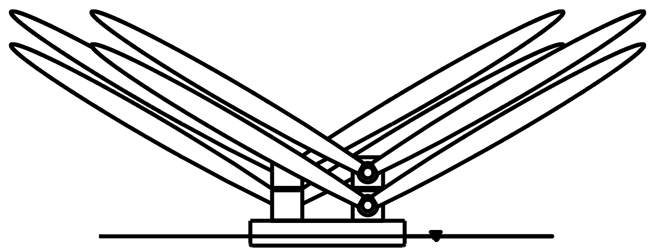


Figure 3-4 Bunny Ear Configuration (Lateral) – End view looking forward
(Source: The Glosten Associates 2009)

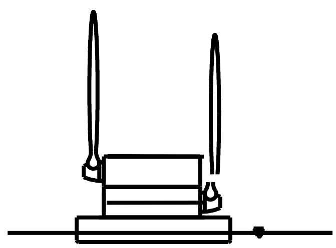


Figure 3-5 Bunny Ear Configuration (Fore-Aft) – End view looking forward
(Source: The Glosten Associates 2009)

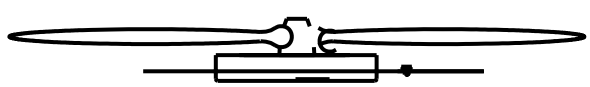


Figure 3-6 Star Configuration – End view looking forward
(Source: The Glosten Associates 2009)

3.2.3.1 Nantucket Sound

Cape Wind Associates has proposed a project for Horseshoe Shoal in Nantucket Sound. The location for that project is shown below in Figure 3-7. The distances from the proposed project site to the potential staging port locations are listed below in Table 3-2.

Water depths in the proposed project area are approximately 3.6 to 18 m (approximately 12 to 60 feet). Information on wave heights and wind speeds is limited for this area. According to the Coast Pilot, during the winter (November-February), wave heights of 3.7 m (approximately 12 feet) can be expected 5 percent to 15 percent of the time. During the summer, wind speed rarely exceeds 15 knots, and wave heights are 1 m (approximately 3.2 feet) or less 98 percent of the time. Additionally, in the summer (May-July), thick fog frequently forms, which could complicate installation operations.

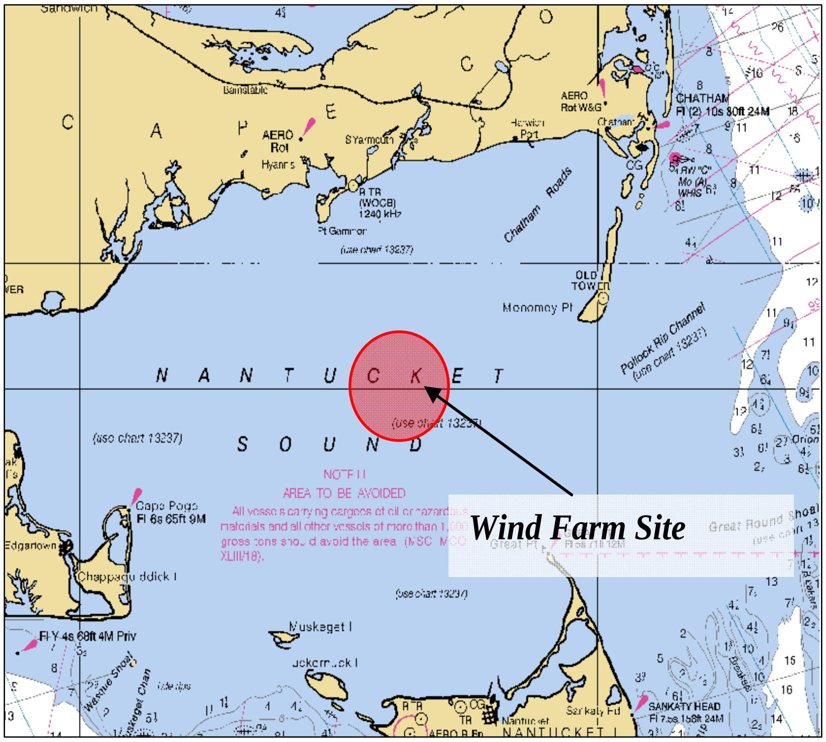


Figure 3-7 Cape Wind Proposed Horseshoe Shoal Site
(Source: The Glosten Associates 2009)

Table 3-2
Distances to Staging Port Locations from the Proposed Cape Wind Site
(Source: The Glosten Associates 2009)

Staging Location	Primary Route Distance [nautical miles]	Alternate Route* Distance [nautical miles]
Boston, MA	130	130
Gloucester, MA	105	130
New Bedford, MA	45	n/a
Fall River, MA	75	n/a
Portland, ME	160	200
Quonset/Davisville, RI	70	n/a

* Alternative route is via the Cape Cod Canal.

3.2.3.2 Rhode Island

Deepwater Wind, in collaboration with First Wind (a Massachusetts-based wind developer), is planning two projects off the Rhode Island coast. The first is a small-scale project, located three nautical miles off Block Island. The second is planned for a utility-scale project, located approximately 12 to 18 nm (15 to 20 miles) off the coast of Rhode Island[3.] This area is shown below in Figure 3-8. The distances from the sites to the potential staging port locations are listed

[3] The precise location of the second Deepwater Wind site will be established based of the results on the forthcoming Ocean Spatial Area Management Plan, which is expected to be completed in 2010.

in Table 3-3. Water depths are approximately 30 to 40 m (100 to 130 feet) at the proposed Rhode Island site. However, due to the large regional area being considered for the wind farm sites, water depths vary widely. Climatology for the general region is presented in numerical and graphical forms in Figure 3-9 and Table 3-4.

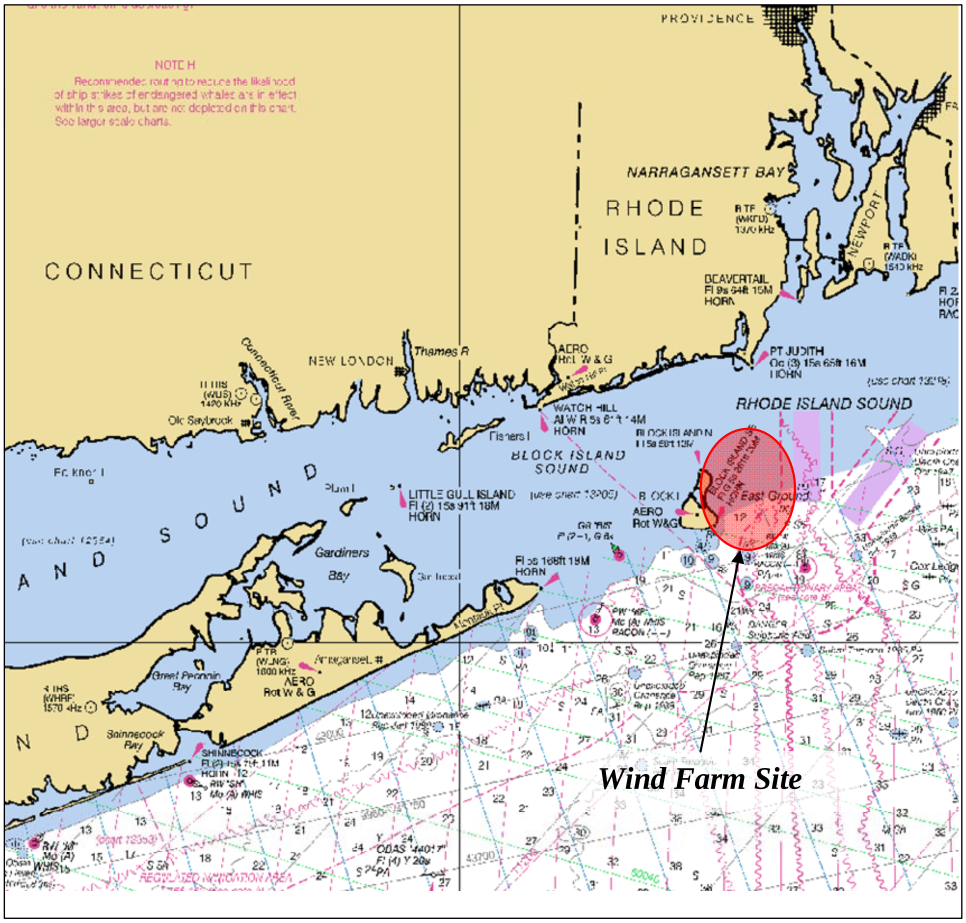
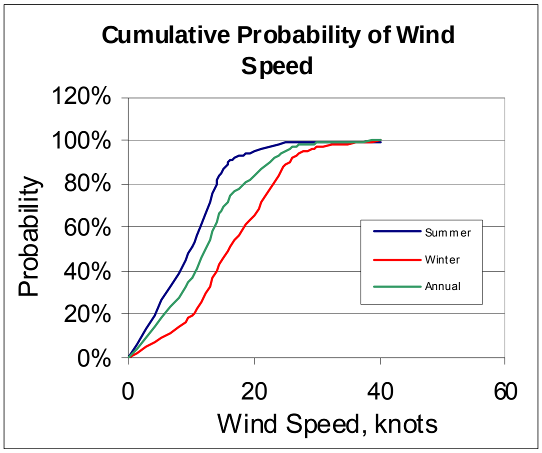


Figure 3-8 Deepwater Wind Proposed Rhode Island Site
(Source: The Glosten Associates 2009)

Table 3-3
Distances to Staging Port Locations from the Proposed Deepwater Site

Staging Location	Primary Route Distance [nautical miles]	Alternate Route* Distance [nautical miles]
Boston, MA	295	120
Gloucester, MA	270	120
New Bedford, MA	50	n/a
Fall River, MA	45	n/a
Portland, ME	325	190
Quonset/Davisville, RI	35	n/a

* Alternative route is via the Cape Cod Canal.



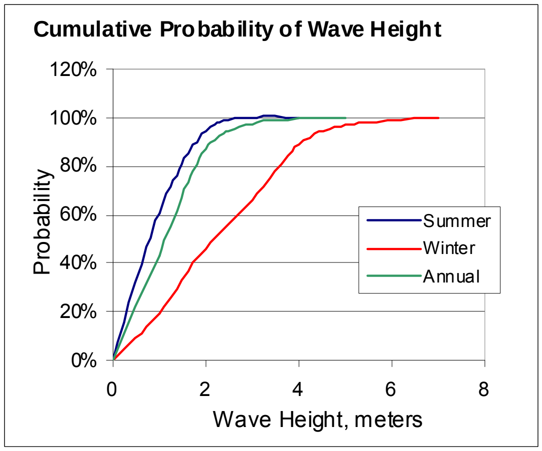


Figure 3-9 Cumulative Probability Graphs of Wind Speed and Wave Height for Coastal Rhode Island

(Source: The Glosten Associates 2009)

Table 3-4
Rhode Island Climatology Data
(Source: The Glosten Associates 2009)

Description	Annual	Winter (January)	Summer (August)
Probability {$H_S \leq 1$ meters}	43.5%	28.5%	60.3%
Probability { $H_S \leq 2$ meters}	86.7%	78.2%	94.3%
Probability { $H_S \leq 3$ meters}	97.2%	95.2%	99.8%
Probability { $H_S \leq 4$ meters}	99.4%	98.7%	99.9%
Probability {$V_W \leq 15$ knots}	36.9%	18.2%	52.6%
Probability {$V_W \leq 20$ knots}	69.3%	45.9%	87.5%
Probability {$V_W \leq 25$ knots}	83.9%	65.9%	95.9%
Probability {$V_W \leq 30$ knots}	95.6%	89.4%	99.8%

3.2.3.3 Delaware Bay

Bluewater Wind and Deepwater Wind have each proposed wind farm sites in the Delaware Bay and in the southern New Jersey coastal area, which are shown below in Figure 3-10. The distances from the sites to the potential staging port locations are listed below in Table 3-5. Water depth in the northwest field varies widely from 9 to 24 m (approximately 30 to 80 feet), and from to 12 to 21 m (approximately 40 to 70 feet) in the southeast field. Climatology for the general region is presented in numerical and graphical forms in Table 3-6 and Figure 3-11.

3.2.3.4 Other Areas

The Massachusetts OMP identified additional areas that could be suitable for commercial wind energy production. The two designated Wind Energy Areas are located near the southern end of the Elizabeth Islands and southwest of Nomans Land Island. Wind and wave conditions at these sites are similar to the Rhode Island sites. Transit distances between these sites and potential staging areas are shown in Table 3-7.

Massachusetts, as well as other states on the Atlantic Seaboard, is working with the U.S. Interior Department, MMS to develop Requests for Information (RFIs) for potential wind projects in federal waters off their respective coasts.

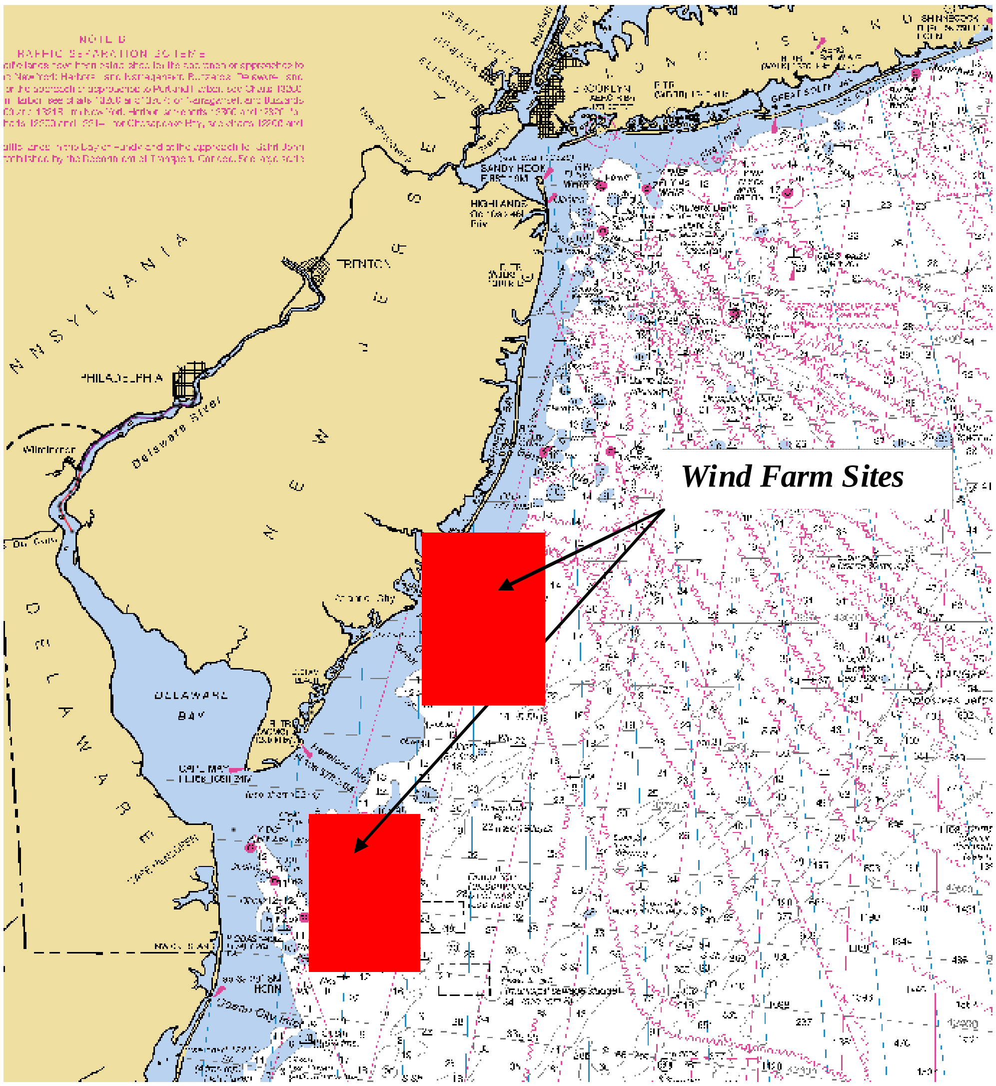


Figure 3-10 Bluewater Wind and Deepwater Wind Proposed Sites
(Source: The Glosten Associates 2009)

Table 3-5
Distances to Port Staging Locations from the Proposed Bluewater/Deepwater Sites

Staging Location	Primary Route Distance [nautical miles]	Alternate Route* Distance [nautical miles]
Boston, MA	470	330
Gloucester, MA	445	330
New Bedford, MA	260	n/a
Fall River, MA	250	n/a
Portland, ME	500	400
Quonset/Davisville, RI	280	n/a

* Alternative route is via the Cape Cod Canal.

Table 3-6
Delaware/New Jersey Climatology Data
(Source: The Glosten Associates 2009)

Description	Annual	Winter (January)	Summer (August)
Probability {$H_S \leq 1$ meters}	66.8%	53.3%	79.4%
Probability { $H_S \leq 2$ meters}	93.4%	88.8%	96.8%
Probability { $H_S \leq 3$ meters}	98.3%	96.7%	98.9%
Probability { $H_S \leq 4$ meters}	99.6%	98.7%	99.9%
Probability {$V_W \leq 15$ knots}	32.1%	21.8%	43.5%
Probability { $V_W \leq 20$ knots}	48.8%	36.6%	61.7%
Probability { $V_W \leq 25$ knots}	60.8%	47.4%	74.4%
Probability { $V_W \leq 30$ knots}	75.5%	61.3%	86.9%

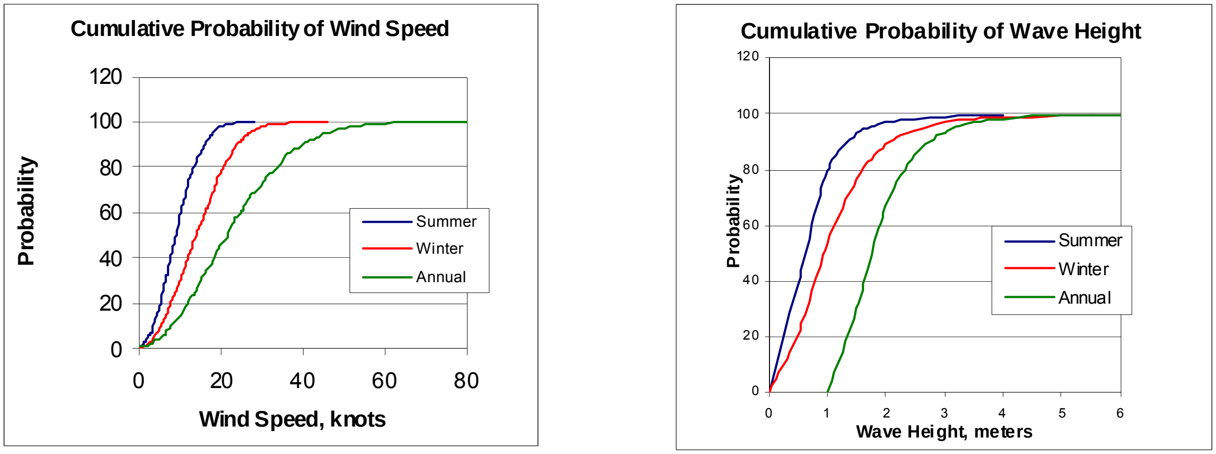


Figure 3-11 Cumulative Probability Graphs of Wind Speed and Wave Height for the Delaware/New Jersey Area
(Source: The Glosten Associates 2009)

Table 3-7
Distances to Staging Port Locations from the OMP Designated Sites
(Near the Elizabeth Islands and Nomans Land Island)

Staging Location	Primary Route Distance [nautical miles]	Alternate Route* Distance [nautical miles]
Boston, MA	260	100
Gloucester, MA	235	100
New Bedford, MA	35	n/a
Fall River, MA	50	n/a
Portland, ME	290	175
Quonset/Davisville, RI	40	n/a

* Alternative route is via the Cape Cod Canal.

3.3 Characteristics of Available Vessels

This section describes the marine vessels that are currently available for use in the construction and maintenance of offshore wind farms. Different vessels are required for the following specific activities:

1. Delivery of turbine components (e.g., tower sections, nacelles, blades) to the staging port;
2. Foundation delivery and installation;
3. Turbine erection;
4. Regular maintenance and personnel transport; and
5. Major maintenance.

The following subsections discuss the basic characteristics, capabilities, limitations, and general availability of the various types of vessels (see Appendix D, Potential Wind Turbine Delivery Vessels, for more details).

3.3.1 Turbine Import/Delivery Vessels

The turbines used for the first round of U.S. offshore wind farms will likely be imported from Europe. Turbines are generally shipped in pieces (e.g., tower sections, nacelle, hub, individual blades) from the point of origin directly to the project site aboard open hatch cargo vessels. Table 3-8 summarizes the principal dimensions of turbine import vessels. An example of this vessel type is shown in Figure 3-12 (Section 3 of Appendix A provides further details).

Table 3-8
Principal Dimensions for Turbine Import Vessels
(Source: The Glosten Associates 2009)

Length Overall	98 to 143 m (330' to 470')
Beam	20 to 23 m (66' to 75')
Design Draft	6.7 to 9.8 m (22' to 32')

Figure 3-12 BBC KONAN In Transit With Turbine Components (Nacelles Stowed Below Deck)
(Source: BBC KONAN)

3.3.2 Foundation Delivery and Installation Vessels

Foundations can be installed using either jack-up crane vessels or floating derrick barges. Jack-up crane vessels are described further below. Large floating derrick barges (as shown in Figure 3-13) are in service on all three major U.S. coastlines and could be mobilized to serve the U.S. East Coast offshore wind energy market.

Depending on the type of foundation being used (i.e., monopile, gravity-base, jacket, or tripod), a derrick barge could transport foundations between the staging port and the wind farm site on its own deck, or foundations could be transported using a separate barge. Floating derrick barges can lift up to 900 mt (approximately 1,000 tons), but a more common lifting capacity is 455 mt (500 tons) or less. Floating derrick barges could be used to install wind turbine foundations in up to 1.5 m (5 feet) seas, with a wind speed limit of around 20 to 30 knots.

Figure 3-13 Self-Propelled Crane Barge with 250 Ton Lifting Capacity
(Source: Marine Transportation Consultants http://www.tug-barge.com/p297.htm)

3.3.3 Wind Turbine Installation Vessels

European offshore wind turbines have been installed using a variety of specialized equipment, which generally falls into one of three categories:

- Leg-Stabilized jack-up crane ships ("partial jack-ups") (see Figure 3-14 for an example);
- Jack-up crane barges (see Figure 3-15 for an example); and
- Jack-up crane ships (see Figure 3-16 for an example).

Figure 3-14 Leg-Stabilized Crane Ship
(Source: A2Sea)

Figure 3-15 Jack-Up Crane Barge
(Source: A2Sea)

Figure 3-16 Jack-Up Crane
(Source: Offshore MPI)

For all three vessel types, the limiting wind speed for at-sea crane operations is approximately 15 to 20 knots. For the leg-stabilized vessels, the limiting sea state for crane operations is approximately 0.5 m (approximately 1.7 feet) seas, as the vessel's hull remains submerged and is subject to wave-induced motion. For the jack-up barges and ships (see Figure 3-17), the process of jacking up and down is limited to approximately 1.5 m (5 feet) seas. The crane can be operated in higher sea states once the vessel is jacked-up.

Figure 3-17 The Dixie Class Lift Boat Represents a Near-Term Option for U.S. Offshore Wind Turbine Installation
(Source: Superior Energy Services, Inc.)

The typical dimensions of wind turbine installation vessels are presented in Table 3-9. Further details are provided in Appendix A.

Table 3-9
Principal Dimensions for Turbine Installation Vessels
(Source: The Glosten Associates 2009)

Length Overall	91 to 137 m (300' to 450')
Beam	30 to 40 m (100' to 130')
Navigation Draft	3.7 to 4.9 m (12' to 16')
Air Draft (legs in up position)	varies, approximately 46 m (150')

No purpose-built wind turbine installation vessels exist that are compliant with U.S. coastwise trade laws (i.e., "Jones Act"). These laws require vessels to be U.S.-built, U.S.-owned, and U.S.-operated. A small number of Jones Act-compliant vessels that are currently operating in the Gulf of Mexico could be used to construct the first-generation U.S. offshore wind farms. These vessels lack the efficiency associated with purpose-built wind turbine installation vessels, such as the ability to transport multiple sets of turbine components and the ability to rapidly jack-up, pre-load the legs, erect the turbines, and jack-down. In order to economically and efficiently achieve GW-scale deployment of offshore wind in the United States, a fleet of purpose-built, Jones Act-compliant vessels will be needed. The industry recognizes this fact and is taking steps to develop the vessel infrastructure. NRG Bluewater Wind, for example, has teamed with the Aker Philadelphia shipyard to develop three purpose-built wind turbine installation vessels. (Bluewater Wind 2009b).

Future wind turbine installation vessels are expected to focus on improving construction efficiency through faster transit speeds, larger payload capacity, and ability to erect turbines in higher wind speeds and larger sea states. Some firms are developing designs that accommodate the transport and installation of fully assembled turbines (see Figure 3-18).

Figure 3-18 Glosten Turbine Installation Vessel Concept
(Source: The Glosten Associates 2009)

3.3.4 Maintenance Vessels

Regular, planned maintenance of offshore turbines requires personnel access to the wind farm facilities. Maintenance personnel for existing offshore wind farms are typically shuttled to the turbines by a crew boat or by helicopter. Specialized crew boats have been developed in Europe to increase the weather window during which maintenance personnel can safely access turbines.

Major maintenance or serial defects in turbines may require mobilization of a wind turbine installation vessel to reverse some or all of the installation process. There is an industry trend to develop maintenance-specific jack-up vessels that have highly capable cranes and limited cargo capacity but relatively slower transit speed. (Gusto MSC 2009).

3.4 Overview of Vessel Constraints and Requirements

The following sections evaluate the marine vessel requirements for deploying and maintaining offshore wind farms along the U.S. East Coast. Understanding the characteristics of these vessels is critical in the overall evaluation of a port's suitability as a staging area for offshore wind farm deployment and maintenance.

Vessel requirements are governed primarily by the following:

- Physical conditions at offshore wind farm sites (i.e., conditions in which vessels must operate);
- Navigational constraints in port and along transit route to the wind farm site;
- Size and weight of turbines being transported and installed; and
- Methodology for transporting and installing turbines.

The Team evaluated the physical conditions (e.g., wind speeds, wave regime and water depth) at proposed offshore wind farm sites along the U.S. East Coast. Navigational constraints in and near the Ports of New Bedford, Boston, Gloucester, and Fall River, MA also were evaluated. The physical properties of large offshore wind turbines (i.e., 3 MW to 5 MW) were reviewed, along with the demonstrated methodologies for transporting and installing these turbines.

The principal dimensions of wind turbine installation vessels/barges and import vessels are summarized below, as are the navigational constraints for all the analyzed ports. Appendix A discusses much of the information that is summarized in this section.

3.4.1 Installation and Transport Vessel Requirements

3.4.1.1 Flag and Class

The Merchant Marine Act of 1920, commonly known as the “Jones Act”, requires vessels engaged in the transport of passengers or cargo between U.S. places to be built and flagged in the United States, and owned and crewed by U.S. citizens. It was assumed for this study that the vessels discussed in this section would be subject to the Jones Act, as bottom-fixed foundations within the U.S. Exclusive Economic Zone (EEZ) are considered U.S. places. Vessels discussed in Appendix A, which are used to transport turbine components from overseas to a U.S. staging port, are not subject to the Jones Act. Therefore, the discussion of turbine installation vessels provided below relates to purpose-built vessels currently operating in the North Atlantic.

Commercial vessels are typically certified by a classification society. The purpose of classing a vessel is to demonstrate compliance with an independent, accepted standard for vessel design, operation, inspection, and maintenance. Several options are available for classing the installation and transport vessels for offshore wind development. Existing European vessels are classed by Det Norske Veritas as "Self-Elevating Units," or by Germanischer Lloyd as "Special Type Offshore Unit – Surface Unit with Stabilizing Legs." Additionally, the American Bureau of Shipping (ABS) Rules for Mobile Offshore Units also are an appropriate classification avenue for installation vessels (see Appendix A and associated references).

3.4.1.2 Principal Dimensions

The key dimensions of a turbine installation and turbine transport vessel are beam, length, draft, and overhead clearance (a.k.a. "air draft"). The following summaries were extracted from Appendix A.

The beam (width) of the installation and transport vessels is largely dictated by the vessel's stability requirements during transit and, if applicable, the stability requirements and structural strength while elevated on legs (i.e., during "jack-up"). Pre-assembled tower components have a relatively high center of gravity, which increases the vessel stability requirements and, consequently, the required vessel beam. Typical European installation vessels, such as SEA JACK and RESOLUTION have a beam in the range of 30 to 40 meters (approximately 100 to 130 feet).

The length of the vessel is dictated by functional and cargo requirements and structural considerations. Typical European turbine installation vessels and barges have an overall length of 90 to 140 meters (approximately 295 to 460 feet).

The vessel's draft, or the required clearance between the waterline and sea bed, is dictated by the hull form and total weight, including the transported cargo. Wind turbine installation vessels and barges tend to have full hull forms with large beam and length. As such, the load-out of these vessels is typically governed more by space requirements than cargo weight. These factors lead to relatively shallow draft requirements. Typical European installation vessels have a draft in the range of 3.5 to 5 meters (approximately 11 to 16 feet).

Overhead clearance, or "air draft", is dictated by three factors: length of legs (for a jack-up barge or vessel), pre-assembly methodology, and crane height in stowed position. The methods of turbine component pre-assembly and transport can vary from project to project. The three most common methods for transporting pre-assembled components from the staging area to the wind farm site were illustrated in Figures 3-4 through 3-6: (1) the bunny ear configuration (lateral); (2) the bunny ear configuration (fore-aft); and (3) the star configuration. For purposes of context, the barge in Figures 3-4 through 3-6 and in the next few figures was drawn to have a beam (width) of approximately 30 m (approximately 100 feet) and an overall length of 122 m (approximately 400 feet). The nacelle and blade dimensions represented are based on a REPower 5 MW turbine (reflecting future equipment sizes). Figures 3-19 and 3-20 show a fully loaded barge with jack-up legs in the transit and jacked-up positions, respectively. Turbine tower sections are typically transported in the vertical orientation, with the maximum height approximately even with the top of the blades in the bunny ear configuration. The legs of a jack-up vessel that is intended to operate in 25 m (approximately 80 feet) of water require an overhead clearance of about 45 m (approximately 150 feet) when the legs are in the up position4. If the barge is required to jack-up in water depths greater than about 45 m, then the leg towers will dictate the overhead clearance requirement. As shown in Figures 3-19 and 3-20, the required overhead clearance is approximately 45 m (150 feet). The star configuration (Figure 3-6) has the lowest overhead clearance requirement, except when transported aboard a jack-up vessel. Overall crane heights vary, but can be approximately as high off the deck in the stowed position as the tower sections. To navigate beneath bridges, the legs can be temporarily lowered if the channel depth is adequate.

The star and lateral bunny ear configurations require a lateral clearance of approximately 130 m (approximately 425 feet) for the 5 MW system components. The lateral clearance for the fore-aft bunny ear configuration is dictated by the barge or vessel beam, which is typically on the order of 30 to 38 m (approximately 100 to 125 feet).

Wind turbines are relatively lightweight for their size. Consequently, cargo vessels that carry turbine components are generally space-limited, rather than weight-limited. This means that these vessels can operate at a light draft of 9 m (approximately 30 feet) or less, even though the design draft may be greater. Table 3-10 presents the principal vessel dimensions for some specific existing turbine import vessels.

The principal dimensions and draft characteristics (navigational and air) of a typical installation or transport vessel are presented in Table 3-11.

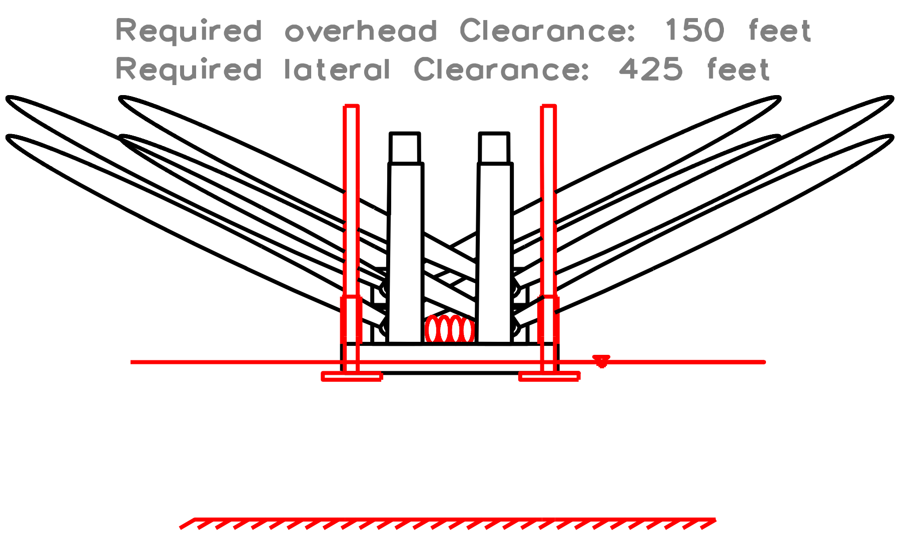


Figure 3-19 Loaded Barge in Transit
(Source: The Glosten Associates 2009)

[4] In general, the legs must be about 20 m (approximately 70 feet) longer than the operating water depth to account for soil penetration and the length of the legs inside the hull and jack house.

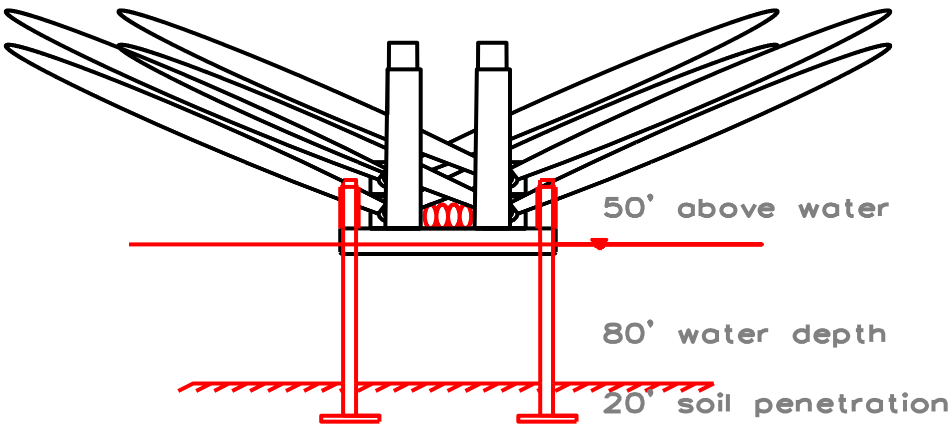


Figure 3-20 Barge Onsite with Legs Down
(Source: The Glosten Associates 2009)

Table 3-10
Principal Dimensions of Specific Turbine Import Vessels
(Source: The Glosten Associates 2009)

Vessel Name	Length Overall	Beam	Design Draft
BBC ELBE	143 m (470')	23 m (74.8')	9.7 m (31.8')
BBC KONAN	127 m (416')	21 m (68.2')	6.7 m (21.8')
Beluga F-Series	138 m (453')	21 m (68.9')	8.0 m (26.2')
Clipper MARINER	101 m (331')	20 m (66.3')	8.2 m (26.9')

Table 3-11
Typical Dimensions of Turbine Installation or Transport Vessels
(Source: The Glosten Associates 2009)

Length Overall	90 – 140 m (300' – 450')
Beam	30 – 40 m (100' to 130')
Navigation Draft	3.6 – 4.9 m (12' to 16')
Air Draft (legs in up position)	varies, approximately 46 m (150')
Air Draft (tower sections, bunny ears)	46 m (150')
Air Draft (crane in stowed position)	varies

3.4.1.3 Propulsion

Self-propelled ships and non-self-propelled barges have both been used successfully to install offshore wind farms in Europe. A self-propelled vessel with a dynamic-positioning system can cost three to five times as much as a barge with the same crane capacity and jacking system. However, a self-propelled vessel can achieve higher transit speeds than a towed barge and can work independently (i.e., without tug boats). It is currently unclear whether the U.S. market will prefer self-propelled ships or barges.

3.4.1.4 Crane Requirements

The key factors that dictate crane requirements for an installation and transport vessel are the:

- Maximum weight to be lifted (i.e., the "pick weight");
- Maximum height to be achieved above sea surface (i.e., "pick height"); and
- Required spatial clearance for objects being lifted.

The first U.S. offshore wind farms will likely use 2.5 MW to 3.6 MW wind turbines, with 5 MW turbines becoming commercially available within the next two years. Maximum pick weight and pick height generally increase with increasing turbine power rating. Table 3-12 summarizes the key crane requirements for two representative turbines (a Siemens 3.6 MW Offshore Turbine and a REPower 5 MW Offshore Turbine) and typical monopile components.

Table 3-12
Crane Requirements for 3.6 MW and 5 MW Turbines and Associated Monopile Foundations
(Source: The Glosten Associates 2009)

	Siemens 3.6 MW	REPower 5 MW	Monopiles
Max Pick Weight*	Nacelle: 125 mt (138 tons)	Nacelle: 290 mt (320 tons)	180 – 455 mt (200 – 500 tons)
Max Pick Height**	80 m (260 ')	85 – 95 m (280'-310')	Less than 30 m (100')

* 1 ton = 2000 pounds = 0.908 metric ton (mt)
** height above calm sea surface

Installation techniques vary for monopiles. A crane can lift the monopile or the monopile can be "tipped up**"** from the horizontal to the vertical position. Monopiles are often installed with a vibratory hammer, which itself can weigh up to 275 mt (approximately 300 tons) and must be lifted by the crane.

3.4.1.5 Jacking System Requirements

The current trend in turbine installation vessels is toward those vessels with a four-leg configuration. In contrast, the oil and gas industry typically uses three-leg jack-ups. The reason for using four legs is to reduce the time required to pre-load the legs (i.e., to test the soil on the sea bottom). A three-legged rig requires sea water ballasting to achieve pre-load position. With four legs, pre-loading can be achieved by lifting one leg at a time, thereby transferring loads to the other legs. A fourth leg also provides redundancy in the event of a leg failure.

3.4.1.6 Limiting Weather Conditions for Pile Driving and Crane Operation

The limiting sea state for monopile installation depends on the equipment used, but tends to be more sensitive to sea conditions than wind conditions. A robust monopile installation vessel can work in up to 2 to 3 m (6 to 10 feet) seas and wind speeds of up to 20-25 knots at the vessel deck level.[5]

[5] Wind speed increases as height above sea level increases. For example, a 20 knot wind at the deck could be a 24 knot wind at the height of the nacelle, as per DNV RP-C205 "Environmental Loads", Section 2.3.2.12.

Existing turbine installation vessels can operate their cranes in wind speeds of up to 15 knots at the deck level (approximately 23 knots at the crane tip) and can jack-up and down in seas as high as 1.5 to 3 m (5 to 10 feet).

3.4.1.7 Requirements for Accommodations

Installation vessels work around the clock when the weather permits, so personnel accommodations are needed aboard the vessel. Turbine installation vessels generally require accommodations for approximately 16 persons. The vessel/barge crew includes a master, an engineer, four to six mates or deck hands, and two stewards. The wind farm owner often requires accommodations for two to five representatives. This brings the total minimum complement of individuals on board to 30 to 35 persons. Many installation vessels in Europe have accommodations for 40 to 70 persons, and some planned new-build vessels are being designed to accommodate up to 200 persons.

3.4.1.8 Power Requirements

The primary systems that require power on a wind turbine installation vessel are the crane and the jacking system (see Appendix A). Since they do not operate simultaneously, a single power plant can be used for both systems. Cranes capable of lifting turbine components require up to 1,500 kilowatt (kW) (approximately 2,000 horsepower [hp]) power supply. This amount of power is generally also sufficient for a jacking system that meets the lifting capacity and jacking speed requirements for a vessel carrying three to four complete sets of turbine components. Heavier vessels with larger jacking systems will require more installed power, perhaps 3,000 to 4,000 kW (approximately 4,000 hp to 5,500 hp).

To achieve even heel and trim prior to jacking operations, the installation vessel must have a relatively robust ballasting system. A total pump capacity of 300 to 600 tons of water per hour (approximately 72,000 to 144,000 gallons of water per hour) would probably be needed, which would require up to 150 kW (approximately 200 hp) of supplied power.

A self-propelled installation vessel will require a separate power plant that can provide 3,000 to 5,200 kW (approximately 4,000 hp to 7,000 hp) of power to the propulsion system. This power plant can also be used to power a dynamic-positioning (DP) system or to power the crane, but is unlikely to suffice for simultaneous operation of the DP system and the jacking system.

Power generation also is required for “hotel loads”, deck lighting, and emergency systems. Existing vessels have installed auxiliary power of roughly 110 kW (approximately 150 hp) for these purposes.

3.4.1.9 Deck Load Requirements

Existing turbine installation vessels have deck capacities in the range of 1.5 to 20 tons/meter^2 (approximately 300 to 4,100 pounds/square foot (psf)). A 272 mt (approximately 300 ton) nacelle with a footprint of 17 m by 4 m (approximately 56 feet by 13 feet) requires a deck capacity of roughly 4.5 tons/meter^2 (925 psf). Typical ocean class deck cargo barges have a deck capacity of 10 tons/meter^2 (approximately 2,050 psf).

3.4.1.10 Safety Equipment

Marine installation vessels also must be equipped with life saving equipment (including life boats), a fire protection system, and pollution prevention equipment. These requirements would not be unique to turbine installation vessels.

3.4.1.11 Requirements Associated with Alternative and Future Vessel Uses

It is possible that a purpose-built wind turbine installation vessel could be employed in other services, such as general marine construction (e.g., harbors, wharfs, piers, bridges) or offshore oil and gas. In both of these industries, there currently exists a wide range of vessel types and capabilities in response to a diverse set of needs. A wind turbine installation vessel would be a highly capable marine construction vessel. For the oil and gas industry, a wind turbine installation vessel would fall in the middle of the “capability spectrum” (e.g., being able to out-perform smaller work boats, but being incapable of performing the most challenging operations). The economic viability of using a purpose-built wind turbine installation vessel in other industries is difficult to predict, since the market forces that generally drive charter rates are highly volatile and industry specific.

3.4.1.12 Parametric Cost Estimate

The capital cost for a new-build jack-up crane barge ranges from $40M to $80M (see Appendix A). New-build self-propelled jack-up crane vessels have been reported to cost between $150M and $250M. However, new-build cost estimates are few and difficult to verify. For perspective, a simple deck cargo barge 90 m (approximately 300 feet) in length x 27 m (approximately 90 feet) beam can cost up to $20M. A mid- to large-sized, state-of-the-art, ice-breaking arctic research vessel with several specialized onboard systems can cost between $100M and $150M.

3.4.2 Tugboat and Auxiliary Vessel Requirements

3.4.2.1 Tug Boat Requirements

Self-propelled wind turbine installation vessels will likely not require tug assistance, as they would be able to move and position themselves using their own propulsion and dynamic-positioning systems. Barges, on the other hand, would require at least one tug of 3,000 to 3,750 kW (approximately 4,000 to 5,000 hp) (see Appendix A). In addition, a smaller tug of around 745 kW (1,000 hp) may be needed to help position the vessel for jacking operations. If a feeder (shuttle) barge is used to transport turbine components from the port staging area to the wind farm site, a 1,500 to 3,750 kW (approximately 2,000 to 5,000 hp) tug would be required to tow and position the barge. These types of tugs are readily available for hire along the entire Northeast coast and should not be a limiting factor.

3.4.2.2 Crew Boat Requirements

For ongoing maintenance, a high-speed crew boat is an essential component of marine logistics. High-speed crew boats, capable of carrying 15 to 20 passengers, are required during wind farm construction. At the peak of construction activity, two boats may be required. Once again, this service is readily available along the entire East Coast and should not be a limiting factor. In Europe, special vessels and foundation boarding arrangements have been developed solely for accessing turbines in rough sea conditions.

3.4.2.3 Other Auxiliary Vessel Requirements

Several auxiliary vessels, which are readily available for hire, are needed to round out the marine fleet for the complex task of building an offshore wind farm. These auxiliary vessels include:

- dredging equipment;
- cable laying vessels;
- survey vessels; and
- rock laying vessels (to provide scour protection around turbine foundations).

Once again, these vessels are readily available along the entire East Coast and should not be a limiting factor.

3.5 Navigational Access and Transit Distances

The required navigational clearances for vessels involved in the construction and maintenance of offshore wind farms were evaluated. The key considerations for navigational access are:

- Vessel draft compared to navigable water depth;
- Vessel beam (including overhanging cargo) compared to channel width; and
- Vessel air draft compared to overhead clearance restrictions (e.g., bridges and aerial cables).

Turbine installation vessels govern the air draft and channel width requirements. Turbine import vessels govern the draft requirements (e.g., navigable water depth). Tables 3-10 and Table 3-11 summarized required vessel clearances for turbine import vessels and turbine installation vessels, respectively. Table 3-13 summarizes the navigational restrictions associated with selected Massachusetts ports. Further details are given in Appendix A.

Table 3-13
Summary of Navigational Constraints at Selected Massachusetts Ports

Staging Port	Potential Obstructions	Lateral Clearance	Overhead Clearance	Controlling Water Depth	Feasible Turbine Load-Out Configurations	Jack-Up Feasible?
New Bedford	Hurricane Barrier	45 m (150')	No Constraints	6.7-9.1 m (22'-30')	all	yes
Gloucester	water depth, channel width	61 m (200')	No Constraints	4.9-5.8 m (16'–19')	fore-aft bunny ear	Marginal (water depth)
Fall River	Mt. Hope Bridge	122 m (400')	41 m (135')	12.2 m (40')	star	Marginal (air draft)
South Boston	Logan Airport	over 150 m (500')	Report air draft to airport traffic control	12.2 m (40')	all	yes
Charlestown / East Boston (inner harbor)	Logan Airport	over 150 m (500')		12.2 m (40')	all	yes
Mystic River	Tobin Memorial Bridge	over 150 m (500')	41 m (135')	7.6-10.7 m (25-35')	star	Marginal (air draft)

Table 3-13
Summary of Navigational Constraints at Selected Massachusetts Ports (continued)

Staging Port	Potential Obstructions	Lateral Clearance	Overhead Clearance	Controlling Water Depth	Feasible Turbine Load-Out Configurations	Jack-Up Feasible?
Chelsea River (West of Chelsea St. Bridge)	Andrew McArdle Bridge	53 m (175')	No Constraints	8.8-12.2 m (29-40')	fore-aft bunny ear	yes
Chelsea River (East of Chelsea St. Bridge)	Chelsea St. Bridge	28 m (93')	25 m (83')	8.8-12.2 m (29-40')	rotor disassembled	no

Transit distances from potential New England staging ports to the proposed or possible offshore wind farm sites are included in Table 3-14.

Table 3-14
Distances from Regional Ports to Proposed Wind Farms

Staging Location	Ports	Distance (nautical miles)	Alternative Route A [Around Nantucket Island] Distance (nautical miles)	Alternative Route B [Through the Cape Cod Canal] Distance (nautical miles)
Delaware Bay (Deepwater)	Boston, MA	470		330
	Gloucester, MA	445		330
	New Bedford, MA	260		Not Applicable
	Portland, ME	500		400
	Fall River, MA	250		Not Applicable
	Quonset/Davisville, RI	280		Not Applicable
Block Island (Deepwater/Northwind)	Boston, MA	295		120
	Gloucester, MA	270		120
	New Bedford, MA	50		Not Applicable
	Portland, ME	325		190
	Fall River, MA	45		Not Applicable
	Quonset/Davisville, RI	35		Not Applicable
Nantucket Sound (Cape Wind)	Boston, MA	130	270	130
	Gloucester, MA	105	240	120
	New Bedford, MA	60	n/a	Not Applicable
	Portland, ME	160	295	200
	Fall River, MA	75	Not Applicable	Not Applicable
	Quonset/Davisville, RI	70	Not Applicable	Not Applicable
MA OMP Wind Sites (Nomans Land Island)	Boston, MA	260		100
	Gloucester, MA	235		100
	New Bedford, MA	35		Not Applicable
	Portland, ME	290		175
	Fall River, MA	50		Not Applicable
	Quonset/Davisville, RI	40		Not Applicable

3.6 Staging Port Through-Put Estimates

This section examines the expected level of activity at a port serving as a staging area for offshore wind farm development. Multiple wind farm construction scenarios were considered in order to develop upper and lower bounds of expected port activity. For this analysis the primary metric of port activity is the number of wind turbines deployed per month, which is referred to as "through-put."

A desktop tool for estimating the construction time line for an offshore wind farm was applied. This time line tool considers numerous parameters representing vessel characteristics, climatology, at-sea construction capabilities, and other project considerations. Using this tool, the expected through-put of wind turbines at a staging port was estimated for a range of wind farm construction scenarios. Each scenario was defined by vessel type, transit distance, and the length of the construction season. The methodology and analysis are detailed below.

Table 3-15
Excerpt from Time Line Model Illustrating the Typical Work Breakdown Structure
(Source: The Glosten Associates 2009)

Cycle Start Time	**10/14/12 20:22**
Cycle #	1
Supply Chain Delay at Staging Area [hours]	0.0
Load Vessel [hours]	24.0
VESSEL LOADED	**3/25/13 18:21**
Vessel Transit to Wind Farm Site [hours]	25.0
Weather Availability for Jacking Up	86%
Jack Up [hours] (includes weahter delay)	9.3
Weather Availability for Installation	61%
Installation of Monopile/Turbines [hours] (includes weather delays)	88.5
Jack Down [hours] (includes weather delays)	4.6
INSTALLATION COMPLETE	**3/31/13 1:48**
Vessel Transit to Staging Area [hours]	25.0
VESSEL ARRIVES AT STAGING AREA	**4/1/13 2:48**
Turbines Installed (total)	3
Cycle Start Time	**4/1/13 2:48**
Cycle #	2
Supply Chain Delay at Staging Area [hours]	0.0
Load Vessel [hours]	24.0
VESSEL LOADED	**4/2/13 2:48**
Vessel Transit to Wind Farm Site [hours]	25.0
Weather Availability for Jacking Up	93%
Jack Up [hours] (includes weahter delay)	8.6
Weather Availability for Installation	72%
Installation of Monopile/Turbines [hours] (includes weather delays)	74.6
Jack Down [hours] (includes weather delays)	4.3
INSTALLATION COMPLETE	**4/6/13 19:16**
Vessel Transit to Staging Area [hours]	25.0
VESSEL ARRIVES AT STAGING AREA	**4/7/13 20:16**
Turbines Installed (total)	6

3.6.1 Methodology and Assumptions

The desktop time line model breaks down the overall wind farm construction process into discrete tasks, assigns a time requirement to each task, and builds a sequential time line for the principal activities. Some tasks have a limiting weather criterion, such as maximum wind speed for conducting crane operations. The time line model cross-references each weather-dependent task with site-specific monthly climatology data to determine whether that task is subject to weather delay.

The work breakdown model is illustrated by the excerpt presented in Table 3-15.

The following is a list of the assumptions that were used in the time line modeling:

1. Study considers turbine construction only. Foundation installation is accomplished independently and with different marine equipment.
2. One installation vessel is utilized at a time.
3. Foundation construction does not delay turbine installation.
4. Operations (and delays) at the staging area do not delay turbine construction. In other words, the turbine installation vessels (TIVs) do not "wait" for the staging area operations.
5. Staging area has 24-hour / 365-day operation.
6. Existing Vessels are capable of transporting 3 turbines.
7. Future Vessels are capable of transporting 5 turbines.
8. Installation vessels are capable of 6-10 knots transit speed.
9. Limiting wind speed for Existing Vessels is 15 knots.
10. Limiting wind speed for Future Vessels is 25 knots.
11. Limiting wave height for jack-up operations (all vessels) is 2.0 m.
12. For Existing Vessels, time to erect one turbine is 12 hours, once on-site and vessel is jacked-up (excluding weather delays).
13. For Future Vessels, time to erect one turbine is 8 hours, once on-site and jacked-up (excluding weather delays).
14. Wind and wave conditions based on U.S. East Coast from Delaware Bay to Cape Cod.

3.6.2 Analysis

The potential utilization of a single port for three different staging scenarios was modeled for this analysis. These scenarios, which all assumed New Bedford, MA as the staging port, were:

- Baseline - The Baseline scenario was defined as:
  - One offshore wind farm project staged out of New Bedford, MA, using Existing Vessel type.
  - Number of turbines: 130
  - Transit distance from staging area to wind farm site: 50 nautical miles

- Optimistic - The Optimistic scenario was defined as:
  - Two projects staged out of New Bedford, MA, using Existing Vessel type.

  - Projects are sequential in time (not concurrent).
  - Number of turbines for Project 1: 130
  - Number of turbines for Project 2: 100
  - Transit distance from staging area to wind farm for Project 1: 50 nm
  - Transit distance from staging area to wind farm for Project 2: 50 nm
- Aggressive - The Aggressive scenario was defined as:
  - Three projects staged out of New Bedford, MA, using combination of Existing and Future Vessel types.
  - Projects are sequential in time (not concurrent).
  - Projects 1 and 2 use conventional vessel type.
  - Project 3 uses future vessel type.
  - Number of turbines for Project 1: 130
  - Number of turbines for Project 2: 100
  - Number of turbines for Project 3: 200
  - Transit distance from staging area to wind farm for Project 1: 50 nm
  - Transit distance from staging area to wind farm for Project 2: 50 nm
  - Transit distance from staging area to wind farm for Project 3: 150 nm

These scenarios are based on development plans discussed during interviews with project developers in July and August of 2009.

3.6.3 Results

The results of the desk top time line modeling of these scenarios for New Bedford, MA were as follows:

- The time line modeling of the Baseline scenario for turbine staging and installation yielded an expected through-put of 15-18 turbines per month for 6-9 months.
- The time line modeling of the Optimistic scenario for turbine staging and installation yielded an expected through-put of 16-22 turbines per month for 12-15 months.
- The time line modeling of the Aggressive scenario for turbine staging and installation yielded an expected through-put of 15-20 turbines per month for 12-15 months; Thereafter, a through-put of 21-25 turbines per month was expected for an additional 8-10 months.

Additional wind farm construction scenarios were evaluated to develop a better estimate of the potential ranges of through-put that may be required at regional staging ports. Each scenario was defined by a vessel type, a transit distance and a length of the construction season. The results of these multiple modeling runs are summarized in Table 3-16.

Table 3-16
Expected Through-Put at Staging Port for Various Construction Scenarios
(Source: The Glosten Associates 2009)

Transit Distance (staging port to wind farm site*)	Existing Vessels**		'Future' Vessels***	
	Summer	Winter	Summer	Winter
50 nautical miles	20-22 turbines/month	16-18 turbines/month	30 turbines/month	30 turbines/month
150 nautical miles	18-20 turbines/month	15-17 turbines/month	21-25 turbines/month	21-25 turbines/month
250 nautical miles	15-17 turbines/month	12-15 turbines/month	16-20 turbines/month	16-20 turbines/month

Notes:
* The transit distance from New Bedford to the Cape Wind site is approximately 60 nm. The transit distance from Boston to Cape Wind is approximately 130 nm. The transit distance from New Bedford to the Deepwater sites near Delaware Bay is approximately 260 nm.
** Existing Vessels means jack-up vessels or barges with slewing cranes, typical of present European offshore wind farm construction practice.
*** Future Vessels means vessels or barges that transport and install fully assembled turbines.

It should be noted that the above through-put estimates are for turbine installation only. Foundation installation is typically completed in advance of turbine installation and can utilize a wider range of vessels and staging ports than turbine installation. For U.S. offshore wind farms, foundation installation can be completed using existing equipment.

3.6.4 Near-Term and Long-Term Demands on Staging Port Support Infrastructure

In the near term (i.e., now through year 2013), a port supporting offshore wind farm development is expected to handle approximately 18 to 22 turbines per month. This estimate assumes that projects are within 150 nautical miles (i.e., a transit distance) of the staging area and that construction operations will take place during spring, summer and fall using conventional methods (see Appendix A). Based on the above turbine through-put estimates, the near-term demand for support infrastructure at an offshore wind farm staging port is approximately as follows:

- 40-90 annual port calls (for cargo vessels delivering components);
- 70-90 annual port calls (for wind turbine installation vessel); and
- 54,500-81,700 mt (approximately 60,000-80,000 tons) of cargo loaded and discharged annually.

These near-term estimates assume:

- 18-22 turbines deployed per month for 12 months;
- cargo vessels deliver 3-5 turbines per port call;
- installation vessel loads 3 turbines per port call; and
- total turbine weight is 272 mt (approximately 300 tons).

Looking ahead to year 2014 and beyond, a port activity level as high as 30 turbines per month may be expected assuming an increase in vessel capabilities compared to the present technology. Based on the above turbine through-put estimates, the long-term demand for support infrastructure at an offshore wind farm staging port is approximately as follows:

- 90-120 annual port calls (for cargo vessels delivering components);
- 120 annual port calls (for wind turbine installation vessel); and
- 99,900-227,000 mt (approximately 110,000-250,000 tons) of cargo loaded and discharged annually.

These long-term estimates assume:

- 30 turbines deployed per month for 12 months;
- cargo vessels deliver 3-5 turbines per port call;
- installation vessel loads 3 turbines per port call; and
- total turbine weight is 272-635 mt (approximately 300-700 tons).

3.7 Staging Port Support Facility Requirements

One developer that was interviewed provided a description of the "ideal" port facility to support offshore wind. In their view, the port would have: a 910 mt (approximately 1,000 ton) crane on rolling tracks that would carry components from a delivery vessel to a storage location; enough linear water front footage or berthing to efficiently load/unload one vessel (with a preference for multiple deepwater berths to potentially unload several vessels concurrently); and about 80 hectares (approximately 200 acres) for assembly and storage.

While no existing Massachusetts port facility has an assembly and staging area this large, the existing Commonwealth facilities could be repaired, upgraded, or expanded to provide sufficient area to meet the other requirements for staging offshore wind farm construction. If it is necessary to provide a larger area at these existing facilities, then a combination of properties at these marine parks or a combination of ports would have the ability to provide additional space. If the berthing area is sufficient, moored barges also could be used for storage.

3.7.1 Physical Considerations Relative to Staging Turbines

There are a few minimum physical port characteristics that are necessary to stage offshore wind farm development. Based on a review of various European projects and available manufacturers, as well as discussions with potential U.S. offshore wind developers, the minimum desirable characteristics include:

1. 7.3 m (approximately 24 feet) depth of water at low tide;
2. minimum 137 m (approximately 450 feet) berth;
3. minimum channel clearance to harbor of 40 m (approximately 150 feet);
4. no restriction or air draft limitation on vertical clearance (in anticipation of a future need to transport fully assembled turbines to the installation site); and
5. relatively short distance in open water to project site.

3.7.1.1 Harborside Area

The harborside characteristics of a staging port facility present the most pertinent information to determine whether a port is worthy of consideration for wind farm construction staging. Water depth criteria directly dictate options with respect to the vessel type, draft and function. Tidal fluctuations change the water depth twice a day. Therefore, the minimum water depth at low tide is the appropriate characteristic to consider with respect to the navigation channel and berth.

The deepest draft vessel used for transporting offshore wind components sets the navigation depth criteria. Horizontal channel clearance not only depends on vessel beam, but also on component overhang during transport to the installation site. An unobstructed vertical clearance is highly recommended. Turbine manufacturers expect 60 m (approximately 197 feet) tall tower sections to be transported to the installation site in the upright position. If the turbines are fully assembled for transport, then the nacelle and blade would add significantly to this height. Furthermore, various installation tasks require jack-up vessels, the retracted legs of which would be in the 'up' position. The Philadelphia Regional Port Authority has submitted a Transportation Investment Generating Economic Recovery (TIGER) application to build a purpose-built wind turbine installation vessel; the jack-up legs are 75 m (approximately 246 feet) long. However, there may be methods for working around vertical obstructions, such as placing a connector pin in the legs or utilizing a hydraulic leg that compresses within itself. The salient point, however, is that vertical obstructions can limit the range of acceptable assembly, transport, and vessel options.

With visits from import vessels and transport or installation vessels overlapping, multiple berths or longer berths become more desirable. The required length of berthing at a staging port is linked to the size of the project and the delivery schedule for its components. If the project is "fast track", the actual amount of material at the staging site might be small in comparison to what is there for a "normal" project. The material would arrive as soon as complete, rather than being stored at the manufacturer's facility, and would be shipped in the most cost-efficient manner in a vessel filled to capacity. The larger berth would also allow for delivery vessels to operate concurrently with the jack-up or other purpose vessels at the dock.

3.7.1.2 Landside or Lay Down Area

The landside or lay down area required for a project is also tied to the project size. More turbine units will require more space. One of the ways that a lack of space at a given site has been addressed in the past is to use alternate sites for different functions. The needs of the foundation contractor may be different from those of the turbine assembly contractor. One approach would be to stage these two functions from different sites. Although the port criteria for turbine assembly may be slightly different from those for foundation assembly, since there is some overlap in the type of vessels used for these different functions, in general, the same or similar staging criteria can be applied to both.

The interviews with developers indicated that the lay down area is seen as one of the most important logistical elements for a staging port facility. It is crucial to have sufficient space to efficiently store and assemble turbine or foundation components. The developers that were interviewed provided the information contained in Table 3-17 regarding indoor/outdoor storage requirements:

Table 3-17
Indoor/Outdoor Storage Requirements
(Source: Developer interviews)

Landside Requirements / Staging Area	4 to 10 hectares (approximately 10 to 25 acres) (Bluewater, Cape Wind)
Quayside Area	150 to 300 m (approximately 500 ft to 1,000 ft) (Cape Wind)
Inside Storage Area	Approximately 465 m^2 (5,000 sq. ft.) (Cape Wind) to up to 929 m^2 (10,000 sq. ft.) (Bluewater Wind with regard to European Experience)
Accommodation Area (e.g., for offices and dormitories for workers)	Approximately 1,400 m^2 (15,000 sq. ft.) (Deepwater)

3.7.1.3 Onshore Construction Area

Developer needs for onshore construction include space for delivery, storage and assembly of turbine components. The estimates obtained for the amount of onshore construction area needed varied widely among the developers, manufacturers and representatives of European staging facilities, but a minimum of 4 hectares (approximately 10 acres) was indicated to be required with 6 to 10 hectares (approximately 15 to 25 acres) of available space being more desirable. If a large development (e.g., 110 turbines) were to be fully accommodated on land, including both assembly and foundation components, the area required would be about 80 hectares (roughly 200 acres). However, the logistics of manufacture, assembly and installation would never require all units to be co-located on the ground at one time.

To maximize the use of construction equipment, vessels and crews, turbine suppliers require storage based on two factors: (1) having a supply of turbine components ready for assembly and deployment; and (2) having an additional area ready for instances where weather precludes deployment to the installation site while import vessels continue to deliver components to the staging port. While turbine assembly continues, the newly arrived unassembled turbine components would need to be stored. Based on manufacturer's recommendations, and assuming storage of 20 or more turbines, the minimum space needed in this scenario is about 3.4 hectares (approximately 8.5 acres). One of the foundation manufacturers suggested that lay down (not manufacturing) might require 1.5 to 2.0 hectares (approximately 4 to 5 acres). Another manufacturer suggested that each turbine (and its components, except foundation) would require about 6,500 sf, which would require an additional 1.2 hectares (approximately 3 acres). The pre-assembly area based on one manufacturer's recommendation would be 200 m x 50 m or 1.0 hectare (or 650' x 165' or 2.5 acres). This suggests that, without foundations, the minimum space needed is about 8.5 acres. Additional area (possibly 0.4 to 3.2 hectares [1 to 8 acres]) would also be needed for parking, field trailers, traffic lanes, and other support functions.

If a through-put of 18 to 22 turbines per month would be deployed to the installation site (based on the results of the time line modeling discussed above), the turbine manufacturer would want 20 nacelles stored at the staging port in advance of assembly and deployment. As workers assemble the turbines in preparation for loading onto the installation vessel, and bad weather hits the installation site, the assembled turbines would have to be stored at the port.

Unassembled turbine components would continue to arrive from the manufacturer and require additional storage space for 20 more turbines.

The preferences for features outlined below for the onshore construction area are based on an offshore wind farm consisting of 30 to 60 turbines and describe a port staging area for wind turbines only. The following information was drawn from one manufacturer's specifications (Vestas Offshore A/S 2008). There may be engineering solutions that could provide alternative arrangements to meet the parameters discussed below.

General

Total onshore area	4.5 to 7 hectares (10 to 17 acres)
Variation factors	Shape of area, Number of turbines, Delivery sequence of turbines
Pier length	Minimum 150 m (495'), preferably 200 m 650') or more
Water depth at pier	Minimum 6.0 m (20')
Assembly area	Pier Length and 40 m (130') behind pier

Details

Electrical

Electrical power supply should be 3 x 400 volts alternating current (V AC) (60 hertz [Hz]) and at least 200 amp capacity. Major power consumers would be offices, welding and machining, and air compressors. It is preferred that the entire site be fully illuminated to facilitate safe night work.

Area Details

Assembly Area	0.5 – 1.0 hectares (1.5-2.5 acres)		
Storage Area	3.5 – 5.0 hectares (9-12.5 acres)	400 m^2 (4,300 ft^2) sheltered with a minimum clear height of 3.5 m (12 ft)	100 m^2 (1,100 ft^2) secured and dry
Access, Office, Parking	0.5 – 1.0 hectares (1.5-2.5 acres)	About 200 m^2 (2,200 ft^2) office and social area.	For minimum 20 persons
Total Site Area	4.5 – 7.0 hectares (11-17.5 acres)		

The area should be enclosed by fencing with a guard or some type of security system. Water supply for fire fighting and general consumption should be available, as well as a wastewater system. A suitable drainage system should be installed that meets all regulatory requirements for stormwater discharge effluent limits.

Onshore Handling Equipment

The following equipment most likely would be necessary for offloading, assembling, and deploying offshore wind turbines:

1	Large crawler crane (DEMAG CC2800 or similar with 78 m boom length), approximately 2,500 tm as 250 mt at 10 m radius
1	Medium crawler crane (Liebherr LR1400 or similar with 42 m boom length), 600 to 800 tm capacity
1	Truck mounted crane, 150 tm capacity
1	Cherry picker (telescopic personnel lift for min 2 persons)
1	Forklift (3 mt (3.5 ton) capacity)
1	Terrain moving telescopic forklift (3 mt (3.5 ton) capacity)
1	Terrain moving telescopic forklift with turntable (3 mt (3.5 ton) capacity)
1	Terrain moving transport vehicle (2-3 persons and minor parts and equipment)
1	Triple axel trailer (suitable for blade transport) moveable with crane truck or similar
1	Self propelled low loader (suitable for tower transport, 150 – 200 mt (165-220 ton) capacity)

3.7.1.4 Inside Storage / Assembly Space

Some interior storage and/or fabrication space is required for most projects. Developers, contractors and manufacturers also have a strong preference for onsite office space. Again, estimates of this requirement varied significantly among those interviewed. While some suggested 464 m^2 (approximately 5,000 square feet) would be adequate for interior storage, assembly and office space, a minimum of 930 m^2 (approximately 10,000 square feet) with appropriate access characteristics was the consensus. Facilities for worker accommodations at the staging location or on a 'hotel' ship at the installation site have been used for some offshore wind farm constructions overseas. One developer suggested an accommodation area of 1,400 m^2 (approximately 15,000 square feet) for office space and worker dormitories. The amount of available inside storage or assembly space did not emerge as a major factor in staging facility selection decisions. None of the Massachusetts Designated Port Areas (DPAs) has such a convenient facility. At this stage of planning, most of the developers had given little thought to such needs. Nevertheless, the DPAs in Massachusetts do have nearby accommodations. Construction workers at the offshore installation site would expect to work in shifts for a 24-hour operation. Crews can travel back and forth on fast transport vessels from the construction site to various points on land, thereby eliminating the need for on-site accommodations (Vestas 2008).

3.7.1.5 Load Capacity

Based on the weight of many of the components, the lay down space may require very high capacity ground or deck. Using a simple "footprint" analysis, these loads can reach over 9.8 mt/m^2 (approximately 2,000 psf). As with many of the facility needs, the deck/ground capacity issue can be accommodated by using certain types of equipment or by placing "load spreading" mats or slabs. Various cranes and other types of material handling equipment will be needed, but it is anticipated that the fabrication or erection contractor would provide these items.

The need for high ground or deck capacity suggests that perhaps a solid fill backland is more appropriate than an open pier type structure, which provides an opportunity for the contractor to establish high load zones as necessary in its lay down configuration. Open pier structures require high capacity piles relatively closely spaced. Historically general cargo and container terminal wharves and piers have load capacities of approximately 2.9 metric tons/m^2

(approximately 600 psf, with the exception being 4.9 mt/m^2 (approximately 1,000 psf) at some terminals. From a cost standpoint, this is often impractical for pile supported structures. Solid fill structures, once out of the active earth zone, can easily have 9.8 metric tons/m^2 (approximately 2,000 psf) load capacity. Load capacity was not used as a criterion to short-list the ports, but rather was a consideration that was further analyzed in the engineering review of the short-listed facilities.

3.7.2 Physical Considerations Relative to Staging Foundations

Some of the harborside restrictions set out for turbine transport may not apply to foundations, because foundations are less delicate and can be transported flat on barges. Barge transport of foundations would not entail the same height, draft or clearance requirements as turbine transport. However the foundation installation vessel may have similar characteristics as the turbine installation vessel. If the foundation installation jack-up vessel was at the construction site and barges were used to transport foundations to the site, then there would be more options for the staging facility. Facilities that are not suitable to stage turbine construction/installation because they are upstream of a bridge with a 41 m (approximately 135') clearance height or require 7.3 m (24') draft or other restrictions could possibly stage foundation deployment.

The review of the currently planned projects indicated that roughly 744 or more turbines would be deployed off the Northeast Coast of the United States (Delaware to Massachusetts). The planned projects examined would create a combined need for 544 monopile foundations and 200 jacket foundations. Monopile foundations are basically large diameter rolled steel piles. Monopiles are comprised of rolled steel plate (3.8 to 12.7 cm (1.5 to 5 inches) thick) components between 2.1 and 5.5 m (approximately 7 feet and 18 feet) in diameter, and often fabricated in 4.5 to 4.6 m (15' to 16') long sections. Jacket foundations are lattices of steel members. Both types of foundations require a transition piece which is also a rolled steel pipe section, with additional add-ons such as electric cable tubes, climbing ladders, platforms and docking areas. Tower sections are also rolled steel. These tend to be supplied by the turbine manufacturers along with the other turbine components.

The staging requirements for foundations depend upon the stage of assembly as they arrive and the size and type of foundation. The size of the foundation depends on the size of the assembled turbine with tower, transition and blades and the maximum wind load imposed on them, as well as the geotechnical conditions at the installation site. The staging facility will need landside areas for loading and unloading, storage, and potentially for assembly of foundations components

Partially assembled foundations would still likely arrive at a Massachusetts facility by vessel. Steel sections for jacket assembly might come from the Gulf of Mexico or overseas. Shipping the steel sections allows for maximizing cargo space and minimizes shipping costs relative to transporting a fully assembled jacket foundation. A factor in selecting a shipping method is the difference between the shipping cost and the labor cost of field welding the bars together. The selection also may depend on the availability of a skilled labor force of welders at the assembly location.

3.7.2.1 Manufacturing and Assembly Requirements

Monopile manufacturing utilizes a series of specialized machines. Modern versions of this equipment are not currently available on the East Coast of the United States. The industry views the potential market as lucrative enough to consider opening facilities in anticipation of offshore wind energy development. However, the investment risk remains similar to that felt by turbine manufacturers and the purpose-built vessel industry. Until a demand for product emerges sufficient to project a profitable return on investment, monopiles for East Coast offshore wind farms will probably come from elsewhere. The difference here is that a piecemeal approach can reduce the initial investment risk. Initial wind farm construction will probably see monopile pieces shipped to a staging facility as ‘cans’, or basically smaller sections of rolled steel. At the staging location the ‘cans’ would be welded together to form the pile sections appropriate for the installation.

One European steel fabrication firm expects that a functional facility would need roughly 16,900 m^2 (approximately 182,000 ft^2) of production floor. The facility would require high capacity floors and fabrication cranes with 136-182 mt (150 - 200 ton) capacity, rail access, and water access. Like the foundation assembly facility, the required water depth for a foundation staging facility would likely be less than is required for a turbine staging facility.

3.7.2.2 Storage Requirements

The storage requirements for foundations are more flexible than the turbines since they are less sensitive structures. The foundation elements will be exposed to the harsh marine environment during their life, and are designed to be exposed to these harsh conditions. If there is a backlog of deployment causing foundation storage to overlap significantly with turbine component storage, then the required storage area could increase by 2 to 4 hectares (approximately 5 to 10 acres). Potentially, barges also could provide additional storage in a sheltered bay or harbor area.

3.8 Rail and Road Access

Issues of port access for the large offshore wind generation components being delivered via rail and highway are unique for each port. There is the potential for delivery of components from domestic North American suppliers, such as those located in the State of Colorado. Height, width, curve radius, and weight limitations associated with rail or roadways are potential constraints. Turbine pieces could potentially be transported by component or sections (including tower sections, wind blades, and nacelles). Turbine sections and wind blades would be transported horizontally and nacelles vertically on transport units, at least for current wind turbines being deployed. This will become less viable as the larger, next generation offshore wind turbines become available.

Shipment specifications (dimensions and weights) for typical offshore nacelle components are presented in Table 3-18.

Table 3-18
Dimensions and Weights of Turbine Components
Technical Data for Vestas V112-3.0 MW
(Source: Vestas 2009a)

Turbine Component	Dimensions			
	Weight	Length	Height	Width/Diameter
Monopile Foundation	150 to 210 mt (165 to 231 ton) for 28 to 40 m (92' to 132') long monopile 500 mt (551 ton) for 60 m (200') long monopile	Varying 28 - 40 m (92' to 131') up to 60 m (197')	N/A	d: 5 m to 5.5 m (16.75' to 18')
Transition Piece	170 mt (187 ton)	17 m (56') per unit	N/A	d: 4.2 m (13.8')
Nacelle (including hub)	125 - 150 mt (138 to 165 ton)	14 m (46')	3.3 m (10.8')	w: 3.9 m (12.8')
One Blade	12.5 to 18 mt (13.77 to <20 ton)	54.6 m (179')	N/A	Max. w: 4.2 m (13.8')
Tower Section	Approximately 70 mt (77.16 ton)	32.5 m (106.6')	N/A	d: 4.2 m to 4.5 m (13.7' to 14.76')

N/A = Not applicable

3.8.1 Overview of Rail

In general, the weight and length proposed for the units (excluding blades) can be handled by rail in the nationwide system depending on how finite certain components can be broken down. There are various routes throughout the United States that can be employed for shipments of oversized shipments. Main line route movement is easier to address than final delivery by rail to the various ports. In Massachusetts, delivery to central distribution points would include Beacon Park Yard in Allston (which is operated by CSX) or Ayer (which is operated by Pan Am Railways in conjunction with Norfolk Southern). From this point, equipment would travel on secondary routes to each of the port areas. There are differences in right of ways, bridge clearances and secondary access corridors for rail lines throughout the United States and in the region. It can be assumed that if the rail link between the manufacturer and a main line rail corridor can handle the equipment that the main line corridor can move the equipment anywhere in the country. For the most part, if there are any unique choke points, there are sufficient other corridors available to handle the move. All of the ports in Massachusetts have rail access. However, direct waterfront access varies by area.

The ability to move component parts via rail is determined by rail corridor track curvatures, component weights, and loaded height on the rail car.

Curvature: The lines to port facilities vary in terms of curvature, so specific routing and the need for single overhang vs. double overhang vs. bolster load loadings must be considered to address any length issues associated with the specific equipment being shipped. Overhang is simply the extension beyond the limits of the rail car either at one end or both. The overhang depends upon the length of the item carried and where the center of gravity is for the load.

Weight: In general, a weight of 81.7 mt (90 tons) can be loaded onto a standard rail car. Heavier loads would require either special equipment that is available in various configurations (including a bolster load and are able to carry up to about 363 mt (400 tons)). The bolster is the part of a railroad car body underneath that connects the truck's pivot to the body (see

Figure 3-21). The bolster also includes and refers to the cross members which provide the frame for the rail trucks which is the piece between the side frames. The bolster load is the maximum weight that the bolster frame and truck assembly can support. Boston and New Bedford's rail network would support standardized loads up to the limits indicated for the rail system. New Bedford track conditions are, in general, not as good as in Boston.

Figure 3-21 Rail Trucks
(Source: MARPRO Associates International 2009)

Height: Heights limitations are very route specific. Overall first generation clearances for container doublestack cargo movement are 5.8 m (19 feet) "above the rail" (ATR). Second generation clearances are approximately 6.8 m (22' 6") ATR. In most cases, Massachusetts rail lines to ports average 5.2 m (17 feet) ATR.

In general, components can be designed to be transported on the national rail system (see Figure 3-22). They can be broken down to insure they do not exceed rail system limitations on weight or clearance. It can be clearly seen in Figure 3-22 that component heights, when loaded on rail equipment, generally average a similar height to standard rail box cars.

Figure 3-22 Broken Down Wind Components on Rail Cars
(Source: MARPRO Associates International 2009)

3.8.2 Overview of Road Transport Requirements

Overweight and large shipment units are limited to State permitting requirements. These requirements allow an excess of 1,240 kg (88,000 pounds) only on roadways either specially designated for such shipments or with the use of specialized equipment such as tri-axle trailers. Shipments are generally limited to a maximum of 1,410 kg (100,000 pounds) and are often only permitted during certain time periods (such as off-peak or overnight periods). Infrastructure is also considered in permitting applications including limitations from overhead utilities, road lighting, road curvatures and intersections.

3.9 Implications of Distance

Developers identified cost as a critical consideration. Under the precept of “time equals money”, schedule generally has a strong impact on project cost. The distance between a staging port and the installation site affects costs both in terms of fuel schedule. Distance also has an effect on controlling the risk of damage or loss during transport. When expensive turbine components are in transit from the staging port to the installation site they are more vulnerable to ocean and weather effects and motion accidents than when they are being managed from a vessel stabilized by jack-up legs. The proximity of the staging port to the installation site, therefore, is a factor in reducing risks and costs and risk.

In terms of component delivery to the staging port, distance also is an important factor, but not typically an overriding factor for the project. Required components and raw materials for a project may come from Europe, Colorado, or Brazil. One manufacturer that was interviewed advised that industry on the Gulf Coast is already set up to manufacture the steel pieces needed for jacket piles. This manufacturer expects to barge the fabricated pieces to a location closer to the installation site for assembly. He believes that manufacturing and shipping is more cost-effective than setting up a manufacturing facility in the region. However, at the same time, the manufacturer wants an assembly location relatively close to the fabrication site so that he does not have to “ship air” (i.e., the spaces between the framework members).

4.0 EVALUATION CRITERIA

The information presented earlier in this report was developed to identify a broad set of direct requirements and highly desirable characteristics of port facilities relative to supporting offshore wind farm construction and operation. In this section, the broad list of considerations is analyzed and further distilled down to a smaller set of criteria that can be used to effectively and adequately differentiate the identified Massachusetts port facilities from each other based on their potential to support offshore wind energy development.

4.1 Summary of Requirements and Desirable Characteristics

Previous sections of this report have discussed the multiple roles a port plays in staging the construction and maintaining the operation of an offshore wind farm. Particular features and characteristics of the port either enhance the port's ability to perform these roles or represent obstacles to providing those services and supporting those functions. The direct requirements and highly desirable characteristics of port facilities were identified through interviews with developers and wind turbine manufactures and then compiled and evaluated. To facilitate review, these requirements and characteristics were grouped into five general categories:

- Aspects associated with the wharf and yard portions of the port;
- Aspects associated with the berthing facilities of the port;
- Aspects associated with navigation into and out of the port;
- Aspects associated with the geographic location of the port relative to potential projects; and
- Aspects and characteristics of the region in the vicinity of the port.

Table 4-1 lists these grouped requirements and characteristics.

Table 4-1
Groupings of Port Characteristics

Aspects of the Port	Requirement or Characteristic
Wharf and Yard	• Has available inside storage capacity • Has sufficient lay down area for required storage and assembly • Would be able to expand the scale of operations • Has adequate rail or road access • Has previously staged offshore projects or development • Has ready access for and experience with large tugs and support vessels
Berthing Facilities	• Has sufficient berth (length and depth) • Already has large cranes of sufficient size and type • Has piers with high load carrying capacities • Has capacity to handle hundreds of additional port calls/year
Navigation	• Has operations 24 hours/day and 365 days/year • Is in a sheltered harbor • Has no restrictive lateral clearance constraints • Has no restrictive air draft constraints • Has sufficient draft at low tide • Has a short route to open water

Table 4-1
Groupings of Port Characteristics (continued)

Aspects of the Port	Requirement or Characteristic
Geographic Location	• Is located proximate to related marine infrastructure and equipment • Is as close as possible to component manufacturers • Is not subject to excessive extreme weather that can adversely affect operations • Is as close as possible to proposed project sites (including MA OMP Wind Energy Areas)
Region in the Vicinity of the Port	• Has accommodations for workers and visitors • Has, or can quickly develop, a trained work force • Has access to a sufficient workforce • Development is welcomed by the community • Development is welcomed by regulators • Development will contribute to economic growth

First, it should be noted that not all of these collected requirements and characteristics were identified to be equally as critical to a port's ability to successfully support offshore wind farm development. Some are "must have" physical requirements, while others represent desirable characteristics that potentially could be worked around provided other features are present and compensate for their absence. Second, a few of the listed characteristics are complementary and linked. For example, ports with ready access to large tugs and support vessels would almost certainly be located proximate to other related marine infrastructure and equipment. As such, the presence of one generally ensures the presence of the other. Third, some characteristics would be shared by any larger port or any port in the Eastern U.S. For example, all port locations in the region have accessible accommodations for workers and visitors and have access to a sufficient work force. Therefore, these characteristics would not enable one to meaningfully discriminate between the ports being comparatively evaluated.

In consideration of these factors, the requirements and characteristics were distilled down into a smaller set of critical criteria appropriate for the comparative evaluation of the ports. The distillation process was conducted so that all of the considerations that were identified as critical or important were preserved as "hard" requirements, as distinguished from softer trade-off characteristics. The criteria that were developed are presented in the next section.

4.2 Criteria Development

Upon further consideration of the requirements and characteristics identified above, two sets of "hard" requirements were identified for comparing the ports: (1) those related to harbor access (referred to as the 1st Tier Criteria) and (2) those related to the port facilities' attributes needed to meet specific developer and turbine supplier needs (referred to as the 2nd Tier Criteria). In addition, a set of "soft" criteria was developed that is somewhat more subjective but nevertheless allows ports to be distinguished from one another relative to supporting offshore wind farm development. Soft criteria attributes may attract developers to consider one port over another, and the absence of these criteria is likely to have financial consequences to port projects.

4.2.1 1st Tier Hard Criteria Relating to Harbor Access

The 1st Tier Hard Criteria identified relative to harbor access were:

- Sheltered harbor (protected from bad weather by means of a barrier);
- Unobstructed vertical (overhead) clearance;
- Minimum horizontal clearance greater than 40 m (approximately 150 feet);
- Minimum low tide navigational channel depth of 7.3 m (24 feet);
- 24/ hour/day and 7 days/week operational availability; and
- Exclusive use of the staging facility.

Ensuring port access as dictated by developer and turbine supplier needs is essential. Hard criteria related to the logistics of the origin of the turbine components and their method of delivery to the staging port and the installation (construction) site are crucial. Possible delivery modes include seafaring vessels, rail, and trucking (see Section 3). Physical parameters for marine vessels to access a harbor emerge as critical criteria, while rail and trucking access were believed to be present or more easily attainable at the set of ports being compared. Staging ports need to accommodate vessels shipping and handling the large components used for commercial scale wind farms. The greatest vessel draft (depth) establishes the criteria for the shipping or navigation channel depth. The widest vessel beam (width) along with the method of component transport, which may involve overhang, establishes horizontal clearances. Along with vessel height, the options for method of transport also contribute to vertical clearance criteria. The potential for bad weather interruptions and the need to maximize labor and equipment availability makes a sheltered harbor an essential criterion, especially for the barges that are adapted as near-term delivery and installation vessels.

Implications of the cost of contractor mobilization, vessel and equipment utilization combined with weather and seasonal limitations on the construction window result in developers and turbine suppliers requiring a port facility that allows operations 24 hours a day, seven days a week. Given that optimal operations would entail moving large components around the clock, the staging port must also provide exclusive use of the staging facility.

A systematic evaluation of these 1st tier hard criteria will address the navigational considerations identified in Table 4-1.

4.2.2 2nd Tier Hard Criteria Relating to Port Facilities

The 2nd Tier Hard Criteria identified relative to the port facilities were:

- Minimum berth length of 138 m (approximately 450 feet);
- Minimum berth water depth of 7.3 m (24 feet);
- Lay down storage and assembly backland area larger than 4 hectares (10 acres); and
- Proximity to likely offshore wind farm site.

These 2nd tier criteria establish port facility attributes that would accommodate industry vessels. Primarily, these 2nd tier hard criteria must include the water depth at and overall length of the facility berth. Water depth must be sufficient to accommodate industry vessel drafts or must be attainable through routine dredging. Additionally, vessel length and the number of vessels operating simultaneously establish the parameters needed for length of the berth.

The size of the backland area landside of the bulkhead for storage and assembly of the turbine components and the ability to handle the loads of components and construction equipment are significant criteria. The requirements of foundation storage and assembly can increase the area requirements, but foundations do not necessarily need to be staged from the same port or have the same delivery vessel-related restrictions. Port proximity to the construction site can affect operational logistics, risks, and significantly costs. The distance from a port facility to potential wind farm sites, therefore, has significance but becomes secondary to the parameters discussed above. If a maximum distance is established to screen ports, it may follow, however, that closer ports have limitations that could have a persuasive effect on logistics, risks, or costs, thereby making more distant ports the more viable option. This has recently been true for the U.K. where deployment operations have been staged out of Denmark in some cases.

A systematic evaluation of these 2nd tier hard criteria will address the wharf and yard and berthing facility considerations identified in Table 4-1.

4.2.3 Soft Criteria

Soft criteria parameters, as noted above, are other port area attributes that may attract developers to consider one port over another. The Soft Criteria identified were:

- Workforce availability;
- Education and training facilities;
- Political climate/community acceptance; and
- Regulatory considerations.

The location of education or training facilities and work force availability, including various skilled labor trades, could be an important factor in port selection. Soft criteria are discussed in more detail in Section 6.4. European offshore wind developers have reported shortages among skilled workers in related trades. Massachusetts ports have ready access to considerable education and training resources that are geared to offshore and underwater construction, seamanship, and technical trades and services. Taking into consideration the nine-plus years' approval process of the Cape Wind project, which was greatly affected by opposition to the project, political climate and community acceptance of a large scale industrial operation to support potentially controversial projects also must be evaluated.

A systematic evaluation of these soft criteria will address the aspects of the region in the vicinity of the port identified in Table 4-1.

4.2.4 Screening and Short-Listing the Ports

The set of ports considered in this study were analyzed using these criteria. Those ports that did not meet minimum thresholds were eliminated from further consideration by the Team. Section 5 provides an overview of Massachusetts ports that could support staging and installation of offshore wind farms, as well as other regional ports that could meet the assembly, construction, and/or servicing needs of the offshore wind industry.

Section 6 describes the process that resulted in the two short-listed ports - the potential South Terminal area in the Port of New Bedford Renewable Energy Marine Park and the existing Dry Dock #4 in the Port of Boston Marine Industrial Park.

5.0 INVENTORY OF PORTS

The following sections provide an overview and general description of Massachusetts ports, as well as regional ports that could support offshore wind development activities. This section also provides an overview of the capability of East Coast and Gulf Coast shipyards to construct new vessels, modify existing vessels, provide support vessels, and provide repair services.

5.1 Profiles of Port Facilities in Massachusetts

The Commonwealth of Massachusetts has a varied mix of marine activities in its five key port areas, with connections to both international and domestic markets. Primarily, these ports serve as transition points where cargo moves to and from marine modes including ship and barge to land-based modes, in particular truck or rail. Appendices F and G provide more detail on these ports and modes of transportation.

Massachusetts has a number of ports that, because of their existing or proposed marine terminals, geographic location, proximity to regional commercial activity, and access to land-based transport to more distant inland markets, already have substantial marine activity including a wide range of freight activity. The Commonwealth has one major tonnage and diversified seaport and five smaller niche ports that operate within the marine network. The major Commonwealth seaport is Boston, and the five niche ports include Gloucester, Salem, the Fore River Shipyard, Fall River, and New Bedford. From north to south, profiles of these Massachusetts ports and their potential for expanded marine industrial activity are presented below.

5.1.1 Gloucester, Massachusetts

<u>Background</u>

The Port of Gloucester is located on Cape Ann and is approximately 22.6 nm (26 miles) north of Boston. Cape Ann is located adjacent to the main shipping routes between Southern and Northern New England. The port is historically known for its fishing industry. See Appendix E for the extent of the Gloucester Designated Port Area (DPA).

Gloucester still has a large fishing industry and the potential to develop an all water ferry connection to the Province of Nova Scotia in Canada. The port has some land area available to develop a new marine facility for commercial activities. It has a readily available skilled work force and diverse marine service sector. It also has a rail line that would provide access to the national rail system, and the Route 128 corridor provides excellent highway connections to the New England highway network.

<u>Facilities</u>

The primary marine industrial facilities in the port are within the Industrial Port (see Figure 5-1). The principal businesses are fishing, fish processing, recreational boating, marine repair and supply, and a fledgling cruise ship business. The Industrial Port has become the city's primary marine industrial area with 98% of the land and pile-supported area within this district dedicated to industrial and accessory-to-industrial uses. It has recently experienced several significant changes, including the opening of the Gloucester Seafood Display Auction, modernization of Americold's and Gorton's waterfront infrastructure, and significant expansion of facilities on the

State Fish Pier. Most recently, the development of the Gloucester Marine Terminal at Rowe Square offers important new opportunities for the port (Garcia et al. 2009). The Gloucester Marine Terminal, the cruise ship facility, is accessed via the North Channel of Gloucester Inner Harbor and can accommodate vessels up to 152.4 m (500 feet) in length and drawing up to 5.5 m (18 feet). The facility is owned by the City of Gloucester and is limited to tourism activities. Larger vessels up to 244 m (800 feet) in length and drawing up to 7.9 m (26 feet) can be accommodated inside the breakwater at Gloucester Harbor.

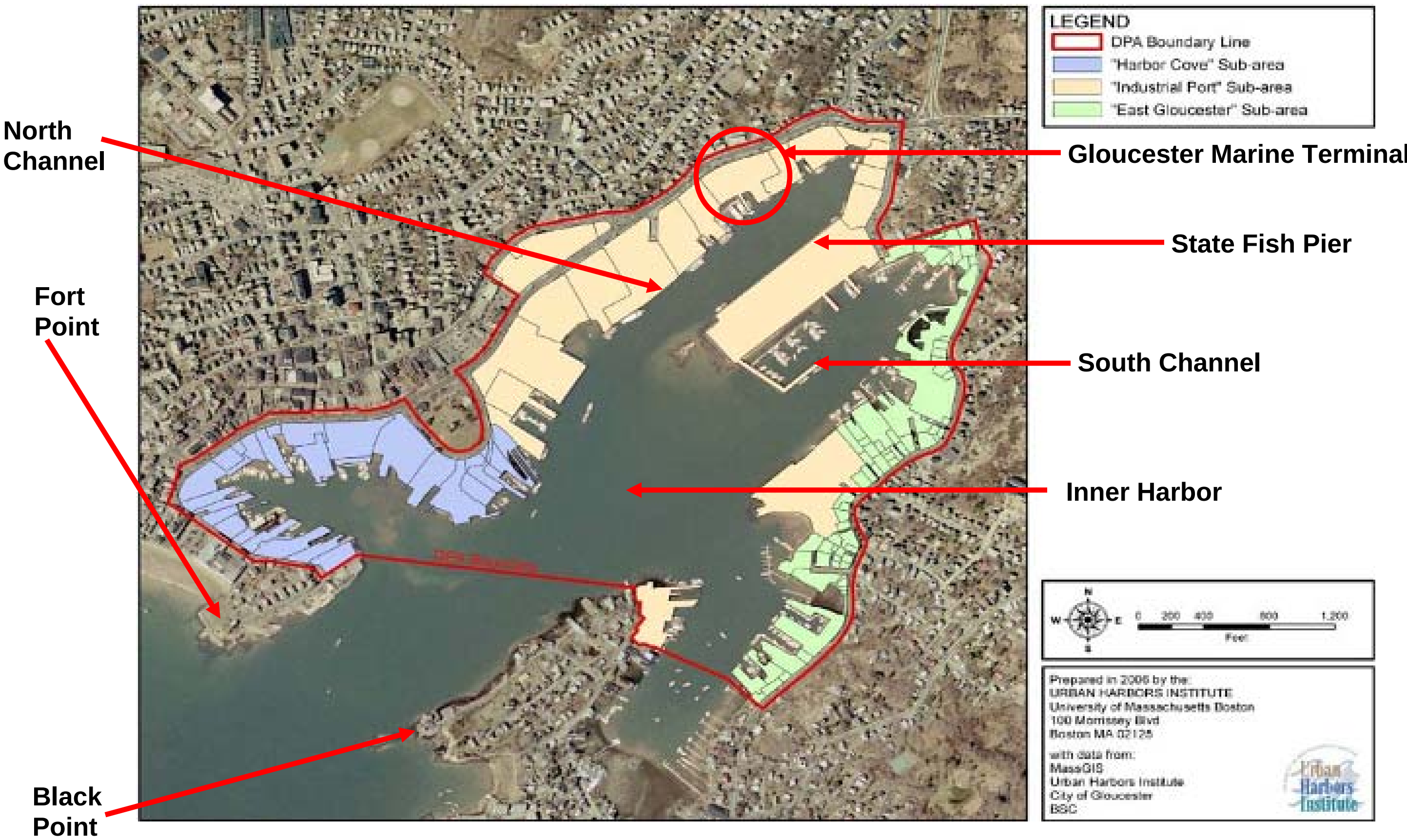


Figure 5-1 Layout of the Inner Harbor at the Port of Gloucester
(Source: City of Gloucester Harbor Plan and Designated Port Area Master Plan 2009)

The largest facility is the State Pier, which is dedicated to fishing activities. The 3.1 hectares (7.8 acre) facility has a 410 m^2 (approximately 4,400 sf) wharf with 425 m (approximately 1,400 feet) of berthing with depths of between 5.2 and 6.1 m (17 and 20 feet) at mean low water (MLW). A dredged channel of 6.1 m (20 feet) at MLW provides access to the pier.

There are several buildings that support the fishing industry onsite, and a number of businesses that support marine activities, including several small boat marinas. There are also a number of repair yards and associated businesses. There is little capability at existing facilities for ROWEI staging.

Harbor Profile

Gloucester Harbor is a well protected harbor with an easily navigable entrance and broad inner harbor located on the south shore of Cape Ann. The entrance to the port is close to the pilot station located in Massachusetts Bay.

The outer harbor has a protective breakwater that extends from the east side of the harbor entrance at Easter Point. Primary access is on the western side of the harbor entrance. The harbor becomes progressively shallower from about 5.5 to 15.8 m (18 to 52 feet) outside the entrance to 7.6 to 9.1 m (25 to 30 feet) within the harbor to less than 4.5 to 7.3 m (15 to 24 feet) in the inner reaches. The channel entrance is approximately 365 m (approximately 1,200 feet) wide with depths of 11.6 to 14.3 m (38 to 47 feet) into the outer harbor.

Tidal range is about 2.65 m (approximately 8.7 feet) average, and currents within the harbor are nominal. Parts of the harbor entrance are difficult to traverse due to breaking waves in severe weather and a number of shoals and submerged obstacles. There is a dredged anchorage for vessels with up to 4.9 m (16 feet) of draft about 275 m (approximately 900 feet) southwest of the State Fish Pier.

The inner harbor is defined by a line between Fort Point and Black Point. The approaches to the inner harbor have water depths ranging from 6.7 to over 12.2 m (22 feet to over 40 feet). Water depths range from 4.72 to 5.8 m (15.5 to 19 feet) in the inner harbor. The lateral clearance is approximately 61 to 76 m (approximately 200 to 250 feet). Gloucester harbor has inner areas known as the Western Harbor (which is closest to the town center) and Southeast Harbor (which is closest to the entrance) (see Figure 5-2). Shoreline areas in the Western Harbor and Southeast Harbor have very shallow water depths. There are shallow channel (6.1 m (20 feet) at MLW) accesses to the State Fish Pier, Gloucester Marine Terminal and East Gloucester.

Advantages

The port is well sheltered and has support mechanisms in place for commercial and industrial activities. No overhead clearance constraints were identified in the approaches to the Port of Gloucester. The port has both rail and highway access which supports the traffic associated with the fish processing industry. There is a waterfront commercial roadway connecting to Route 128.

Disadvantages

Water depth and lateral clearance are the most significant constraints for the inner harbor at the Port of Gloucester (see Figure 5-2). The harbor entrance is narrow and deep, but becomes shallow quickly. There is little deep water access to shore areas for large vessels, but access is suitable for barges Turbine installation vessels should be able to navigate the Port of Gloucester, but turbine import vessels most likely would not be able to call at this port. The lateral clearance limits turbine load-outs in the fore-aft bunny ear configuration. The immediate area in and around the shoreline is congested and has mixed traffic flow. Although there is rail service to the City, it is limited at this time to commuter rail.

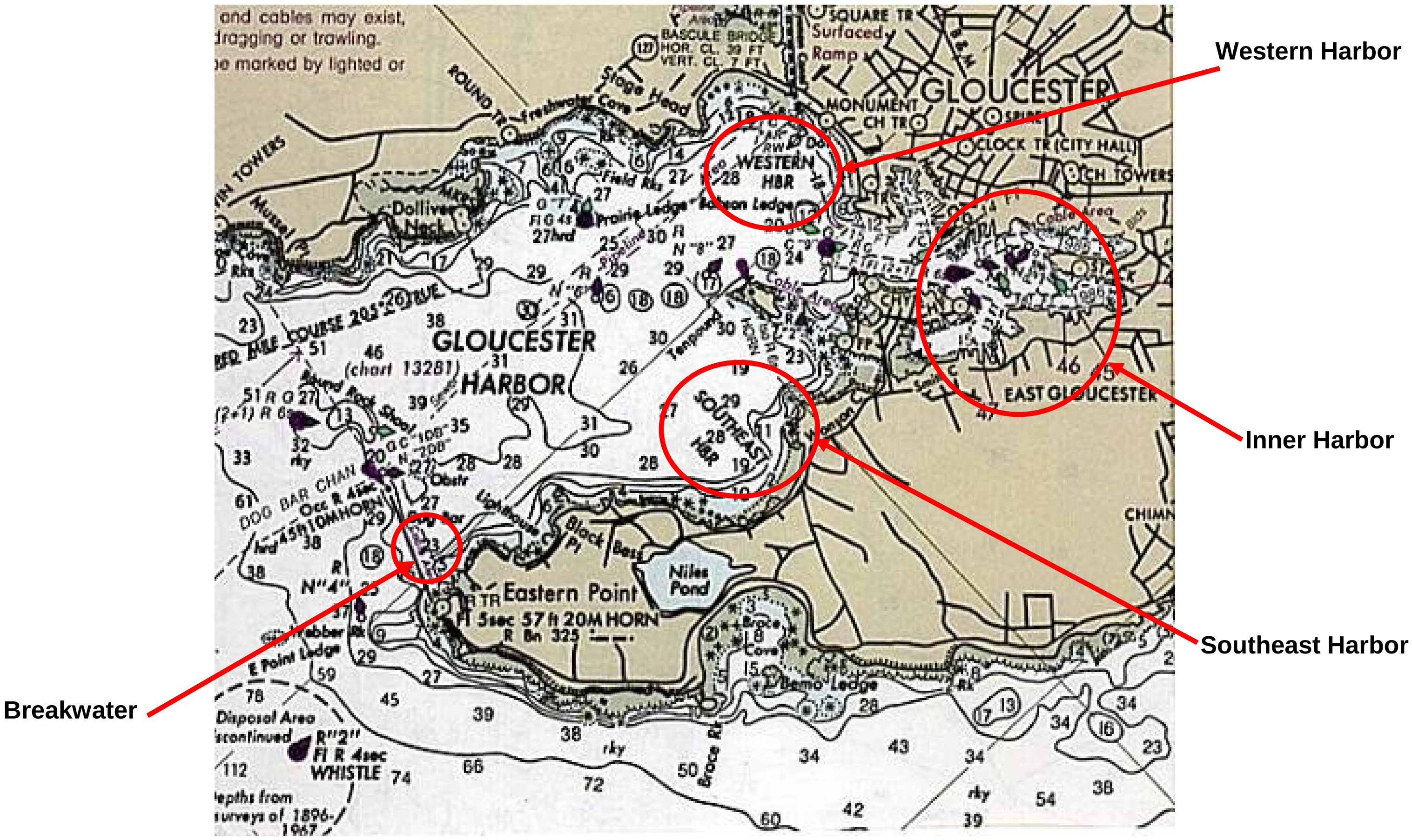


Figure 5-2 Gloucester Harbor and Shoreline Areas
(Source: MARPRO Associates International 2009)

Potential

There are limited areas for industrial growth adaptable to ROWEI staging. It is unlikely that a suitable location within the port of sufficient size could be identified to handle processing and assembly. To take advantage of existing water depth, highway connections and other access issues, any facility should be located on the west side of the harbor.

5.1.2 Salem, Massachusetts

Background

The Port of Salem is located 9.6 nm (11 miles) southwest of Cape Ann and is approximately 10.4 nm (12 miles) northeast of Boston. It is a small harbor, part of an irregular indentation in the shoreline of Massachusetts Bay (see Figure 5-3). The watershed area also includes Manchester, Beverly and Marblehead Harbors. The port is primarily known for its recreational and yachting industry. It also has a deepwater oil facility and commuter passenger service connecting to Boston. See Appendix E for the extent of the Salem DPA.

Figure 5-3 Aerial View of Salem Harbor
(Source: MARPRO Associates International 2009)

<u>Facilities</u>

The principle deepwater facility in Salem Harbor, Salem Terminal, is located at the head of the harbor. The facility handles petroleum for the 27 hectares (approximately 67 acre) New England Power Company plant owned by Dominion Energy. In addition, Key Span Energy operates the adjacent 6 hectares (15 acre) support facility for an offshore liquefied natural gas handling platform. The port has a 0.8 hectares (approximately 2 acre) commuter ferry facility with connecting service to Boston. There are several fishing and recreational boat slips in the harbor, and the National Park Service has a 244 m (800 foot) berth that is used for historic vessels.

The port has fuel, water, provisions, and general marine services available, including several small machine shops that mostly service smaller craft. There are no dry-dock or shipyard facilities in the port for large commercial craft.

Salem has limited potential for substantial expanded marine industrial activities. The Salem Waterfront is shallow and has poor road connections to the waterfront. The port already provides supplemental marine support for the expanding petroleum and gas network in New England. The port's only deepwater commercial terminal is situated at the head of the harbor, and there are several former rail rights-of-way that connect to inland points. The expansion of pipeline connections from the terminal into the gas and petroleum network was first identified in the study conducted in 1994 by the Governor's Commission on Commonwealth Port

Development (MARPRO Associates International 2009). While the terminal is primarily used to supply the needs of the Salem Power Plant, it has the capacity to handle additional marine operations, including ROWEI staging. The port, however, does not have enough of a transportation network to meet a wide range of industrial needs, which would require adequate waterfront property, deep water access, unencumbered road access, and direct highway and rail connections. It does have the potential for other water based activities not dependant on road or rail connectivity.

Harbor Profile

Salem Harbor is a well protected harbor with three main channels that serve the watershed area. The Salem Channel, which is 9.4 m (approximately 31 feet) deep, is the primary access channel for deep draft vessels and passes through Salem Sound for approximately 3 nm (see Figure 5-4). The channel connects to a turning basin at the west side of the harbor at the Salem Terminal Wharf. The turning basin has a controlling depth of 8.2 m (approximately 27 feet). The harbor also has a special anchorage area. The harbor extends to the Salem Waterfront where the National Park Service's recreational and fishing piers and ferry terminal are located. Depth in most cases at the Salem Waterfront is less than 5.5 to 6.1 m (18 to 20 feet).

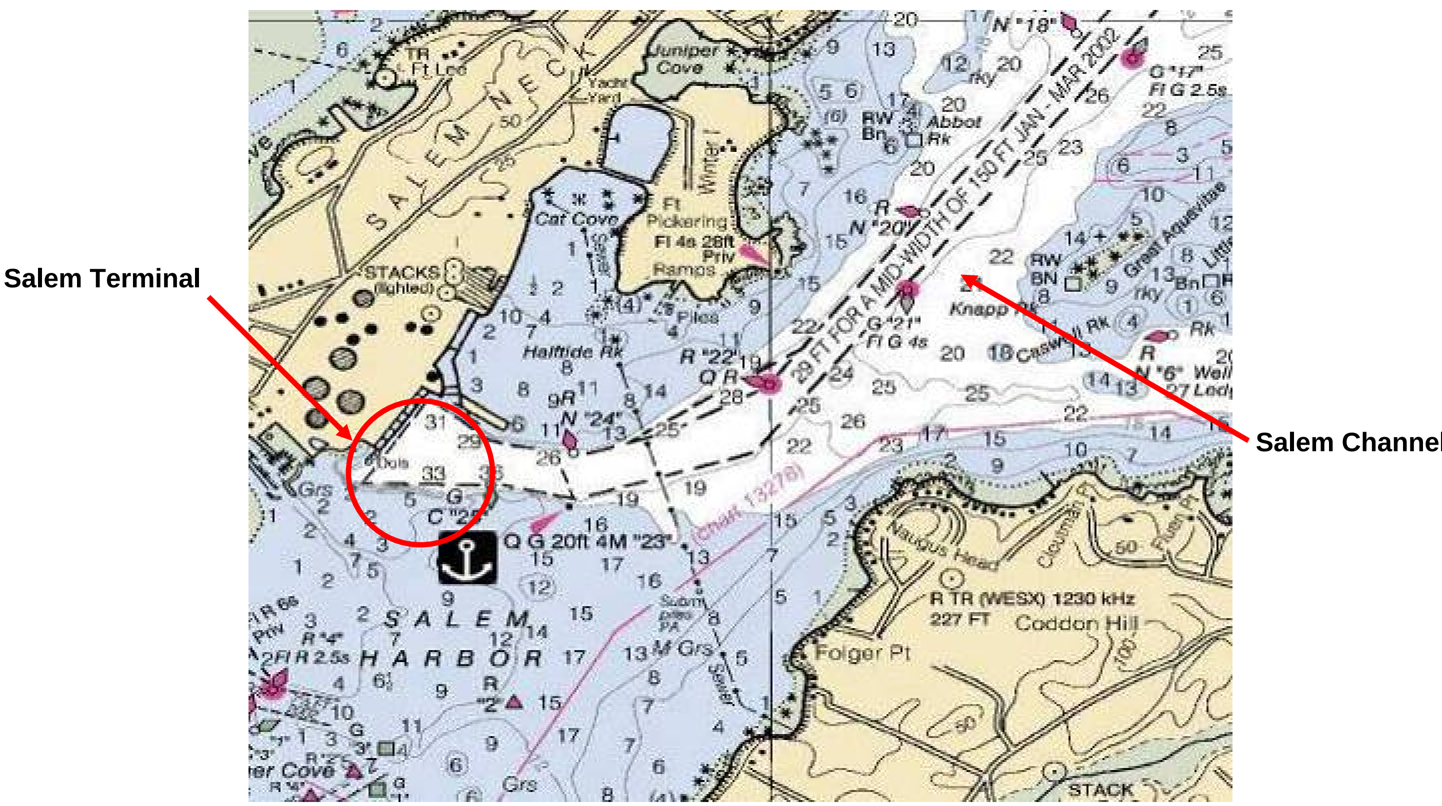


Figure 5-4 Salem Harbor and Shoreline Areas
(Source: MARPRO Associates International 2009)

The overall range of the tide in the harbor is between 2.6 and 2.75 m (8.5 and 9 feet). Within the harbor the current has minimal velocity. There is ice buildup at the head of the harbor during very cold winter months, mostly in January and February. Tug services are available out of Boston, and Salem is a U.S. Customs Port of Entry.

Advantages

The port is well sheltered and has some commercial vessel activity. The Salem Terminal site is underutilized and may be adaptable for some ROWEI staging activities. No overhead or lateral clearance constraints were identified in the approaches to the Port of Salem.

Disadvantages

The community is a popular tourist destination, and the surrounding waterfront communities have significant recreational vessel activities that have hindered industrial waterfront development. A potential focus of Salem Harbor is developing the emerging pocket cruise ship industry.

Water depth is a constraint. There is little deep water access to shore areas near the center of the waterfront. There is also very little area outside of Salem Terminal where large vessels can handle ROWEI components. The immediate area in and around the waterfront is congested, has poor capacity for high volume traffic flow, and does not have adequate and acceptable truck access. Although there is rail service to the City of Salem, it is limited at this time to commuter rail. The rail does not extend to the harbor areas, but there are former rail rights of way that connect to the harbor area. There is little space around the harbor for the development of additional freight activities other than what is currently handled at Salem Terminal.

Potential

The main area for commercial growth lies with the tourism-based cruise business. The community is well known and has good growth opportunity in marine based tourism activities. There is limited capacity for ROWEI staging or fabrication.

5.1.3 Boston, Massachusetts

Background

The Port of Boston is located north of Cape Cod and is adjacent to the main shipping routes between Southern and Northern New England. Within New England, the Port of Boston is the second largest tonnage port (after the Port of Portland, Maine,) the largest container port, the largest international passenger port and the largest oil port in Massachusetts. The port is historically known for its diverse maritime mix. The port has two shipyard facilities, hosts several commuter ferry operations, marine research activities, marinas, and the largest U.S. Coast Guard facility in New England (see Figure 5-5). While in recent years some segments of the port's activities have declined, notably fishing, the Port of Boston remains the largest of the Commonwealth's five major seaports. See Appendix E for the extent of the Boston DPA.

Boston is the largest and most prominent freight port in the Commonwealth. It has the most diversified port mix and handles the largest volume of containers in New England and the second largest amount of petroleum cargo. The port mix includes containers, general cargo, automobiles, scrap metal, road salt, project cargo, refined petroleum products, liquefied natural gas, international port of call and homeport cruise passengers, and domestic commuter and outer harbor ferry operations. Including liquid bulk cargo, the Port of Boston handled over

13.6 million mt (approximately 15 million tons) of cargo in 2007. Only the Port of Portland handled more, approximately 22.7 million mt (25 million tons) of cargo, mostly crude oil bound for Canada. Of the Port of Boston's total tonnage, 1.54 million mt (1.7 million tons) were containerized cargo representing 216,434 intermodal shipping container TEUs. With 4 container cranes, the annual port throughput averages 5,288 containers per hectare (2,140 containers per acre). The port hosted over 1,000 vessel calls in 2007.

Figure 5-5 Aerial View of Boston Harbor

(Source: http://www.mappingboston.org/html/map20-a.htm)

Boston has some critical key advantages and some distinct disadvantages for potential growth (see Figure 5-6). The port is situated within one of New England's largest market areas for products and commodities, and there is a significant amount of related port business, a wide range of diversity in the port operational mix, and a strong commitment to expanding activities. The port also has numerous terminals, deep water access, full marine services, and a large and skilled work force. The port has enhanced the economies of scale at its two major freight terminals, Conley and Moran Terminals, by consolidating container operations at Conley Terminal in South Boston, nearest the open seas and deep water areas, and shifting auto import and processing operations to Moran Terminal in Charlestown. This has resulted in lower overall operating costs and has enhanced the Moran Terminal operating authority's ability to attract and retain auto carrier and processing services. This trade suits the terminal's draft limitations and longer port transit.

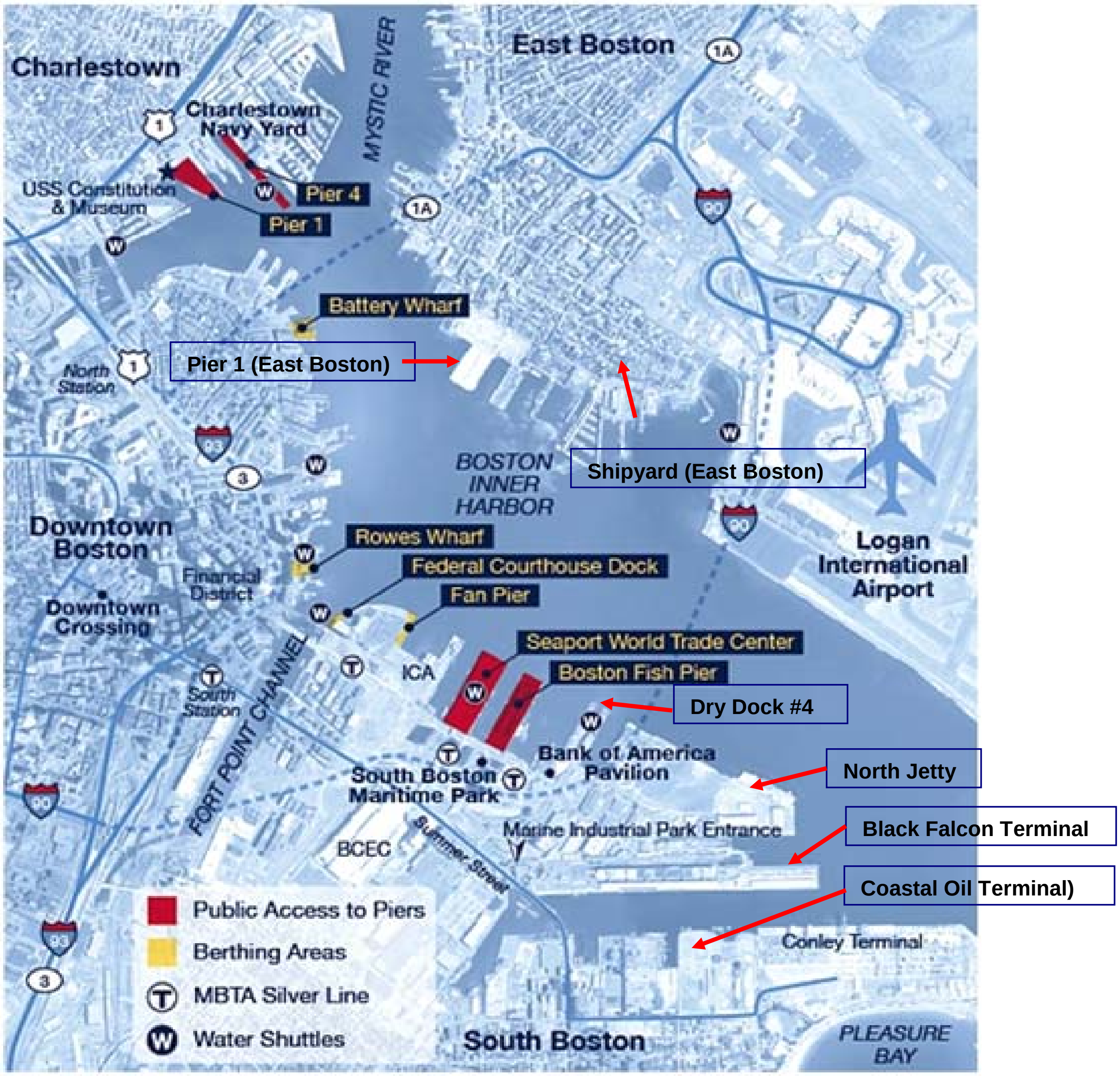


Figure 5-6 Massport Facilities

(Source: http://www.massport.com/business/pic/c_haarborwide.pdf)

Boston has been limited in its ability to take full advantage of significant industrial growth. A series of development projects has gentrified port areas, which has created choke points for the marine terminals. South Boston, for example, had been developed by the railroads for the handling of freight at numerous piers, but most of the original infrastructure has been replaced by new and non-related commercial and residential development. The result is that most of the rail infrastructure has been removed and direct rail connections to the waterfront are gone. Roadways are congested and direct street connections between the terminal and highway connectors are inefficient. The nearest major rail terminal is located at Allston Yard, some 14 miles from the port, which would make transport and transfer of turbine components or ancillary material expensive.

Facilities

The public marine passenger and cargo facilities in the Port of Boston are managed by the Massachusetts Port Authority (Massport). Massport is an independent public authority that develops, promotes and manages Massachusetts' airports, seaport and transportation infrastructure. Massport owns, operates and leases approximately 202 hectares (500 acres) of property in Charlestown, East Boston, and South Boston. Most of the properties are located within the Commonwealth's regulated DPAs, which are restricted to maritime industrial activities. These facilities include the Boston Autoport located at the combined Mystic River Piers and Moran Terminal in Charlestown and East Boston Pier 1 and adjacent properties in East Boston. Massport also owns the Paul W. Conley Container Terminal, the Black Falcon International Cruiseport, the North Jetty cargo facility, and the Boston Fish Pier all located in South Boston.

The 41 hectares (101 acre) Paul W. Conley Container Terminal South Boston is the largest marine facility in the harbor and is utilized for cargo container operations. The facility has 610 m (approximately 2,000 linear feet) of berthing with depths of between 12.2 and 13.7 m (40 and 45 feet). The terminal is equipped with four, low profile gantry cranes capable of 30 moves an hour, and the terminal can handle vessels up to an average of 5,000 TEUs, considered mid-size in the current vessel market. The container terminal handled nearly 220,000 TEUs in 2007, up 10% from 2006. The North Jetty is located on the waterfront in the Marine Industrial Park next to the Black Falcon Cruise Terminal. It offers 245 m (approximately 800 feet) of berthing space with a depth of 12.2 m (40 feet) at MLW (Massport website accessed February 2010). The North Jetty facility in South Boston is underutilized and adaptable to ROWEI assembly.

Boston Autoport in Charlestown is primarily used for automobile import, processing and distribution and has capacity for approximately 50,000 cars per year. It is also the location for the Wind Technology Testing Center (WTTC), a joint project with the U.S. Department of Energy to build a large wind turbine blade testing facility. There is some covered storage for high-value automobiles on site in the former Mystic Pier transit shed. The property encompasses approximately 20.2 hectares (50 acres) of land, not all of which is actively utilized and is consequently potentially suitable for ROWEI staging. The facility is also equipped with a shore-side gantry crane. The Boston Autoport is upstream of the Tobin Bridge and, therefore, is subject to vertical navigational constraints.

Another Massport facility in Charlestown is the former Revere Sugar site, now known as the Medford Street Terminal, which comprises approximately 5.7 hectares (14 acres) of waterfront industrial property with deepwater access. The Medford Street Terminal is being utilized for some storage and has good potential for ROWEI assembly. This terminal is upstream of the Tobin Bridge, which imposes a vertical constraint of approximately 41 m (135 feet). This restriction makes navigation marginal for jack up vessels and limits turbine load-outs in the star configuration.

The East Boston Shipyard is located on Marginal Street in East Boston between Piers Park and the site of the former Navy Fuel Pier. The shipyard is the only ship repair facility in Boston Harbor equipped to serve mid-sized commercial vessels. Features include: 3.6 hectares (9 acres) of backland, including 4 piers and approximately 8.1 hectares (20 acres) of water sheet, 18,580 m^2 (200,000 square feet) of commercial office and industrial building area in 12 structures, and 762 m (approximately 2,500 linear feet) of commercial berthing space (Massport website accessed February 2010).

Moran Terminal has rail access through Sullivan Square, and Massport owns the freight rail line from Sullivan Square into the Terminal. Conley Terminal does not have rail access and there are no identified plans for extending rail service into the facility. There is a proposed rail line connection that would provide access from the North Jetty for bulk, project and other cargos. Most of the roadway system in and around Massport's South Boston and Charlestown facilities is heavy weight rated for handling oversized loads up to 45.4 mt (approximately 100,000 pounds or 50 tons). The port has handled a number of project cargos using specialized tri-axle road trailers and has received State permits for transportation out of the terminal areas. Massport and the Boston Redevelopment Authority, which would have a approximately 15.25 m (50 foot) wide right-of-way and would eliminate some potential limitations with local utility infrastructure for very large component pieces. The roadway would provide better and unencumbered access to the Central Artery/Tunnel connections in South Boston. Massport also has proposed the extension of Cypher Street and the reconstruction of E Street as part of the freight roadway system with adequate turning curvatures and heavyweight access up to State authorized permit levels.

Harbor Profile

Boston Harbor is the largest physical harbor in New England and is well protected with a wide and easily navigable entrance and large inner harbor with deep water access. The entrance to the harbor has numerous shoals and islands. There are two dredged channels and two traffic separation schemes which define the approaches to and into the harbor for deep draft vessels. The entrance is well marked by navigational aids, and the entrance to the port is close to the pilot station located in Massachusetts Bay.

Boston's Main Ship Channel extends from the harbor entrance to the mouths of the Mystic and Chelsea Rivers and to the Charlestown Bridge on the Charles River. The Federal project channel depth is 12.2 m (40 feet) deep from the harbor entrance to the mouth of the Mystic River and is 10.6 m (35 feet) in areas near the south side of the harbor to just seaward the location of the Third Harbor. The Boston Harbor Deep Draft Navigation Improvement Project proposes to deepen the existing channel (USACE 2008). There are several deep draft ship anchorages in the harbor with the anchorage on the north side of President Roads used most frequently for ships and barges. Tidal range is around 2.75 to 2.9 m (9 to 9.5 feet) with two highs and two lows per day. Harbor currents are generally less than 1 knot.

Table 5-1 below summarizes the navigational constraints in the Port of Boston and their operational implications. This report focuses on the port facilities in South Boston, Charlestown, and East Boston discussed above. Other facilities on the Chelsea River currently are not considered feasible for ROWEI staging due to lateral and overhead restrictions, which are shown in Table 5-1, and are not discussed further.

Table 5-1
Summary of Navigational Constraints in Boston

Staging Port	Potential Obstructions	Lateral Clearance	Overhead Clearance	Controlling Water Depth	Feasible Turbine Load-Outs	Jack-Up Feasible ?
South Boston (all ports)	Logan Airport	over 152 m (500')	report air draft to airport traffic control	12.2 m (40')	all	yes
Charlestown / East Boston (inner harbor ports)	Logan Airport	over 152 m (500')		12.2 m (40')	all	yes
Medford Street Terminal and Mystic River	Tobin Memorial Bridge	over 152 m (500')	41 m (135')	7.6 – 10.7 m (25'-35')	star	marginal
Chelsea River (west of Chelsea St. Bridge)	Andrew McArdle Bridge	53.3 m (175')	none	8.8 – 12.2 m (29'-40')	fore-aft bunny ear	yes
Chelsea River (east of Chelsea St. Bridge)	Chelsea St. Bridge	28.3 m (93')	25.3 m (83')	8.8 – 12.2 m (29'-40')	rotor disassembled	no

Advantages

The port is well sheltered and has significant support mechanisms in place for commercial vessel activity and ROWEI assembly. There are numerous roadway connections to most of the main marine terminals which are heavily used. The port is the largest support center for marine activities in New England with a diversified mix of services and associated businesses.

Disadvantages

Boston is a typical metropolitan port, with gentrification pressures and limited ability to expand marine activities. The Port of Boston is affected by air traffic at Logan Airport. While maritime operations are not restricted, according to the Coast Pilot®[6], all vessels with air draft greater than approximately 25.9 m (85 feet) must advise air traffic control of their presence (U.S. Department of Commerce, National Oceanic and Atmospheric Administration and National Ocean Service 2009). South Boston facilities do not have significant navigational constraints. All turbine load-out configurations (i.e., bunny ear fore-aft, bunny ear lateral, and star) can be accommodated. Jack-up vessels can navigate between these ports and the sea. Long-term staging operations in South Boston should be evaluated in the context of the vertical limitations due to proximity to Logan airport and related FAA regulations.

While there are numerous road connections to terminals, many are congested and pass through residential areas creating potential conflicts with pedestrian and automobile traffic. Rail connectivity is very limited in several areas including South Boston, Charlestown and East

[6] The United States Coast Pilot® consists of a series of nautical books that cover a variety of information important to navigators of coastal and intracoastal waters and the Great Lakes. Coast Pilot 1 covers the coasts of Maine, New Hampshire, and part of Massachusetts, from West Quoddy Head in Maine to Provincetown in Massachusetts. Major ports are at Portsmouth, NH and Boston, MA.

Boston. Boston's container and auto terminals have no direct access to the nation's doublestack (Gen2) rail network. Boston is considered to be a high cost port due to existing labor agreements and work rules, expensive infrastructure and limited volume capacity. The marine terminals, particularly Conley Terminal, have limited area to expand their property boundaries, which would affect utilization for other activities. Vessel access to the inner harbor, specifically, Charlestown and Chelsea Creek is draft and length limited.

Potential

There is adjacent property that can be purchased and added to the existing terminal footprints to allow for expanded yard area allowing for dedicated ROWEI processing. Roadway connections to the terminals in most cases also need to be improved to provide appropriate capability.

Boston's industrial marine growth is tied to three major areas to expand marine activities. These include:

- Expansion of terminal size;
- Improvement of roadway connections to main highways that avoid the inner city roadways; and
- Creation of a better connection to the national rail network.

5.1.4 Fore River Shipyard

Background

Fore River Shipyard is less than 10 miles south of Boston. This approximately 45 hectares (111 acre) site is situated partially in both Quincy (2/3) and Braintree (1/3) (see Figure 5-7). Fore River Shipyard was once a prominent shipyard in the United States, producing ships for World War II (WWII), peaking with approximately 50,000 employees during this time. In the 1970s, the 1,200 ton "Goliath" crane (since removed in 2008) was built specifically to place aluminum spheres (pressure vessels) on the LNG vessels constructed there. Recently, Fore River Shipyard has served as the Central Receiving Point for new car delivery to local dealerships. See Appendix E for the extent of the Fore River (Weymouth, Quincy and Braintree) DPA.

The site is currently undergoing an initial planning process to determine potential new uses for the site, including marine-related, residential, retail, office, and entertainment. Current planning goals are to create a mixed-use, working waterfront development at the site. At this time, the Shipyard is actively seeking industrial tenants for both indoor and outdoor space. The Fore River which flows directly into Boston Harbor has recently been dredged by the Army Corps of Engineers, and can accept "Panamax" class vessels (i.e., vessels of a maximum size to fit through the existing Panama Canal).

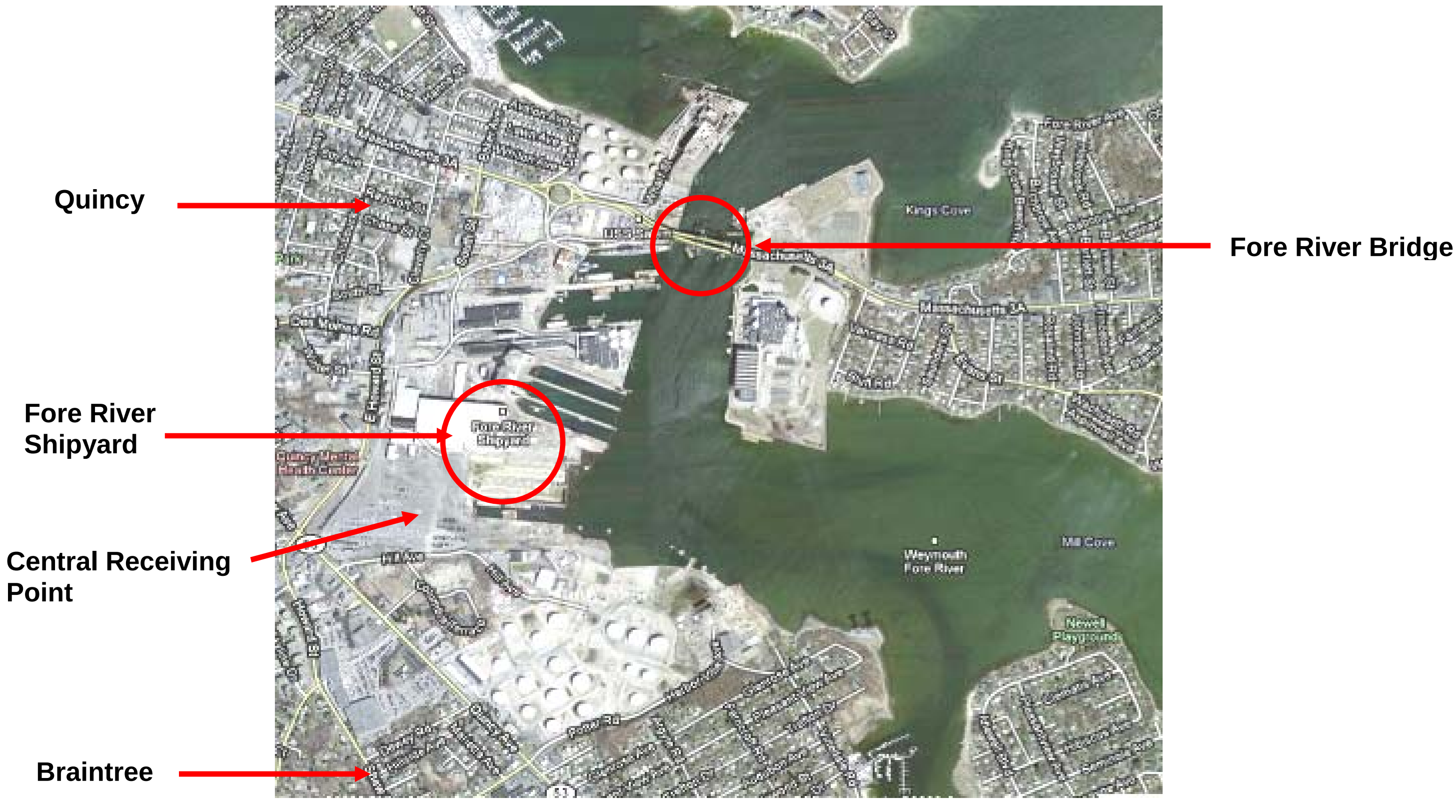


Figure 5-7 Aerial View of Fore River Shipyard
(Source: Google Earth, Fore River Shipyard, 2010)

<u>Facilities</u>

The site is currently owned by Daniel Quirk, a local auto dealer, and is used as the Central Receiving Point for new car delivery. The port area also contains a ferry terminal for commuter boats to Boston and Hull that is run by Harbor Express for the Massachusetts Bay Transportation Authority (MBTA). The yard also is used by Jay Cashman, Inc., for heavy construction and marine equipment services, the Massachusetts Water Resources Authority, as a sewage sludge heat-drying and pelletizing facility, and by the Fore River Transportation Corporation for short line freight rail service to CSXT South Braintree (discussion with Daniel Quirk).

The site currently features rail and roadway access, a 41,800 m^2 (450,000 square foot) open floor building, a 9,290 m^2 (100,000 square foot) open floor building, and additional buildings for a total of 55,740 m^2 (600,000 square feet). The site also includes a 11,150 m^2 (120,000 square foot) Wet Basin with a current 6.1 m (20 foot) draft that can be dredged to deeper than 9.1 m (approximately 30 feet).

<u>Shipyard Profile</u>

The Shipyard is located in a well protected area with adequate draft to accept “Panamax” class vessels. The entrance to the Shipyard is narrow, restricted by the Fore River Bridge, which currently has a 53.3 m (175 foot) vertical clearance and a 53.3 m (175 foot) horizontal clearance. This bridge is a temporary lift bridge and plans are not yet finalized as to whether the replacement bridge will be a lift style or bascule style drawbridge. North and East of the bridge, the approach channel ranges from 41 to 183 m (136 feet to 600 feet) wide and is approximately 9.75 m (32 feet) deep. South of the bridge, the channel opens to 122 m (400 feet) wide. Channel depth is 9.75 m (32 feet). Tidal range is around 3 to 3.1 m (9.8 to 10.2 feet).

Advantages

The port is well sheltered and has significant support mechanisms in place for commercial vessel activity. There are numerous roadway connections and an active railroad line.

Disadvantages

The entrance to the Shipyard is laterally and vertically constrained by the Fore River Bridge. Additionally, the site is currently undergoing an initial planning process to determine new potential uses for the site, including marine-related, residential, retail, office, and entertainment. Currently, the site is serving as the Central Receiving Point for new car delivery to local Quirk car dealerships. Much of the infrastructure is significantly aged.

Potential

New bridge design for the Fore River Bridge is yet to be finalized. Additionally, improvements could include the following:

- Improvement of roadway connections to main highways that avoid the inner city roadways;
- Creation of a better connection to the national rail network; and
- Facilities to support secondary functions associated with offshore wind deployments.

5.1.5 Fall River, Massachusetts

Background

The Port of Fall River is located at the mouth of the Taunton River at the head of Mount Hope Bay, at the northeast side of Narragansett Bay, near the Massachusetts-Rhode Island border. The port is approximately 18 nm from the south entrance of Narragansett Bay, which flows into Rhode Island Sound, 17 nm west of the Cape Cod Canal and approximately 90 nm south of Boston. It is geographically located about 74 kilometers (km) (46 miles) south of Boston, 26 km (16 miles) southeast of Providence, RI and 19 km (12 miles) west of New Bedford. The port is historically known for its manufacturing and distribution and has developed an active break-bulk trade. Cargo operations have included handling mostly break-bulk cargoes such as bananas, wallboard, heavy equipment, automobiles, wood pulp, chemicals, newspaper and seafood. See Appendix E for the extent of the Mount Hope Bay (Fall River and Somerset) DPA.

The Port encompasses the waterfronts of Fall River and Tiverton, Rhode Island on the east side of the Taunton River and the waterfront of Somerset, MA on the west side of the river. The port has good highway access and is served by U.S. Route 6, Routes 24, 79 and 138 and Interstate 195 that connects to Providence, RI with Cape Cod. There are rail freight activities through CSX connecting to several industrial sites in Fall River. In addition to freight activities, there are several cruise ship visits each year and a number of recreational vessels activities supported by marina facilities at several locations.

Fall River is also an active niche port serving several international markets. The area is ringed with liquid bulk terminals and has the potential for expanded industrial activities at the State Pier. The State Pier has available storage and land area for operations but is used for both industrial and tourism based activities. One way of enhancing Fall River's ability to handle more marine industrial operations is to remove tourism-based activities from the State Pier. The port has good highway access and a rail corridor that requires additional infrastructure improvements.

Facilities

The port has a number of active private facilities and one principal public facility (see Figure 5-8). The Borden and Remington Corporation Wharf is 116 m (380 feet) long with a water depth of 8.5 m (28 feet) alongside. The pier is currently used for handling of latex and caustic soda, is owned by the Tillotson Co., and is operated by the Borden and Remington Corp.

The primary marine facility for the City of Fall River is the State Pier and is located on the site of the former Fall River Line Pier, which was a major steamship operator in New England. The State-owned general marine terminal provides two deep-water berths, a 120 m (398 foot) berth with a depth of 4.5 to 10.7 m (15 to 35 feet) alongside, and a 189 m (620 foot) berth with a 10.7 m (35 foot) water depth alongside. There is also a 7,900 m^2 (85,000 sf) terminal and roll-on/roll-off facility, as well as 2.8 hectares (7 acres) of open storage yards. The terminal is equipped with an approximately 24 m (80 foot) roll-on/roll-off ramp and a 45 mt (50 ton) truck scale. There are three rail spurs, which provide direct on-dock rail connections, but only one is currently operable. The State Pier handles break-bulk and containers. This cargo comes primarily from the Cape Verde Islands, and vehicles and equipment from Angola. The port also handles frozen fish, totaling approximately 680 mt (750 tons) per year, from a fish processing vessel as well as petroleum products at several private terminals. The State Pier represents the best alternative for ROWEI staging.

Just north of the State Pier is the *USS MASSACHUSETTS* Battleship Memorial where a number of former naval vessels are berthed. The Memorial is an active museum that is open to the public and cannot be utilized for marine industrial activities. Two miles above the State Pier is the former Shell Oil Company Wharf that has a 213 m (700 foot) berth with a 9.1 m (30 foot) water depth alongside. Shell Oil discontinued the petroleum products operations in the 1990s, and it is now owned by Fall River Marine, LLC. This site, which is the proposed location of the Weaver's Cove LNG Terminal, could be adaptable for ROWEI staging if it is abandoned by Weaver's Cove. The Mt. Hope, Braga and Brightman Street bridges would impose navigational restrictions. The Mt. Hope and Braga bridges each have a 41.1 m (135-foot) vertical clearance and a 121.9 m (400-foot) horizontal clearance. The Old Brightman Street Bridge has a 29.9 m (98-foot) horizontal clearance but no vertical restriction, and the New Brightman Street Bridge has a 18.3 m (60-foot) vertical and 61 m (200-foot) horizontal clearance.

On the west side of the Taunton River is the Brayton Point Station Dock which has a 310 m (1,017 foot) berth with a 10.6 m (34 foot) water depth alongside. The facility is designed to handle fuel oil and coal and is owned by New England Power Company. Montaup Electric

Company owns and operates a wharf with a 197 m (645 foot) berth and an alongside depth of 10.6 m (34 feet). The facility is designed for handling fuel oil and coal.

The rail line that serves New Bedford also serves Fall River and extends to the State Pier facility in the harbor. Wind turbine components could be delivered to Fall River via road or rail as long as they do not exceed dimension and weight limitations.

Harbor Profile

The main access to the Port of Fall River is from the shipping lanes of the Atlantic Ocean, into Narragansett Bay, through Mount Hope Bay, and down the Taunton River. The harbor is a medium deep-water harbor with a 10.7 m (35 foot) deep federal channel through Mount Hope Bay to about 0.9 nm (approximately 1 mile) above the New Brightman Street Bridge (see Figure 5-8). There are additional deep dredged channels near the north Tiverton waterfront with between 6.1 and 10.1 m (20 and 33 feet) of water depth. The harbor has no designated anchorages.

Figure 5-8 Aerial View of Fall River Harbor
(Source: Google Earth, Fall River, MA, 2010)

There are two bridges which cross the Taunton River. They include the fixed Braga Bridge at the State Pier with an air draft clearance of approximately 41 m (135 feet). The second bridge is the bascule style New Brightman Street Bridge with a 18.3 m (60 foot) clearance about 1.1 nm (approximately 1.3 miles) above the fixed bridge. There are additional bridges upstream on the Taunton River but outside of the deepwater port.

Tidal currents are generally not a problem for navigation. The mean range of the tide is around 1.4 m (4.5 feet). Pilotage is compulsory for foreign and U.S. vessels under register of 356 mt (392 tons) or more. Pilotage is provided by Northeast Marine Pilots. The Port has U.S. Customs port of entry capability through New Bedford. Tug services are available in the port from Providence, RI. There are some repair services but no dry-docking capability. There are two small shipyards in the port on the west side of the harbor that provide skilled workforce capability for wind projects.

Advantages

The port is well protected and has support mechanisms in place for commercial vessel activity, including ROWEI assembly and staging. There is cargo storage and handling capacity that can be utilized for fabrication, and the area is supported by good road and reasonable rail access. The port has a roll-on/roll-off facility at the State Pier, which can be used for handling wheel-based industrial components. There is also capacity at some of the private terminals for new industrial development. Water depth is not a significant constraint for Fall River, as dredged channels have water depth in excess of 9.1 m (30 feet). The lateral clearance at the Braga and Mt. Hope Bridges is 122 m (400 feet).

Disadvantages

Vertical clearance is the most significant navigational constraint for the Port of Fall River with respect to deployment configurations for offshore wind turbines and assemblies. The Braga Bridge and Mt. Hope Bridge each impose a height restriction of approximately 41 m (135 feet). This restriction makes navigation marginal for jack-up vessels and limits turbine load-outs in the star configuration. Vessel draft is limited to a 10.7 m (35 foot) overall depth that restricts large vessel access. The State Pier can only handle small cargo ships. The warehouse space at the terminal is unheated and provides only temporary storage, but does provide weather protection for project assembly. Most of the critical infrastructure in the port is aging and in need of repairs and improvements.

The port’s commercial and industrial expansion is also hindered by gentrification and a focus on tourism-based activities on the Fall River waterfront. There have been a number of proposals for expanded industrial development, including a proposal for developing an LNG import facility that has been met with significant local opposition.

Potential

There are several main areas for industrial growth well suited to ROWEI staging. Its proximity to the major shipping route near the Cape Cod Canal places the Port of Fall River in a position to facilitate ROWEI staging using smaller ships and barges.

One of the most significant opportunities is the stalled construction of a LNG facility in the port. If not completed, this could potentially provide a parcel of available land for ROWEI staging. However, the Mt. Hope, Braga, and New Brightman Street Bridges, all seaward of the LNG terminal, have vertical and horizontal clearance restrictions that could preclude certain turbine import and installation vessels and load-out configurations.

Required Improvements

The State Pier requires additional investment to bring it up to industry standards for expanded cargo handling, and there are several other facilities that require infrastructure improvements, including bulkheads, piers and wharves. The site needs to be expanded, and there is an unused salt storage area near the State Pier that could be annexed to create increased capacity. The rail line needs to be restored in some areas and the trackage improved to accommodate increased cargo shipments. An estimated $15 million is required for State Pier improvements (MARPRO Associates International 2009).

5.1.6 New Bedford, Massachusetts

Background

The Port of New Bedford is located on the northwestern side of Buzzard's Bay and is approximately 83 miles south of Boston. The port, encompassing the City of New Bedford and the Town of Fairhaven (see Figure 5-9), is historically known for its fishing industry connections but has developed a significant break-bulk trade. The harbor, considered to be small geographically, is located at the mouth of the Acushnet River, and has direct access into Buzzards Bay, Vineyard Sound and the Atlantic Ocean. The harbor entrance is approximately 10 nm from the beginning of the south entrance of the Cape Cod Canal. See Appendix E for the extent of the New Bedford - Fairhaven DPA.

Figure 5-9 Aerial View of New Bedford Harbor
(Source: MassGIS, 2001)

The Port of New Bedford is a deepwater port and is one of the nation's major fishing ports. The fishing fleet includes more than 500 vessels operating out of the port. The Port of New Bedford also supports a diverse market of cargo transport. Barge operations move aggregate and break-bulk cargo to the Islands of Martha's Vineyard and Nantucket. Shipments of break-bulk cargo consisting primarily of house goods are exported to Cape Verde and Angola. The Port of New Bedford has the largest throughput tonnage of break-bulk perishable commodities in New England.

The port hosts reefer (refrigerated) vessels that handle fresh fruit and fresh and frozen fish. The labor force consists of approximately 30 International Longshoreman's Association personnel for vessel operations and 20 Teamsters for warehouse operations. The port currently handles around 25 freighters per year (MARPRO Associates International 2009).

New Bedford is already an active freight seaport and is a major logistical connection for agricultural products entering the New England market. Highway connections are good, and the port could benefit from expanded and improved rail connections to meet freight needs. New Bedford is a small niche port that can continue to expand activities with some infrastructure improvements and investment. It has sufficient deep water access for the size and type of vessel common to most break-bulk and project cargo and has available property for expansion.

Facilities

The New Bedford waterfront has a number of large and small piers and wharves that are primarily used by the commercial cargo and fishing industry (see Figure 5-10). Most facilities have good highway connections as well as rail connections. Harbor regulations and berthing limits, except berthing for private terminals, are enforced by the Harbor Development Commission (HDC) and the Port Maritime Security Unit.

New Bedford South Terminal Wharf has a 488 m (approximately 1,600 foot) berth with 9.1 m (30 feet) of water depth and serves as the major off-loading center for fish product. The wharf has 7,080 m^3 (250,000 cubic feet) of refrigerated storage on site and handles primarily seafood. The southernmost portion of the facility has the potential to build out a 122 m (400 foot) solid fill bulkhead. The site currently has 4.0 hectares (approximately 10 acres) of backland.

Sprague Terminal just North of South Terminal has a 225 m (740 foot) berth with an 8.2 m (27 foot) water depth alongside. The pier primarily handles petroleum products, but was originally part of the operations of a defunct electric power plant (the building is still standing on site.)

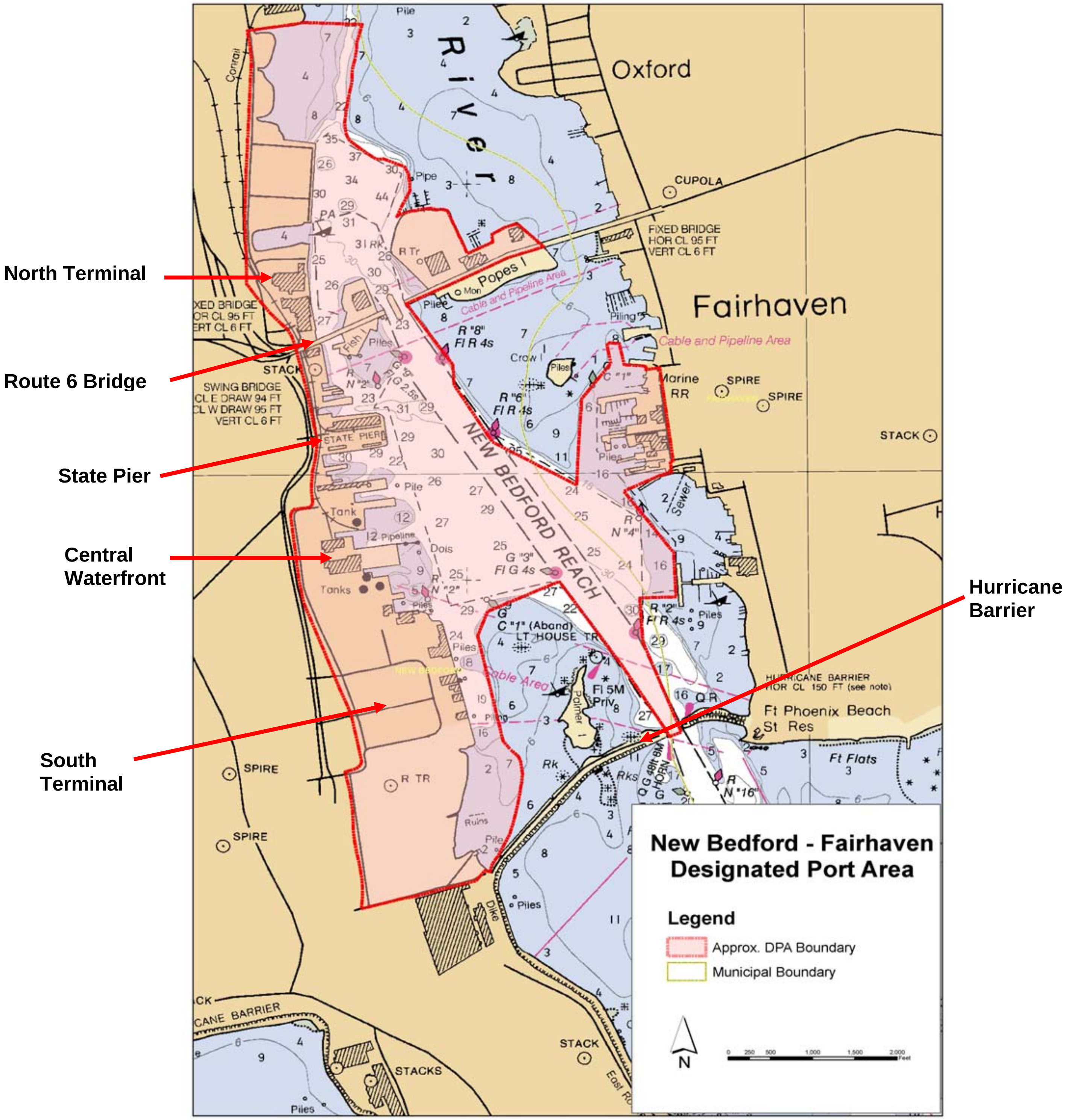


Figure 5-10 Navagational Map of New Bedford Harbor

The State Pier Terminal at the center of the Inner Harbor has three berths measuring 137 m (450 feet), 183 m (600 feet), and 236 m (775 feet) with a 9.1 m (30 foot) water depth alongside. There are 11,610 m^2 (125,000 square feet) of covered storage for general cargo. The facility can support freighter service and store over 135 containers. American Cruise Lines operates out of the facility with a minimum of 20 ports of call on an annual basis and up to 89 passengers per trip. Ferry services also operate out of the State Pier, including passenger and cargo service to Cuttyhunk Island and passenger service to Martha's Vineyard. Ferry service brings over 115,000 passengers through the port annually. The Quick Start Ferry facility on the State Pier allows intermodal transfers of waterborne freight and freight carried by truck and rail. This terminal features an 8.2 m (27 foot) pier depth, roll on/roll off capability, offsite cold storage, and easy access to the interstate highway system. The ramp is approximately 30.5 m (100 feet) long and 5.5 m (18 feet) wide and will hold up to 182 mt (approximately 200 tons). The State Pier requires a significant amount of investment to bring it up to industry standards for cargo handling (see Section 7).

Above the Route 6 Bridge are the Maritime Terminal, Bridge Terminal and North Terminal. The Maritime Terminal Wharf, operated by Maritime Terminal International, has a 183 m (600 foot) berth with a 9.5 m (31 foot) water depth alongside. The facility has 84,960 m^3 (3 million cubic feet) of refrigerated storage and is one of the largest U.S. Department of Agriculture-approved cold treatment centers on the East Coast for use with controlled imported agricultural products. The terminal receives approximately 25 vessels a year, each carrying between 1,362 and 3,630 mt (1,500 and 4,000 tons) of fish or, approximately 1,816 to 2,723 mt (2,000 to 3,000 tons) of fruit.

The Bridge Terminal Wharf, on the northeast side of the harbor, is 137 m (450 feet) long with a 8.5 m (28 foot) water depth alongside. The wharf has a 14,160 m^3 (500,000 cubic foot) refrigerator warehouse and handles frozen and chilled food products. The facility is owned and operated by Bridge Terminal Inc.

American Pride Seafood is a private facility operating out of the North Terminal and one of the world's leading seafood product processors. The bulkhead supporting this operation is 177 m (580 feet) long with a 7.6 m (25 foot) water depth alongside. The facility has 5,890 m^2 (63,400 square feet) of refrigerated warehouse space, 5,342 m^2 (57,500 square feet) of freezer space and 3,224 m^2 (34,700 square feet) of covered warehouse space.

Within the New Bedford North Terminal Wharf are commercial properties managed by the HDC. These properties cover 10.1 hectares (approximately 25 acres) of land. Tenants include the seafood processors Eastern Fisheries and Seawatch International, barge operators, ship repair facilities, and other maritime service businesses. A 0.8 hectares (2 acre) terminal site is proposed to come on-line over the next 5 years. This facility is currently operated by the EPA as part of the superfund clean-up will revert back to the City of New Bedford in the next few years. The facility has rail connections that lead directly to the water's edge.

The port is considered a full service port with associated maritime industries include vessel maintenance and repair conducted at dockside or at repair facilities in New Bedford or in Fairhaven. The port has two moderate size shipyards, and equipment and provisions to support commercial and recreational vessels.

New Bedford is served by a rail line operated by CSX. Roadway bridge constraints prohibit doublestack (Gen2) access to the port. However, this is not a problem limited to New Bedford. An application has been submitted for TIGER Grant money to extend the rail line to the State Pier, but further extension to the proposed South Terminal Development site is unrealistic. The port has handled overweight and oversized project cargo in the range of 45.4 mt (approximately 50 tons) out of the northern part of the harbor. Wind farm components could be moved by road into New Bedford as long as the loaded units do not exceed permit requirements for oversized loads, including weight and overall dimensions. The highway system accessing New Bedford conforms to federal standards that allow a minimum vertical clearance under overhead structures of 4.88 m (16 feet) in rural areas and 4.27 m (14 feet) in urban areas. Routes into New Bedford include US I-195 and Route 18 which connects the west and south port areas to the main highways system.

The Port of New Bedford is considered a moderately deep-water port with overall depths of 9.1 m (30 feet). The harbor is protected by a hurricane barrier (see Figures 5-9 and 5-10) that is constructed across the harbor entrance and is equipped with an opening that can be closed during hurricane conditions and severe coastal storms. The port is considered a harbor of refuge for vessels in the region.

The harbor approach is characterized by a number of ledges and shoals. The approach channel allows for safe navigation and avoids most of the obstructions. The hurricane barrier entrance is 45.7 m (approximately 150 feet) wide and opens up to a 107 m (350 foot) wide channel, at a depth of 9.1 m (30 feet), extending to a turning basin approximately 305 m (1,000 feet) above the New Bedford-Fairhaven Bridge. The range of the tide is 1.1 to 1.2 m (3.5 to 4.0 feet), and harbor currents are overall considered weak. Maximum ebb and flood tide currents are under an average of 2.5 knots.

There are vessel limitations due to the hurricane barrier and the Route 6 highway bridge in the Inner Harbor (see Figure 5-10). The hurricane barrier opening width is 45.7 m (approximately 150 feet) and the Route 6 New Bedford–Fairhaven Bridge is 28.0 m (approximately 92 feet) wide. All vessel transit to and from northern portion of the harbor (upstream of the Route 6 Bridge) is subject to daylight only restrictions for vessels with overall length above 121 m (400 feet) and/or beam above 18 m (59 feet) and to wind velocity restrictions

Advantages

The port is well protected by the hurricane barrier and has support mechanisms in place for commercial and industrial vessel activity, including ROWEI staging. The port is has good road and rail access, and adaptable warehouse capacity is significant. The port has several opportunities for expansion to accommodate ROWEI assembly.

The harbor is challenged by a significant pollution problem due to local industries which up until the 1970s discharged wastes containing polychlorinated biphenyls (PCBs) and toxic metals into New Bedford Harbor. There are high levels of contamination throughout the waters and sediments of the harbor that extend into Buzzards Bay. This contamination led to New Bedford Harbor being designated as a Superfund Site. Since 2004 the EPA has been dredging to remove the PCBs in contaminated sediments. The EPA is expected to explore new technologies (confined aquatic disposal) that will reduce the demand for land-side facilities. This could accelerate the process of bringing the terminal facility under City control and opening other waterfront parcels up for development.

As a result of the contamination, no maintenance dredging has occurred for over 50 years. The port faced the loss of waterfront business unless maintenance dredging could be implemented. In 2005, the first navigational maintenance dredging was conducted restoring portions of the harbor to useable depths. This has allowed business to increase and larger commercial vessels to return to the harbor.

The navigational draft within the Port of New Bedford is sufficient for turbine installation and import vessels. As turbine components are relatively lightweight for their size, import vessels are space-limited, rather than weight-limited. As such, they would be able to enter New Bedford Harbor with a draft of less than 9.1 m (30 feet). No overhead clearance constraints were identified in the approaches to the Port of New Bedford.

Disadvantages

While advantageous to port safety, the hurricane barrier however is a significant navigational constraint for the southern section (i.e., seaward of the swing bridge) of the Port of New Bedford (see Figure 5-10). The lateral (horizontal) clearance is 45.7 m (150 feet), which restricts turbine load-outs in the fore-aft bunny ear configuration. The Route 6 New Bedford–Fairhaven Bridge has a lateral clearance of 28 m (92 feet), which makes turbine transport above (i.e., upstream of) the swing bridge marginal. The Route 6 Bridge not only imposes lateral constraints for vessels transiting to and from the northern section of the harbor but also is outmoded and causes delays in travel time. The turning basin can only handle small cargo ships.

Potential

There are several port areas adaptable for marine terminal expansion capable of supporting ROWEI staging. The State Pier requires a significant amount of investment to bring it up to industry standards for cargo handling. However, there are several other facilities, including the South Terminal that could accommodate ROWEI staging with infrastructure improvements. The rail corridor needs to be extended and trackage improved to accommodate increased and oversized shipments. Commuter rail improvements are being planned, and the engineering of the commuter rail should include upgrades for freight transport. Development and of staging areas for trucks is also critical for increased activity in the port.

The South Terminal is convenient to the mouth of the harbor. Expansion of, and repairs to, the South Terminal would create a multi-use manufacturing and shipping facilitate suitable for ROWEI staging. Dredging along the bulkhead, improvements to the pier structure, and an extension of the existing bulkhead would allow for larger deeper-draft vessel berthing and expanded use of the South Terminal facility.

The North Terminal can be improved for handling of ROWEI fabrication and staging. Terminal facilities should be equipped with a versatile mobile harbor crane and ground support equipment. This equipment can be used for both cargo handling and wind farm components. Additional dredging to provide better access to all deepwater berths could be completed, and the turning basin could be lengthened to accommodate longer, higher tonnage cargo vessels. Improvements to the Route 6 Bridge are critical to the passage of vessels to North Terminal and maximizing vessel access.

5.2 Profiles of East Coast Ports Outside of Massachusetts

The other East Coast ports that were evaluated in this study are described briefly below.

5.2.1 Portland, Maine

Portland Harbor, at the western end of Casco Bay, is the most important port on the coast of Maine (see Figure 5-11). The ice-free harbor offers secure anchorage to deep draft vessels in all weather. The harbor is home to significant domestic and foreign commerce in petroleum products, paper, wood pulp, scrap metal, coal, salt and containerized goods. It is also the Atlantic terminus pipeline for shipments of crude oil to Montreal and Ontario. In 1998, Portland became the largest port in the Northeast based on throughput tonnages.

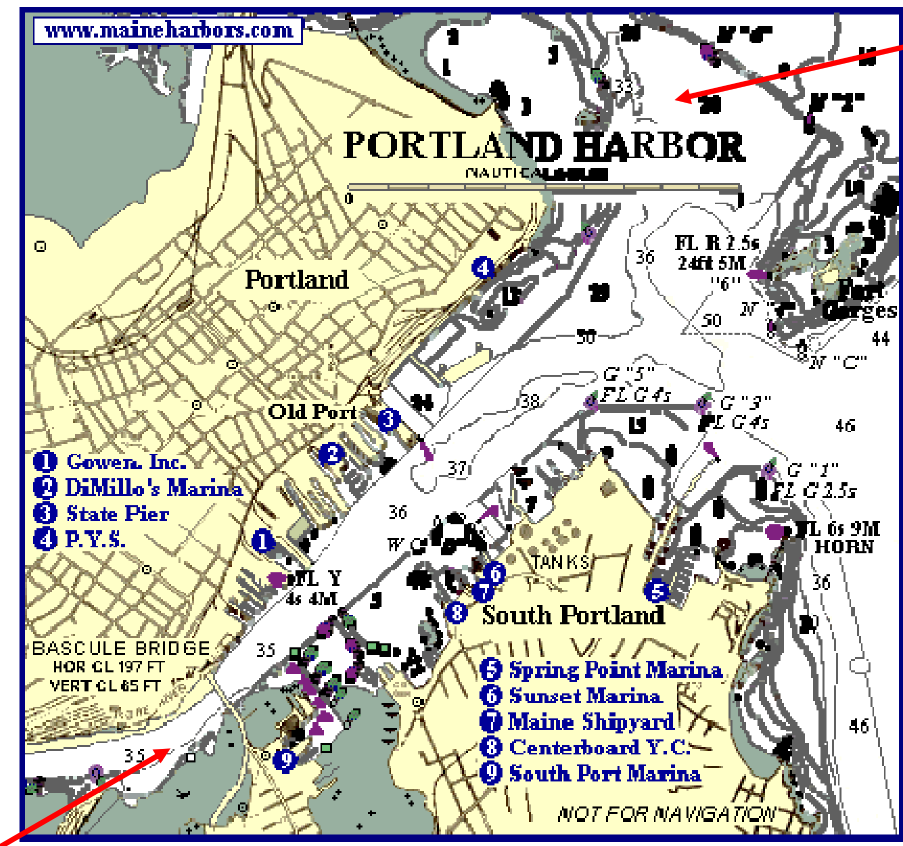


Figure 5-11 Portland Harbor and Shoreline Areas
(Source: www.maineharbors.com)

Portland is served by Pan Am Railways and the St. Lawrence and Atlantic Railroad, connecting the Port to a national network that also reaches into Canada. Passenger and freight ferries serve the nearby islands. Three scheduled airlines operate from the airport, and charter and air taxi service is available. Numerous truck lines serve the greater Portland area with interstate and intrastate service.

Although Portland is equipped to handle above-water hull and engine repairs of deep-draft vessels, major repairs to large vessels are typically made in Boston or, to a lesser extent, in

Bath. Deepwater facilities at Portland include seven petroleum terminals, one general cargo terminal, and one international ferry terminal. All have highway connections and most have railroad connections.

The channel from the sea to Fort Gorges has a depth of 13.7 m (45 feet), continuing at 10.7 m (35 feet) in the Inner Harbor and Fore River to a turning basin seaward of the railroad/highway bridge. The harbor includes two well-protected deepwater anchorages. Casco Bay Bridge, approximately 1.3 nm (approximately 1.5 miles) above the entrance to the Fore River, has a bascule span with a clearance of approximately 16.7 m (55 feet).

5.2.2 Portsmouth, New Hampshire

Portsmouth Harbor, located approximately 3 nm inland of the mouth of the Piscataqua River, is the only harbor of refuge for deep-draft vessels between Portland, ME and Gloucester, MA (see Figure 5-12). The harbor has sufficient depth to accommodate large deep-draft ships and is open throughout the year. The north side of the river, on Seavey Island in Kittery, ME, is occupied by the U.S. Navy and the Portsmouth Naval Shipyard. Foreign trade includes petroleum products, gypsum, frozen fish, fish products, and salt. Oil shipments in tankers drawing as much as 10.7 m (35 feet) arrive frequently in the fall, winter, and spring. The Division of Ports and Harbors of the Pease Development Aurhority oversees the maintenance, development and use of the port.

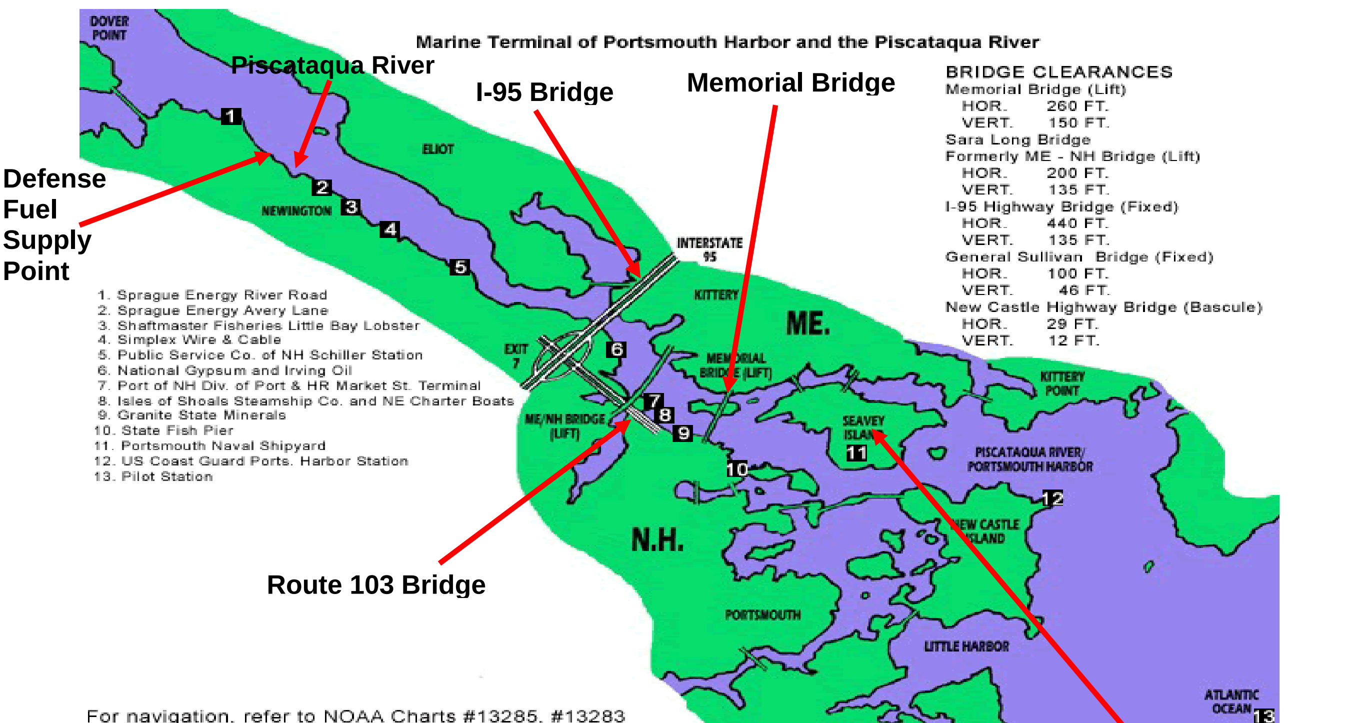


Figure 5-12 Portsmouth Harbor and Shoreline Areas

The port is served by a freight branch of the Boston and Maine Railroad, local and interstate highways, and is located within a mile of the International Airport on the Pease International Trade Port (formerly the Pease Air Force Base). There are no facilities for dry-docking deep-draft vessels in Portsmouth Harbor (the nearest for large vessels is Boston). However, local machine shops can make minor repairs to machinery, and several boatyards are capable of hauling out boats up to approximately 26 m (85 feet) in length.

All active commercial deep-draft facilities are located on the south bank of the Piscataqua River between the first bridge, Memorial Highway Bridge, and Dover Point and have highway connections, and all except the Defense Fuel Support Point Newington Dock have rail connections. Deepwater facilities at Portsmouth include seven petroleum terminals and 3 general cargo terminals.

Depths of about 10.3 m (34 feet) are present in the marked channel through Portsmouth Harbor to the Memorial (U.S. Route 1) Highway Bridge. From this bridge, a dredged marked channel with a depth of 7.9 m (26 feet) leads for about 3.0 nm (3.5 miles) to a turning basin about 0.35 nm (0.4 mile) above Frankfurt Island in the Piscataqua River. The controlling depth in the turning basin is 10.7 m (35 feet).

The principal bridges in Portsmouth Harbor are Memorial (U.S. Route 1) Highway Bridge, which has a lift span with clearances of 5.8 m (19 feet) down and 45.7 m (150 feet) up, and the combined U.S. Route 1 Bypass highway and Boston and Maine railroad bridge, which also has a lift span with clearances of 3 m (10 feet) down and 41 m (135 feet) up.

5.2.3 Providence, Rhode Island

Providence is located at the head of navigation on the Providence River, approximately 6 nm (7 miles) above the junction of the Seekonk River, which empties into the head of Narragansett Bay between Nayatt Point and Conimicut Point. The port’s chief waterborne commerce includes petroleum products, cement, lumber, steel scrap metal, general cargo, and automobiles. Providence is served by rail, highway, and air.

The piers and wharves of the Port of Providence are located along both sides of the Providence River below Fox Point. Deepwater facilities at Providence include six petroleum terminals, one LNG terminal, and six general cargo terminals. The alongside water depths range from 8.5 to 12.2 m (28 to 40 feet) with berth lengths ranging from 152 to 396 m (approximately 500 feet to 1,300 feet). All the facilities described have highway connections, and most have rail connections.

The port contains 42.5 hectares (105 acres) of on-dock rail, open storage areas and covered warehouses, and is a fully licensed, bonded deep water port specializing in dry, liquid bulk, and break-bulk commodities (see Figure 5-13). Among the principal products moving through the port are chemicals, heavy machinery, lumber, coal, scrap metal and steel products. The Providence and Worcester Railroad’s on-dock rail facilities allow direct vessel to rail transfer, indoor rail for warehouse loading, and a rail line alongside 8.1 hectares (20 acres) of open lay down area. The Providence and Worcester rail line connects to all major rail carriers offering service from the Providence area to anywhere in the contiguous U.S. and Canada.

Figure 5-13 Port of Providence
(Source: http://www.provport.com)

The East Passage, the principal passage in Narragansett Bay, has a depth of about 18.3 m (60 feet) for approximately 9.6 nm (11 miles) up the marked channel to the entrance of the dredged channel to Providence. The Newport Bridge, a fixed highway suspension bridge, crosses East Passage about 3.1 nm (3.6 miles) above the entrance. Vertical clearance through the 457 m (1,500 foot) wide center span is 64.9 m (213 feet) at the center, with lower clearances towards the outside of the center span.

The Providence River has a 12.2 m (40 foot) deep channel from just below Prudence Island Light to Fox Point near the junction of Providence and Seekonk Rivers. A hurricane barrier crosses the Providence River about 183 m (600 feet) above Fox Point. The hurricane barrier has a group of three large movable gates that span the Providence River. Each of the three gates is 12 m (40 feet) wide. The narrow gates prohibit large ships from passing into the inner downtown harbor. However, modern ocean-going vessels now dock at the Port of Providence, located south of the barrier (Schachterle et al 2010). There are no bridges over Providence River between the mouth and the principal wharves.

5.2.4 Quonset Point / Davisville, Rhode Island

Situated between New York and Boston and at the entrance of Narragansett Bay, the Port of Davisville in Rhode Island provides one of the best deep water ocean ports on the east coast. Major cargo arriving at the port includes automobiles, quarried stone, and general cargo. The port has three major piers with over 2,073 m (approximately 6,800 linear feet) of deep water dockage and onsite rail tracks. The Port of Davisville is operated by the Rhode Island Economic Development Corporation (see Figure 5-14).

Figure 5-14 Quonset Business Park
(Source: RI Department of Environmental Management)

Quonset Point is located on the north side of Wickford Harbor, with Quonset Point Business Park located near the eastern end of the point. The site of two former U.S. Naval installations, Quonset Business Park comprises over 1,214.1 hectares (3,000 acres) of land. This land is currently administered by the Quonset Development Corporation (QDC), a subsidiary of the Rhode Island Economic Development Corporation. Land uses within the Park currently consist of mixture of industrial (light, heavy, and waterfront), office uses and public amenities, in addition to the Port of Davisville. The Port of Davisville offers 1,371.6 m (4,500 feet) of berthing space, consisting of two Piers (each 365.8 m [1,200 feet] in length), a bulkhead, 8.8 m (29-foot) channel draft, on-dock rail and a 5.7 hectare (14 acre) lay down area (Quonset Development Corporation website). Currently under construction at the Business Park is a mixed-use project with hotel, retail, restaurant, and office space. The piers at Quonset Point and Davisville are usually approached from East Passage and through a buoyed dredged channel with a depth of 10 m (33 feet) to a turning basin with depths between 9.75 and 10.7 m (32 and 35 feet), from which a channel leads to the piers at Davisville.

Rail service, provided daily by the Providence & Worcester (P&W) Railroad, consists of approximately 14 miles of track in two branches. The P&W rail network allows access to the entire United States and Canadian rail system. The railroad offers double-stack intermodal transportation services and provides a custom-house broker, shipping agent and forwards foreign freight for its customers. Interstate Routes 95, 195 and 295 allow access to regional and national markets. Direct trucking service is available to every state, Mexico, and most of the Canadian Provinces.

5.2.5 New Haven, Connecticut

New Haven Harbor, an important harbor of refuge, is located about 59 nm (68 miles) from New York, 155 nm (179 miles) from Boston via the Cape Cod Canal, and 149 nm (171 miles) from the Nantucket Shoals Lighted Whistle Buoy N (LNB). It is the largest deep water port in Connecticut and comprises all the tidewater northward of breakwaters constructed across the mouth of the bay, including the navigable portions of the West, Mill, and Quinnipiac Rivers. The inner harbor, northward of Sandy Point and Fort Hale, is shallow for the most part, except where the depths have been increased by dredging. Waterborne commerce in the harbor consists of petroleum products, scrap metal, lumber, automobiles, gypsum, paper and pulp products, steel products, chemicals, rock salt, and general cargo.

The main channel has a depth of 10.7 m (35 feet) and a width of 122 to 244 m (400 to 800 feet) to a point just below the junction of Mill River and Quinnipiac River (see Figure 5-15). This channel depth is sufficient for accommodating ships in the range of 18,156 to 36,312 mt (approximately 20,000 to 40,000 deadweight tons). Tomlinson Bridge, at the head of the main harbor at the confluence of Mill and Quinnipiac Rivers, is a vertical lift span with a horizontal clearance of 73.1 m (240 feet) and a vertical clearance of 4.0 m (13 feet) down and 18.6 m (61 feet) up. Just above this bridge is a fixed highway bridge with a clearance of 18.3 m (60 feet).

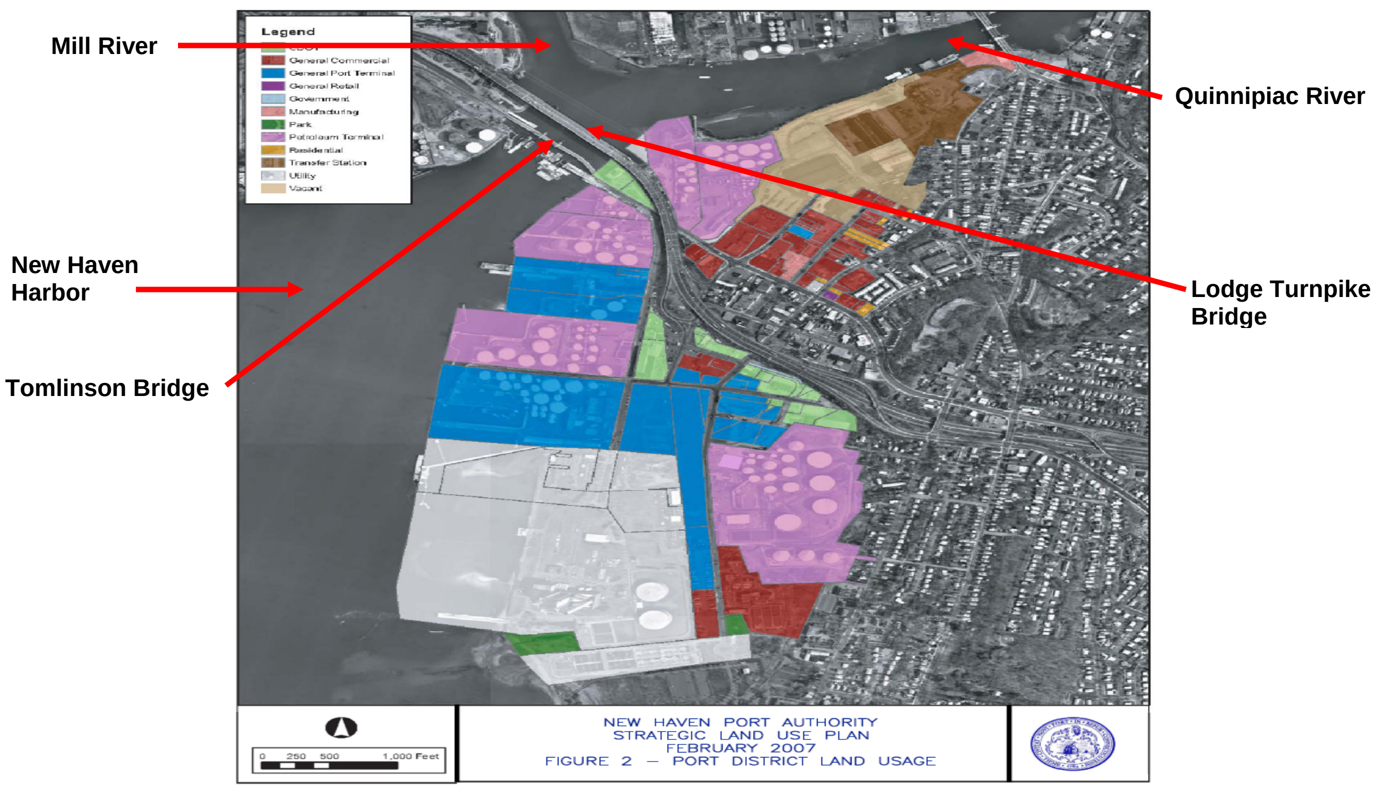


Figure 5-15 Aerial View of New Haven Harbor
(Source: http://www.cityofnewhaven.com/PortAuthority)

The deep draft facilities at the Port of New Haven are along the north and east sides of the inner portion of New Haven Harbor. Facilities for smaller vessels and barges are along the sides of the harbor and in Mill, Quinnipiac, and West Rivers. All deep draft facilities have direct highway connections, and most have railroad connections. The port is proximate to the regional highway network and I-95. Rail service is being restored to the port along with a series of siding tracks proposed for the private terminals. Rail service is provided by the P&W Railroad, and, although not serving the port directly, CSX provides rail freight service in the New Haven area.

New Haven has no facilities for making major repairs or for dry-docking deep draft vessels. However, machine shops in the area can make limited repairs to machinery and boilers and fabricate shafts and other pieces of equipment.

5.2.6 New York and New Jersey

New York Harbor is the principal entrance by water to New York City and the surrounding ports. The harbor is divided by The Narrows into Lower Bay and Upper Bay. The Battery, the southern tip of Manhattan, is at the junction of East River and Hudson River. The main channel from the sea to the deep water terminals in the Hudson River has a depth of 13.7 m (45 feet).

The Verrazano-Narrows Bridge between the Lower Bay and the Port of New York and New Jersey has vertical clearances of between 55.8 and 66.5 m (183 feet and 215 feet). There also are three fixed bridges with vertical clearances ranging from 127 feet to 135 feet.

The Port of New York and New Jersey (see Figure 5-16) has over 1,100 waterfront facilities. Most of these facilities are privately owned and operated, and the rest are owned or operated by either the railroads serving the port, the Port Authority of New York and New Jersey, the City of New York, the States of New York or New Jersey, the Federal Government, or other municipalities. This bi-state port includes terminals in New York City and across New York Harbor in Elizabeth, NJ and Newark, NJ. The port has a major steamship passenger terminal, containership terminals, break-bulk general cargo terminals, and petroleum and other liquid cargo facilities. Most of the waterfront facilities throughout the port have highway and railroad connections. The Port Authority is undertaking a $600 million ExpressRail project to build or expand on-dock and near-dock rail terminals. The Port of New York and New Jersey is served by three trunk line railroads and one short-line railroad, numerous trucking firms engaged in long-haul and short-haul freight service, and several bus companies. Elizabeth, NJ offers the only double-stack intermodal rail access to the port.

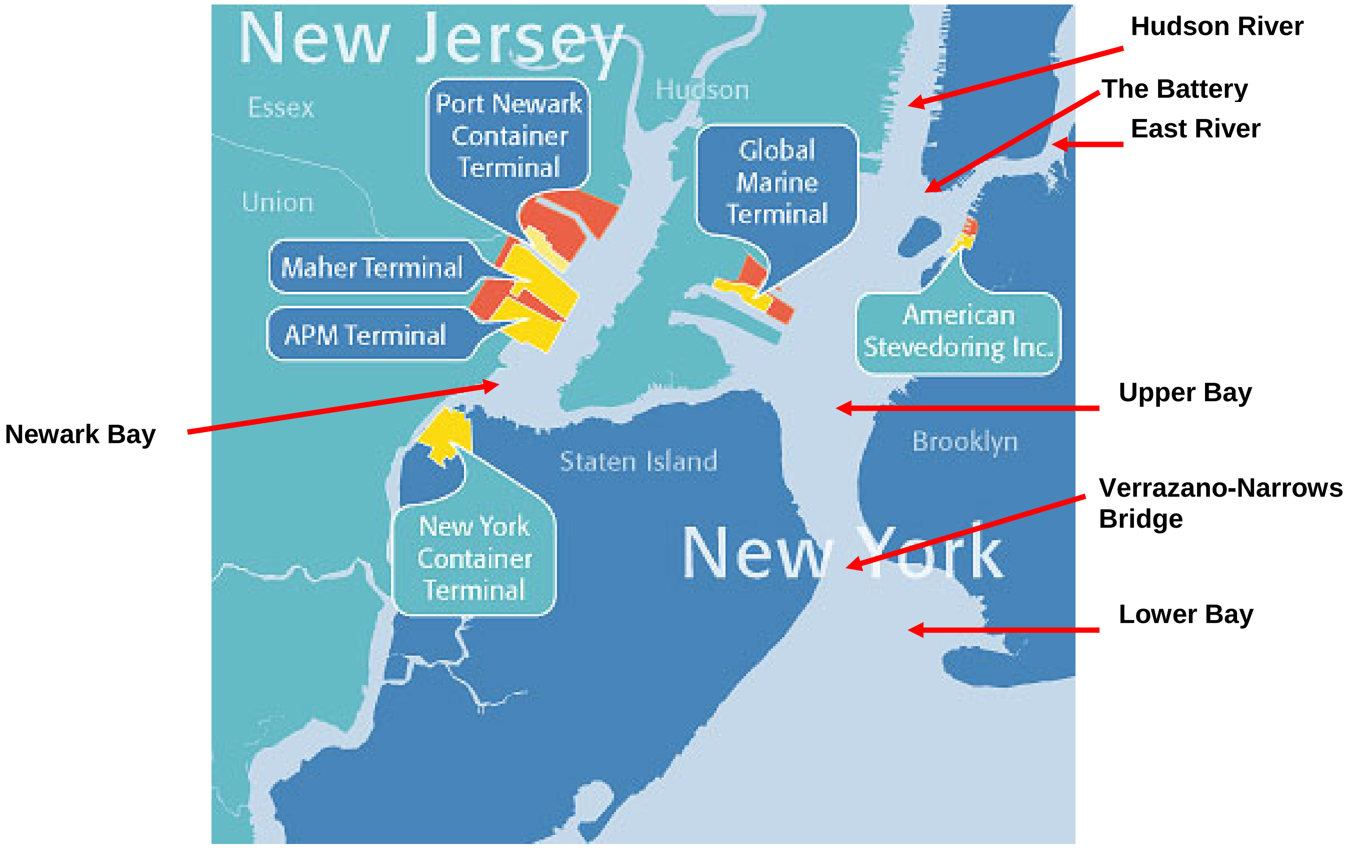


Figure 5-16 Terminal Areas at the Port of New York and New Jersey
(Source: http://www.panynj.gov/port)

5.2.7 Philadelphia, Pennsylvania

Philadelphia is one of the chief ports of the United States and is located at the junction of the Delaware and Schuylkill Rivers (see Figure 5-17). Philadelphia's seaport focuses on several areas of international trade, such as the importing of perishable cargoes from South America and high-quality paper products from Scandinavia. Philadelphia has both container and break-bulk terminals, along with good rail and highway connections. It is especially strong as a Northeast departure point for carriers in the Caribbean islands trades, and for inbound fruit shipments (from Latin America) and meats (from Australia). There have been efforts for years to create a bi-state port with the Port of South Jersey across the Delaware River in Camden, NJ.

The main channel from the sea to the Philadelphia Naval Shipyard has a depth of 12.2 m (40 feet), with the other channels through Philadelphia Harbor having varying depths. The Port of Philadelphia is in the process of deepening the main channel to 13.7 m (45 feet). There are four bridges between Delaware Bay and the Port of Philadelphia with vertical clearances ranging from 39 to 57.9 m (128 feet to 190 feet).

Figure 5-17 Port of Philadelphia
(Source: http://aapa.files.cms-plus.com/SeminarPresentations/07_OPSAFIT_Walsh_Jim.pdf)

The Port of Philadelphia is operated by the Philadelphia Regional Port Authority. Philadelphia has more than 45 deep water piers and wharves along its Delaware River waterfront and along the Schuylkill River. Port facilities can be accessed by vessel, rail and highway. The port facilities are serviced by three railroads. Norfolk Southern provides double-stack intermodal service between Philadelphia and major Midwest destinations. Terminal facilities are located in close proximity to interstate highways.

5.2.8 Baltimore, Maryland

The Port of Baltimore is located at the head of tidewater navigation on the Patapsco River. Baltimore Harbor consists of the entire Patapsco River and its tributaries. While part of the waterfront lies outside the municipal limits of Baltimore, by state law the port is within the jurisdiction of the Maryland Port Administration. When compared to other East Coast ports, Baltimore has a logistical disadvantage as it is 109 nm (125 miles) inland from the ocean, up the Chesapeake Bay.

The main channel between the Virginia Capes and Fort McHenry, Baltimore has a depth of 15.2 m (50 feet), and other channels in the harbor have depths ranging from 12.2 to 15.2 m (approximately 40 to 50 feet). The main channel between the Delaware Capes and Baltimore via the Chesapeake and Delaware Canal is 10.7 m (35 feet) deep.

Principal imports include general cargo, petroleum products, coke of coal, iron ore, aluminum manganese, inorganic chemicals, salt, gypsum, lumber, motor vehicles, fertilizers and sugar; exports are chiefly: general cargo, coal, automobiles and machinery. Most of the piers and wharves in Baltimore Harbor have direct connections with mainline railroads. CSX offers double-stack intermodal service at the 28.3 hectares (70 acre) Seagirt Marine Terminal. More than 100 steamship companies connect Baltimore with principal U.S. and foreign ports. About 150 motor truck carriers service the port.

Baltimore is well equipped to make major repairs to large vessels. The largest graving dock and the largest floating dry-dock in the area are located at the Bethlehem Steel Sparrows Point yard. Marine railways can haul out vessels up to approximately 38 m (125 feet) and up to 270 mt (approximately 300 tons). A plan to dredge the port's berths to 15.2 m (50 feet), the same depth as the main channel, is under consideration (see Figure 5-18).

Figure 5-18 Port of Baltimore
(Source: http://en.wikipedia.org/wiki/File:Baltoport.jpg)

5.2.9 Wilmington, Delaware

The Port of Wilmington is a full-service deep water port and marine terminal handling over 400 vessels per year. This port has an annual import/export cargo tonnage of over 3.63 million mt (4 million tons). Today, Delaware's port is the busiest terminal on the Delaware River. Located at the confluence of the Delaware and Christina Rivers, 56.5 nm (65 miles) from the

Atlantic Ocean, the port is owned and operated by the Diamond State Port Corporation (see Figure 5-19). The Port of Wilmington has wharves that support barge traffic as well as deep water facilities. The Port facilities include seven deep water general cargo berths, a tanker berth, a floating berth for roll on/roll off vessels on the Christina River, and an automobile and roll on/roll off berth on the Delaware River. The Port of Wilmington has the nation's largest dock-side cold storage facility.

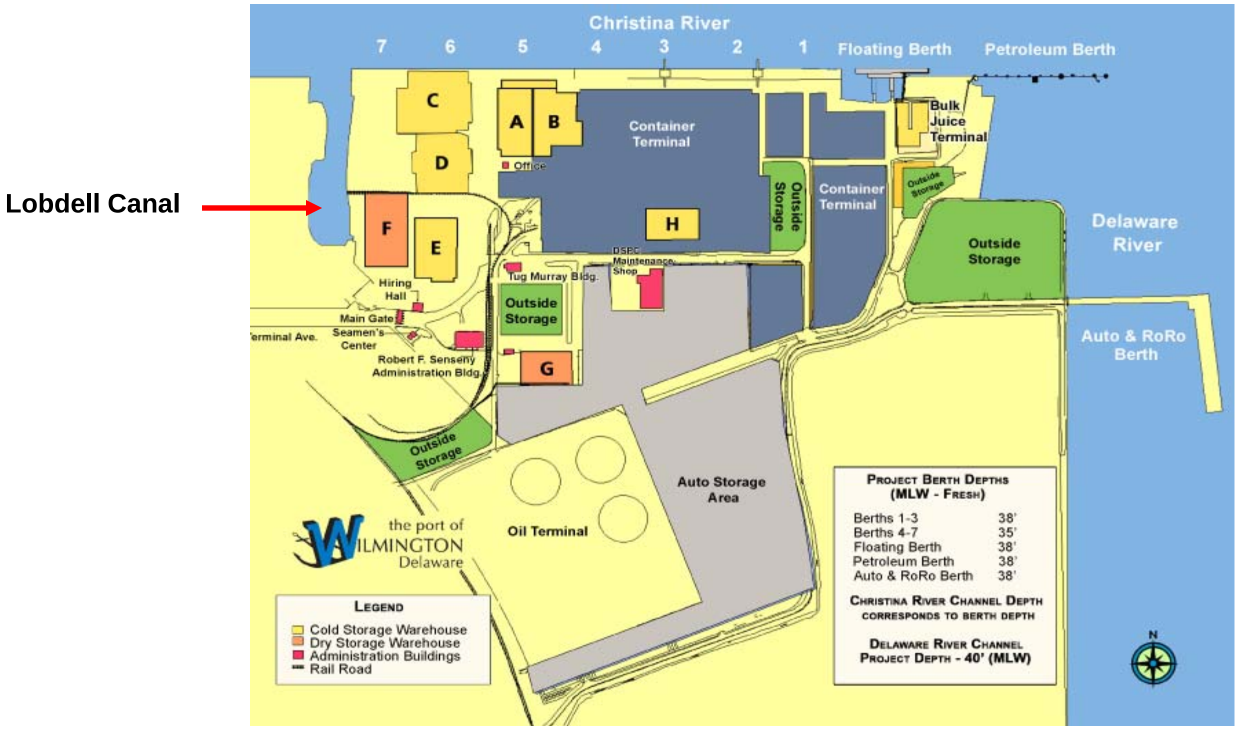


Figure 5-19 Terminal Areas at the Port of Wilmington
(Source: http://dedo.delaware.gov)

There are no bridges or overhead power cables over the deep water section of the Christina River. The Delaware Memorial Bridge has twin suspension spans over the main channel with a clearance of 57.3 m (188 feet). There is a 10.7 m (35 foot) channel from the Delaware River to Lobdell Canal and a 11.6 m (38 foot) deep turning basin opposite the Wilmington Marine Terminal.

Since it was founded in 1923, the Port of Wilmington has been a major Mid-Atlantic import/export gateway for a wide variety of maritime cargoes and trade. Future expansion is planned to provide more storage capacity for existing and future commercial businesses. Rail access to the port is available via Norfolk Southern and CSX Transportation, with railcar loading docks located next to terminal warehouses.

5.2.10 Virginia Port Authority

Chesapeake Bay, the largest inland body of water along the Atlantic coast of the United States, is 146 nm (168 miles) long with a width of 20 nm (23 miles). The bay is the approach to Norfolk, Newport News, Baltimore, and many lesser ports. Deep-draft vessels use the Atlantic entrance, which is about 8.7 nm (10 miles) wide between Fisherman's Island on the north and Cape

Henry on the south. Medium-draft vessels can enter from Delaware Bay on the north via Chesapeake and Delaware Canal, and light-draft vessels can enter from Albemarle Sound on the south via the Intracoastal Waterway. The Port of Virginia has the advantage of being served by the deepest ice-free channels on the East Coast. When the harbor is dredged to a 15.2 m (50 foot) depth, Norfolk will be the first East Coast port able to accommodate a fully loaded 8,000-TEU ship, which means the port would be able to accommodate large purpose-built offshore wind vessels (see Figure 5-20).

Figure 5-20 Port of Virginia
(Source: Google Earth)

Hampton Roads, at the southwest corner of Chesapeake Bay, is entered 13.9 nm (16 miles) westward of the Virginia Capes. It includes the Port of Norfolk and the Port of Newport News. Hampton Roads is the world's foremost bulk cargo harbor. Coal, petroleum products, grain, sand and gravel, tobacco, and fertilizer constitute more than 90 percent of the cargo handled at Hampton Roads ports. Hampton Roads ports are served by a terminal beltline, several large railroads, and by more than 50 motor carriers. In addition, over 90 steamship lines connect Hampton Roads with the principal U.S. and foreign ports.

Norfolk Harbor comprises a portion of the southern and eastern shores of Hampton Roads and both shores of the Elizabeth River. Norfolk Harbor has numerous wharves and piers of all types, the majority of which are privately owned and operated. All have freshwater connections and access to highways and railroads.

The Virginia Port Authority is expanding capacity to meet increased demand for terminal space. When this renovation is complete, it will be home to eight of the largest cranes in the world and the wharf will be a state-of-the-art facility capable of handling the heaviest cargo in the world. In addition, Maersk Sealand plans to invest a total of $450 million for a new terminal on approximately 100 hectares (250 acres) of Virginia Port Authority property in nearby Portsmouth, Virginia, the first major privately developed terminal in the United States.

Hampton Roads has extensive facilities for dry-docking and making major repairs to large deep-draft vessels. The shipyard at Newport News has one of the largest and best equipped graving docks in the United States. There are many other yards that are especially equipped to handle medium-sized and small vessels.

The approach to Hampton Roads is through the 16.7 m (55 foot) Thimble Shoal Channel. There are natural depths of 6.1 to 24.2 m (20 to 80 feet) in the main part of Hampton Roads, but the harbor shoals to less than 3 m (10 feet) toward the shores. Dredged channels lead to the principal ports. Two main Federal channels, marked by buoys, lead through Hampton Roads.

5.3 U.S. East and Gulf Coast Shipyard Construction and Repair Capacity

The construction of new tonnage and repair of marine equipment in both the propelled and non-propelled market has become an issue in recent years because of shifting shipyard capacity throughout the world. While new capacity in other parts of the world has replaced lost capacity in the U.S., declining domestic demand has reduced the number of available shipyards in this country for new construction or repair of large vessels. At the same time, recent regulations such as the Jones Act, require vessels in domestic service or operating in domestic waters to be built and serviced in U.S. yards. As the number of yards available for new construction or repair decreases due to declining demand, the number of yards able to comply with Jones Act requirements also decreases. This is particularly evident in the Northeast U.S. where shipyards able to handle large tonnage vessels, including deep water cargo ships, tankers and specialty vessels such as offshore delivery and support vessels, have dramatically decreased.

While yards that handle large tonnage vessels have decreased, the demand has remained relatively stable for yards that handle smaller vessels such as tugs, offshore service vessels and barges. Current and anticipated demand for commercial construction of cargo and petroleum vessels has been addressed by fewer facilities that have increased their size and capability in some cases.

Specialty wind farm vessels have unique construction and servicing requirements. For the purpose of this analysis, a purpose-built vessel with a length overall (LOA) of 143 m (470 feet) and a width (beam) of 39.6 m (130 feet) was selected to establish the largest dimensions for representative turbine import and installation vessels. Smaller service vessels including offshore supply boats (that can be readily adapted for serving offshore wind farm equipment) and tug and barges also were considered as they are employed regularly in offshore activities. Whereas installation and service vessels handling offshore wind turbine components within the territorial waters of the U.S. would be subject to the Jones Act, import/delivery vessels could be foreign flagged if their operation were limited to equipment delivery at a single U.S. port.

The following analysis assesses construction capacity and repair capacity at U.S. shipyards. See Appendix H for more detail.

5.3.1 Construction Demand and Capacity

Construction demand for small vessels over the last nine years in the U.S. has been steady and has increased due to the fact that numerous vessels are reaching the end of their serviceable life. A growing number of stricter regulations and replacement requirements have increased demand for new small vessel construction in recent years, particularly in the tug and barge industry. Tug and barge construction demand is illustrated in Table 5-2.

Table 5-2
Nine Year Tug and Barge Construction Demand-U.S. Shipyards
(Source: MARAD Shipbuilding Statistics)

Vessel Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	9-Year Totals	Average per Year
Tugs and Towboats	72	63	73	60	73	70	94	121	165	791	88
Dry Cargo Barges >5000 Gross Tons	1	3	2	0	4	1	3	2	4	20	2
Inland Dry Cargo Barges	775	609	672	217	427	219	672	846		4,427	553

Vessel construction has begun to increase over the last several years as the need for larger and more versatile vessels has risen. Towing and offshore supply companies are replacing smaller horsepower vessels with larger units, such as tractor tugs or higher capacity, higher horsepower supply vessels.

Barge construction is of particular importance as the servicing and installation of offshore renewable energy facilities may well be handled by tugs and barges because of their lower operational costs. The demand for barge construction is using up ship construction capacity in the yards where offshore specialty vessel construction could take place. Production of tank barges has increased to meet regulatory requirements for double-hulled barges under the Oil Pollution Act of 1990 (OPA 90). The age comparison between the overall barge fleet and tank barges is of note. Only 30% of all barges are more than 25 years old, whereas fully 50% of tank barges are 25 years or older. This is expected to result in a surge of tank barge orders in the next 5 years to replace existing barges aging past their prime. In 2008 alone more than 132 new tank barges were built, increasing delivery times and reducing capacity for other types of construction. While shipyards are positioned to meet most vessel construction demands, there are longer delivery times for new vessels. At present there is sufficient building capability to meet both new construction demands with backlogs running six months to one year. This is considered by the industry to be reasonable for vessel orders and deliveries. Due to the complexity and unique nature of specialty offshore vessels, a significantly longer lead time should be considered when calculating construction cycles and delivery needs.

There were recently 63 vessels under construction that have been delivered or planned for delivery by U.S. shipyards by the end of 2009, most being tugs and towboats. A compilation of the results of a survey conducted of shipyards with recently completed contracts is presented in Table 5-3.

Table 5-3
Recent Shipyard Contracts as of 2009
(Source: MARAD Shipyard Statistics)

Vessel Name	Shipyard	Owner	Type	GT	Delivery
Safety Team	B. & B. Boatbuilders	AEP River Operations	1,550-hp Towboat	157	May-09
Miss Lucy	B. & B. Boatbuilders		Pushboat	29	May-09
Shiney V. Moran	C. & G. Boat Works	Moran Towing	5,360-hp Tug	192	May-09
Roger Binsfeld	Hope Services	Brennan Marine	Towboat	144	May-09
Mountain State	Quality Shipyard	AEP River Operations	6,000-hp Towboat	774	May-09
Coon Wise	GNOTS Marine	GNOTS Reserve	2,400-hp Towboat	107	May-09
Blake Boyd	Eastern Shipbuilding	Florida Marine	2,600-hp Towboat	260	May-09
Pat Voss	Verett Shipyard		Towboat	347	Apr-09
Yellowfin	Thoma-Sea Shipbuilders	Penn Maritime	4,000-hp ATB Tug	223	Apr-09
San Brendan	Bludworth Shipyard	Buffalo Marine	1,320-hp Towboat	185	Apr-09
Elvis	Inland Boat Works		Pushboat	52	Apr-09
Hunter M	Orange Shipbuilding	Bay-Houston Towing	6,300-hp Escort Tug	425	Mar-09
Salvation	Raymond & Associates	Eckstein Marine	2,000-hp Towboat	167	Feb-09
Greg McAllister	Eastern Shipbuilding	McAllister Towing	6,000-hp Tug	172	Jan-09
Severn	Thoma-Sea Boatbuilders	Vane Brothers	4,200-hp Tug	341	Jan-09
Corpus Christi	Eastern Shipbuilding	US Shipping	12,000-hp ATB Tug	919	Jan-09
C-Tractor 19	GulfShip	Alpha Marine Services	Tractor Tug	298	4-May-09
Parker A. Settoon	Eastern Shipbuilding	Settoon Towing	3,000-hp Towboat	289	22-Apr-09
Joshua Caleb	A. & B. Industries	CLM Marine	Towboat	95	22-Apr-09
Lamar Golding	D.E.S. Boatworks	Golding Barge Line	Towboat	277	20-Apr-09
Susanne T	Hardrock Marine Services	Endeavor Marine		21	16-Apr-09
Scott Stegbauer	Steiner Shipyard	Southern Towing	3,200-hp Towboat	402	14-Apr-09
George	Main Iron Works	Harbor Docking	6,140-hp Harbor Tug	734	10-Apr-09
Miss Cassie	Robert Crawley	Robert Crawley	Pushboat	13	9-Apr-09
Safety Forever	B. & B. Boatbuilders	AEP River Operations	1,550-hp Towboat	157	9-Apr-09
Janis R. Brewer	Eastern Shipbuilding	Crounse Corp.	4,000-hp Towboat	472	9-Apr-09
Ruth M. Reinauer	SENESCO	Reinauer Transportation	4,000-hp ATB Tug	485	8-Apr-09
Capt C H Guidry	Eastern Shipbuilding	Florida Marine	2,600-hp Towboat	260	7-Apr-09
Mannie Cenac	Intracoastal Iron Works	Cenac Towing	Pushboat	95	3-Apr-09
Captain Robert	A. & B. Industries	Odyssea Vessels	4,200-hp Towboat	97	31-Mar-09
Anacostia	Thoma-Sea Boatbuilders	Vane Brothers	4,200-hp Tug	341	30-Mar-09
Genie Cenac	Tres Palacios Marine	Cenac Towing	3,200-hp Towboat	189	27-Mar-09
Delta Billie	Nichols Bros Boatbuilding	Bay Delta Marine	6,800-hp Escort Tug	194	26-Mar-09
Commitment	VT Halter Marine	Crowley Marine	9,280-hp ATB Tug	465	26-Mar-09
Holy Cross	Raymond & Associates	Eckstein Marine	2,000-hp Towboat	167	16-Mar-09
Affirmed	C. & C. Boat Works	Turn Services	Towboat	147	10-Mar-09
Kyle A Shaw	Hope Services	Maryland Marine	1,800-hp Towboat	144	4-Mar-09
Capt Dean	Eastern Shipbuilding	Florida Marine	2,600-hp Towboat	260	27-Feb-09
AK Hotchkiss	Progressive Industrial	Riverside Basin Marine	Pushboat	17	26-Feb-09
W. J. Authement	Intracoastal Iron Works	Intracoastal Iron Works	Towboat	95	25-Feb-09
Patuxent	Thoma-Sea Boatbuilders	Vane Brothers	4,200-hp Tug	341	25-Feb-09

Vessel Name	Shipyard	Owner	Type	GT	Delivery
Morgan City	Raymond & Associates	Kirby Inland Marine	1,800-hp Towboat	223	26-Feb-09
Austin C. Settoon	Eastern Shipbuilding	Settoon Towing	3,000-hp Towboat	289	19-Feb-09
Alton St. Amant	Sneed Shipbuilding	Blessey Marine	1,700-hp Towboat	249	19-Feb-09
Ted	Main Iron Works	Harbor Docking	6,140-hp Habor Tug	481	17-Feb-09
Safety Priority	B. & B. Boatbuilders	AEP River Operations	1,550-hp Towboat	157	17-Feb-09
Sesok	Diversified Marine	Vessel Mgmt. Svces.	1,362-hp Tug	143	12-Feb-09
Nachik	Diversified Marine	Vessel Mgmt. Svces.	1,362-hp Tug	133	12-Feb-09
Orca One	Geo Shipyard	Orca Maritime	Towboat	299	10-Feb-09
Panther	Serodino	Serodino	Towboat	75	10-Feb-09
Gladiator	Gulfbound	Dragnet Seafood	Towboat	90	10-Feb-09
Mr Nelson	Diversified Marine	AC Marine	Towboat	77	4-Feb-09
Danny L Whitford	Gulf Inland Marine	Hunter Marine Transport	Towboat	445	3-Feb-09
Celine B	Inland Boat Works	Joseph B. Fay Co.	Pushboat	23	29-Jan-09
Anna Marie	A. & B. Industries	Terral Riverservice	Towboat	80	29-Jan-09
Donnie Verret	Verret Shipyard	T & B Towing	Towboat	73	23-Jan-09
Cynthia G Esper	Marine Builders	SCF Marine	3,200-hp Towboat	256	23-Jan-09
Holy Rosary	Raymond & Associates	Eckstein Marine	2,000-hp Towboat	167	14-Jan-09
Perry M D	Perry & Son Towing	Perry & Son Towing	Towboat	82	12-Jan-09
Lady Loren	Lockport Fabrication	LA Carriers	1,980-hp Towboat	96	12-Jan-09
Blessed Trinity	Raymond & Associates	Eckstein Marine	2,000-hp Towboat	167	7-Jan-09
Citation	C. & C. Boat Works	Turn Services	Towboat	147	6-Jan-09
Safety Challenger	B. & B. Boatbuilders	AEP River Operations	1,550-hp Towboat	157	6-Jan-09
GT = Gross Ton = Long Ton = 1,016 kg = 2,240 pounds					

5.3.2 Shipyard Availability

The number of shipyards that have current capacity for large specialty vessel construction is limited within the U.S. Of the 350 active vessel construction companies in the U.S., only 52 have a history of significant vessel construction in the Eastern or Southern regions of the country. Eight are located on the U.S. Atlantic Coast and the rest on the U.S. Gulf Coast. Because of their proximity to potential offshore installation sites, Atlantic and Gulf coast shipyards were examined in more detail. A limited number of yards are capable of handling large specialty vessels based on yard size, but a number of them could handle smaller specialty vessels. The yards that can build vessels on the Atlantic and Gulf Coasts are highlighted in Table 5-4.

Table 5-4
Active East Coast and Gulf Coast Shipyards with Significant Construction Records
(Source: MARPRO Associates International 2009)

Shipyard	Location
Atlantic Coast	
Blount Boats	Warren RI
Chesapeake Shipbuilding	Salisbury, MD
Cianbro	Portland, ME
Derecktor Shipyards	Bridgeport, CT
Gladding-Hearn	Somerset, MA

Shipyard	Location
SENESCO	North Kingstown, RI
Washburn & Doughty	East Boothbay ME
Yank Marine	Tuckahoe, NJ
Gulf Coast	
A & B Industries	Morgan City, LA
B. & B. Boat Builders	Bayou La Batre AL
Bludworth Shipyard	Corpus Christi, TX
Boconco	Bayou La Batre, AL
C. & C. Boat Works	Belle Chase, LA
C. & C. Marine and Repair	Belle Chase, LA
C. & G. Boat Works	Bayou La Batre, AL
C. & G. Boat Works	Mobile, LA
Candies Shipbuilders	Houma LA
Conrad Industries	Morgan City, LA
Duckworth Steel Boats	Tarpon Springs, FL
Eastern Shipbuilding	Panama City FL
Eymard & Sons Shipyard	Harvey LA
Gulf Island Marine Fabrication	Houma, LA
Gulf Ship	Gulfport, MS
Halimar Shipyard	Morgan City, LA
Hope Services	Dulac, LA
Horizon Shipbuilding	Bayou La Batre, AL
Inland Marine	Bridge City, TX
Intracoastal Iron Works	Bourg, LA
Leevac Industries	Jennings LA
Lockport Fabrication	Lockport, LA
Main Iron Works	Houma LA
Marine Inland Fabricators / Sisco Marine	Panama City, FL
Master Marine	Bayou La Batre, AL
Master Boat Builders	Coden AL
Orange Shipbuilding	Orange TX
Patti Shipyard	Pensacola, FL
Portier Shipyard	Chauvin, LA
Progressive Industrial	Palmetto, FL
Quality Shipyards	Houma LA
Raymond & Associates	Bayou La Batre AL
Rodriguez Boatbuilders	Bayou La Batre, AL
Rodriguez Boatbuilders	Coden AL
SEMCO	Lafitte, LA
Sneed Shipbuilding	Channelview, TX
Sneed Shipbuilding	Orange, TX
Southwest Shipyard	Houston, TX
Steiner Shipyard	Bayou La Batre, AL

Shipyard	Location
Thoma-Sea Boatbuilders	Houma, LA
Thoma-Sea Shipbuilders (formerly Halter Lockport)	Lockport, LA
Trinity Madisonville	Madisonville, LA
Trinity Port Allen	Port Allen, LA
Verret Shipyard	Plaquemine, LA
West Gulf Marine	Galveston, TX

5.3.3 Capacity and Delivery Estimations

In the Northeast, many of the yards have compressed operations due to increasing environmental concerns and gentrification of industrial areas. Several of the yards confine activities to repair and have refocused their efforts on small craft (such as ferries, yachts and similar commercial watercraft). In the Gulf of Mexico, a number of the shipyards have not fully restored operations to pre-Katrina levels primarily due to a shortage of qualified personnel and absence of infrastructure.

The Gulf of Mexico region still has the highest percentage of multi-purpose construction and repair yards in the country. Average small vessel construction, such as tugs or offshore supply/service vessels, can run from six months to a year depending on complexity. Barge construction can run from 3 to 9 months depending on size and function. Construction of larger specialty vessels can exceed 12 to 18 months and run up to 24 months. There are several smaller yards in the Northeast and Gulf that have no backlogs and have immediate capacity for new vessel orders. Very few have multiple vessel capacity, and backlogs do not extend beyond 2011.

5.3.4 Vessel Repair Capacity

Most of the shipyards on the Atlantic Coast that build vessels also have some level of repair capacity. There is only limited repair capacity in New England. Some yards only handle military contracts. However, in recent weeks, General Dynamics has announced an expansion of its facilities in Bath, Maine to accommodate the construction of components for offshore wind farms. Atlantic Coast repair yards are listed in Table 5-5.

Table 5-5
Listing of Shipyards on the Atlantic Coast with Build and/or Repair Capacity
(Source: MARPRO Associates International 2009)

US Atlantic Coast	Type	Size	Location	State
Atlantic Marine Boston	R	L	Boston	MA
Atlantic Marine Florida	B	M	Jacksonville	FL
Bayonne Drydock	R	L	Bayonne	NJ
Blount Boats	B	S	Warren	RI
Broward Marine	B	Y	Dania Beach	FL
Caddell Dry Dock	R	S	Staten Island	NY
Chesapeake Sbldg.	B	S	Salisbury	MD
Cianbro	BR	S	Portland	ME
Davis Boat Works, Inc.	R	S	Newport News	VA
Derecktor Shipyard Connecticut	B	S	Bridgeport	CT

US Atlantic Coast	Type	Size	Location	State
Derecktor Shipyard Florida	BR	S	Dania	FL
Derecktor Shipyard New York	BR	S	Mamaroneck	NY
Detyens Shipyards	R	L	N. Charleston	SC
Detyens Shipyards	R	S	Jacksonville	FL
Fairhaven Shipyard	R	S	Fairhaven	MA
Fore River Dock and Dredge	BR	S	South Portland	ME
G.M.D. Shipyard	R	L	Brooklyn	NY
GD/Bath Iron Works	B	L	Bath	ME
GD/Electric Boat	B	L	Groton	CT
General Ship Repair Corp.	R	S	Baltimore	MD
Gladding-Hearn	BR	S	Somerset	MA
Global Ship Systems	R	S	Savannah	GA
Kelley Shipyard, D. N.	R	S	Fairhaven	MA
Lyon Shipyard	R	S	Norfolk	VA
Marine Hydraulics	R	T	Norfolk	VA
May Ship Repair Contracting	R	S	Staten Island	NY
Metro Machine of VA	R	L	Norfolk	VA
Muller Boat Works	R	S	Brooklyn	NY
Newport Shipyard Company	R	S	Newport	RI
Scarano Boat Building	B	S	Albany	NY
Seaboats	BR	S	Fall River	MA
SENESCO	B	S	North Kingstown	RI
Thames Shipyard & Repair Co.	R	S	New London	CT
Union Dry Dock & Repair	R	S	Hoboken	NJ
Washburn & Doughty	B	S	East Boothbay	ME
KEY Type Codes: B = Build; R = Repair Size Codes: S = small; M = medium; L = large				

5.3.5 Conclusions Relative to Construction and Repair Capacities on the Atlantic Coast

Large vessel construction and small vessel construction most likely would be handled by different shipyards. Yard capacity varies from region to region. The industry can meet the demand for a phased-in cycle of new vessels on a limited basis up to approximately three units per year using multiple yards in various regions of the U.S. Barge construction demand is expected to increase, thereby reducing overall new vessel construction capability. This will affect the ability of some shipyards to meet larger specialty vessel construction. New England has new construction capability limited to smaller vessels, but adequate repair capability for smaller vessels and some capacity for larger vessels. Both Atlantic and Gulf Coast shipyards will need to be considered to meet vessel construction and demand requirements. A developer should anticipate an 18-month lead time for design, contracting, construction and delivery of small vessels and up to 24 months for larger vessels.

6.0 SHORT-LISTING OF PORTS FOR FURTHER EVALUATION

Based on the evaluation criteria developed in Section 4 and analysis, the Team has concluded that New Bedford and Boston Harbor have the best potential to support the assembly and deployment of the planned and prospective offshore wind energy projects. The process by which these two short-listed ports were identified is described below.

6.1 Massachusetts Port Criteria Evaluation Matrix

As described in Section 4, the Team identified a broad set of direct requirements and highly desirable characteristics of port facilities relative to supporting offshore wind farm construction and operation. This list was further distilled down to a smaller set of criteria that could be used to differentiate the candidate port facilities based on the potential of that port to support offshore wind energy development. These criteria included some “hard” criteria that had minimum quantitative measures with which to judge the feasibility or suitability of a port relative to that consideration. Those ports that failed to meet the majority of our hard criteria (recognizing that modifications, upgrades or work arounds could potentially be made to ports relative to one or two characteristics to allow them to achieve the minimum threshold criteria) were eliminated from the evaluation process. This screening resulted in the selection of six Massachusetts ports (located in DPAs) for further consideration. The Massachusetts Port Criteria Evaluation Matrix (see Table 6-1) clearly demonstrates how these six Massachusetts ports compare against each other with respect to our established “hard” criteria. Application of the identified “soft” criteria was reserved for only the short-listed ports and is discussed later in this report.

Table 6-1
Massachusetts Port Criteria Evaluation Matrix

PARAMETERS		PORTS					
Criteria	**Recommended Values/Ranges**	**Boston**	**New Bedford**	**Fall River**	**Gloucester**	**Salem**	**Fore River**
First Tier Harbor Navigational Access							
Protected Harbor	Sheltered from Weather Conditions	Yes	Yes	Yes	Yes	Yes	Yes
Shipping Vessel Channel Depth	Minimum 7.3 m (24’)	12.2 – 13.7 m (40' - 45')	9.1 m (30')	10.7 m (40')	4.9 - 5.8 m (16' - 19')	9.4 m (31’)	9.8 m (32')
Overhead Clearance	No Vertical Obstruction	NVO, but FAA approval required	NVO	41 m (135')	NVO	NVO	53.3 m (175')
Horizontal Clearance	40 m (130') (beam plus overhang)	131 m (430')	45.7 m (150')	122 m (400')	61 m (200')	85.3 m (280')	53.3 m (175')
24/7 Operational Ability	24/7 operations	Yes	Yes	Yes	No	Yes	Yes
Exclusive Use of Port Facility	Ability to Offer Exclusive Use	Yes	Yes	No	No	No	Yes
Comments				Mt Hope Bridge height restriction	Navigational constraints	Salem DPA in full use by power plant	Fore River Bridge height restriction
Second Tier Port Facilities							
Berth Length	Minimum 138 m (450’)	549 m (1,800')	488 m (1,600')	189 m (620')	427 m (1,400')	177 m (580')	244 m (800')
Shipping Vessel Water Depth	Minimum 7.3 m (24’)	12.2 – 13.7 m (40' - 45')	9.1 m (30')	10.7 m (40')	4.9–5.8 m (16'-19')	9.4 m (31')	9.8 m (32')

Table 6-1
Massachusetts Port Criteria Evaluation Matrix

PARAMETERS		PORTS					
Criteria	**Recommended Values/Ranges**	**Boston**	**New Bedford**	**Fall River**	**Gloucester**	**Salem**	**Fore River**
Total Wharf and Yard Upland Area	4.0 hectares (10 ac)	5.7 – 6.9 hectares (14-17 ac)	4.0+ hectares (10+ ac)	2.8 hectares (7 ac)	3.2 hectares (7.8 ac)	NA	44.9 hectares (111 ac)
Rail Access	Rail Access	Limited	Limited	Yes	Yes	No	Yes
Highway Access	Highway Access	Yes	Yes	Yes	Yes	No	No
Comments				State Pier can only accommodate small cargo vessels.	Limited adaptable area	Insufficient work area; additional focus on tourism	Multiple berths/ rough estimate; plans for mixed-use waterfront development

Legend NVO = No vertical obstruction
[shaded box] = Criteria not met
NA = Not available for ROWEI staging

6.2 Implications of Applying the Hard Criteria Relating to Navigational Access and Port Facilities

6.2.1 Evaluation of Each Hard Criterion

Protected Harbor: All of the six Massachusetts ports are in protected harbors. The hurricane barrier in New Bedford adds an additional layer of protection for portside operations during inclement weather.

Shipping Channel Depth and Overhead Clearance: Navigational access to Fall River and Fore River is constrained by the overhead height restrictions of existing bridges (indicated by a shading of the matrix cell in Table 6-1), and the Port of Gloucester does not meet the minimum shipping channel depth of 24 feet. On the other hand, the shipping channels of New Bedford and Boston Harbors meet the minimum depth criterion. New Bedford's navigation channel is 30 feet deep, and the New Bedford HDC is proposing to dredge to extend the 30 foot channel to the planned bulkhead extension at the South Terminal. Navigation channels to Boston Harbor's DPA are between 40 feet and 45 feet deep. Both New Bedford and Boston Harbor have unobstructed overhead clearance. There are no vertical obstructions, such as bridges and/or power lines, which would prohibit offshore wind component delivery and installation vessels, including jack-up vessels, from accessing either harbor. However, as noted previously, FAA approval may be required in Boston Harbor because of the harbor's proximity to Logan International Airport.

Horizontal Clearance: None of the selected ports are restricted by horizontal (lateral) clearances less than 130 feet. The minimum horizontal clearance criterion eliminated facilities in New Bedford upstream of the New Bedford-Fairhaven Bridge (92 feet of lateral clearance). However, the South Terminal at New Bedford Harbor is downstream of the New Bedford-Fairhaven Bridge and upstream of the Hurricane Barrier.

24/7 Operational Ability and Exclusive Use of Port Facility: All ports being evaluated, with the exception of the Port of Gloucester, can operate around the clock and all year. The Ports of Gloucester and Salem also did not have the ability to offer exclusive use of their facilities.

Berth Length and Shipping Vessel Water Depth: Off-shore wind farm construction is associated with multiple berthing operations, including offloading of parts for final assembly or pre-assembly; loading of special barges with the pre-assembled or assembled elements (rotor with blades, foundations or tower sections); mooring of jack-up vessels, crane vessels or any type of specialty purpose-built vessel for service (fuel and maintenance), preparation and deployment; mooring and service of crew boats; emergency response support; and any other activity supporting staging and construction. The established berth length and channel and portside depth criteria reflected minimum requirements for accommodating these operations. The Port of Gloucester failed to meet the depth criterion. All other ports had sufficient length and depth.

Total Wharf and Yard Upland Area: Landside (upland) port facilities provide storage, staging and assembly work areas to facilitate offshore wind farm installation. To fulfill these tasks it is important that landside facilities have adequate acreage, warehouse space, onsite equipment, and high load bearing capacity. Most working ports have existing equipment that could be used or adapted to offload, assemble and load some or all current turbine and foundation components. The Team determined that given sufficient land area, storage, assembly, and load bearing issues could be addressed with improvements to the port. Neither Fall River, Gloucester, nor Salem has sufficient adaptable space for the work area required to support offshore wind farm staging.

Rail Access: None of the Massachusetts ports evaluated for this study has second generation rail access[7]. Existing tracks will not be able to handle the expected size of future generation nacelles and rolled steel components. Existing rail lines could be used primarily for delivery of aggregate and related products rather than turbine or foundation components. Whereas Fall River, Gloucester, and Fore River have existing freight rail lines to the waterfront, Boston and New Bedford currently have limited rail access, and Salem has none. Boston has active rail to the Boston Marine Industrial Park, but not to the North Jetty or Dry Dock #4. Boston has designed the rail extension to the North Jetty and Dry Dock #4, and funding for construction has been requested through a TIGER application[8]. New Bedford has rail access to the waters' edge, and there is a pending TIGER request[9] to connect the existing tracks to the State Pier, but not the South Terminal.

Highway Access: Road connections are important for transport of ancillary material and equipment, as well as personnel. Overweight and large shipment units are subject to state permitting requirements, which also take into account possible roadway infrastructure

[7] First generation rail clearance for container doublestack cargo is 19 feet above the rail (ATR). Second generation doublestack clearance is 22.5 feet ATR.

[8] The Boston Redevelopment Authority has requested a grant of $84 million for expansion of the Black Falcon Cruise Terminal; track improvements to the Boston Marine Industrial Park rail line; improvements to the East, North and South Jetties; and reconstruction of the FID Kennedy West and Access Roads.

[9] The New Bedford HDC has requested a grant of $36.4 million to improve North Terminal infrastructure; rehabilitate the rail line to the State Pier; update and rehabilitate Herman Melville Boulevard; procure cranes and modify terminals for roll on-roll off capability; and develop the southern portion of the South Terminal.

constraints, such as overhead utilities, road lighting, road curvatures and intersections. Neither Salem Harbor nor the Fore River Shipyard has capacity for high volume traffic flow due to local roadway congestion. There is no direct interstate highway access from the City of Salem; the nearest highway access to Route 128 is along Route 114 in neighboring Peabody. Fore River's access to the interstate highway network is via Route 3, a limited-access roadway that is about two miles away from the Shipyard.

6.2.2 Results of the Evaluations

Based on the hard criteria established in Section 4 and displayed in Table 6-1, the ports of Fall River, Gloucester, Salem, and Fore River fell short of the minimum requirements for navigational access and port infrastructure to support offshore wind development activities. The ports of New Bedford and Boston emerged as the two short-listed ports.

6.3 Engineering Cost Analysis of Port Upgrades at Short-Listed Ports

This section provides a further evaluation of the two short-listed ports and rough order of magnitude estimate of the required maintenance and upgrades that would improve the ability of those ports to serve offshore wind farm development.

6.3.1 New Bedford Harbor

The Team identified two possible locations in New Bedford Harbor that might reasonably support offshore wind farm construction. One is the South Terminal area (Figure 6-1) and the other is the State Pier facility (Figure 6-2). Both facilities failed to meet all of the hard criteria discussed above, and demonstrated some level of deficiency in their current physical condition.

6.3.1.1 South Terminal

The City of New Bedford has identified the expansion of the South Terminal (Figure 6-1) as a major priority. The City has applied for a TIGER grant to expand the berth by approximately 245 m (800 feet) and dredge a 9 m (approximately 30 feet) deep channel from the main channel to the new berth. The new facility would have significant backland load bearing capacity. There are between 5.6 and 8.1 hectares (14 and 20 acres) of land adjacent to the berth. The proposed rebuild would utilize a tied-back steel sheet pile bulkhead backfilled with the dredge spoils. The cost of the new bulkhead and dredging is estimated to be approximately $20 million. Table 6-2 presents the cost estimate for the South Terminal expansion.

Additional improvements, including paving, utilities and site equipment (such as a large crane), could add an additional $15 million and would provide a "future" life as a general cargo or container handling facility. The new bulkhead construction would allow the terminal to be designed to a high live load capacity, which will provide a significant number of options for material handling. Immediately adjacent to the site (across the street) there are several warehouses of approximately 930 m^2 (10,000 square feet) or more. There would be ample space to construct a shelter on the site without reducing the outside lay down space.

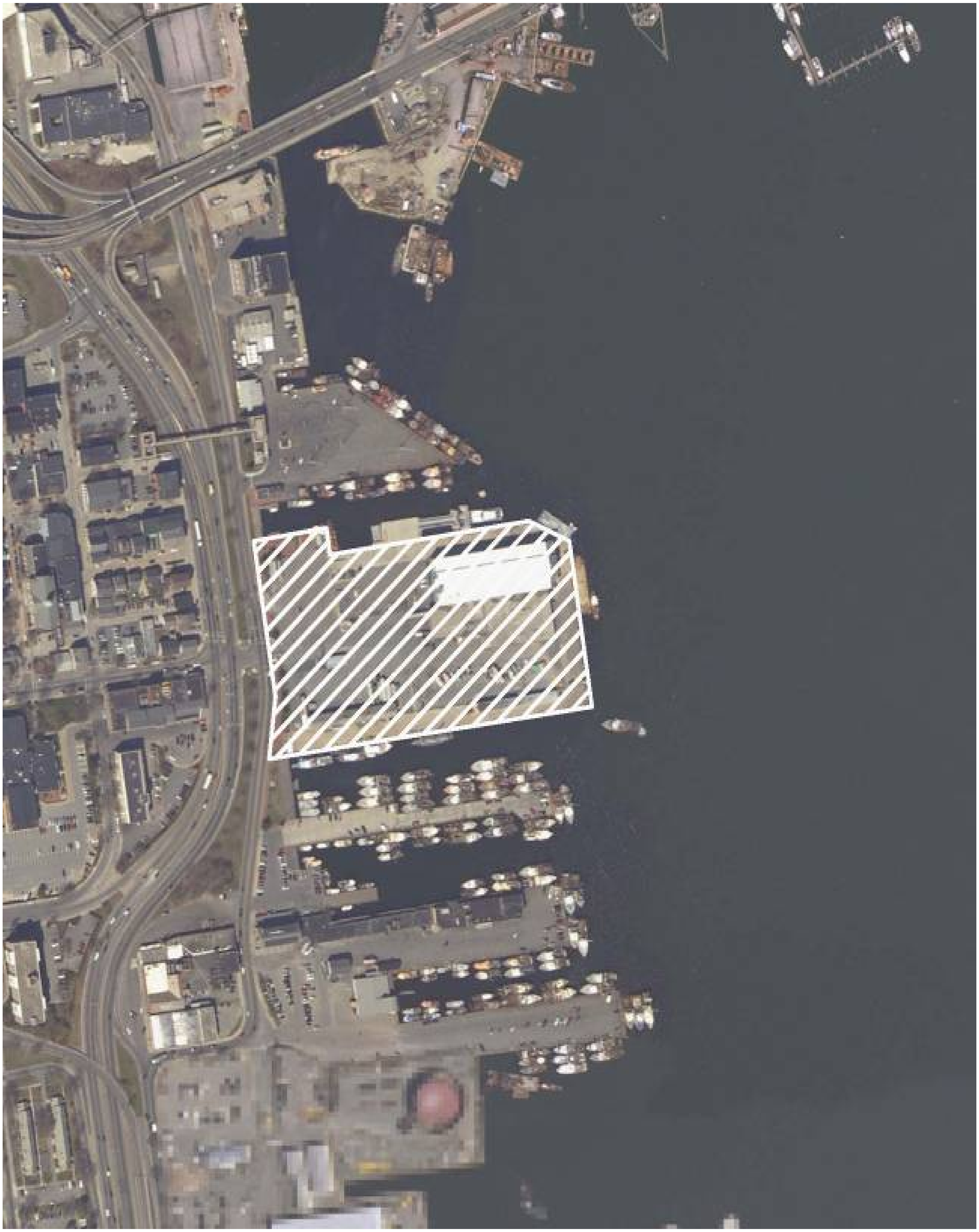


Figure 6-2 State Pier Port of New Bedford
(Source: Childs Engineering Corporation)

Figure 6-1 South Terminal Port of New Bedford
(Source: Childs Engineering Corporation)

Table 6-2
Cost Estimate for New Bedford Harbor South Terminal Expansion
(Source: Childs Engineering Corporation 2009)

Item Description	Quantity	Units	Unit Cost	Item Cost
Harbor Development Commission Staff	3	LS	$ 40,000	$ 120,000
Final Engineering/Procurement	1	LS	$ 1,000,000	$ 1,000,000
Organics Removal	15,185	CY	$ 35	$ 531,481
Organics Disposal (CAD Cell)	15,185	CY	$ 55	$ 835,185
Sheeting - PZ40	1,706,940	LB	$ 3	$ 4,267,350
Shoes for Sheets	273	EA	$ 250	$ 68,333
Mudslab Installation	3,796	CY	$ 200	$ 736,158
Wale -][MC12x31	42,813	LB	$ 3	$ 128,438
Weep Drains @ 10' o.c.	83	EA	$ 150	$ 12,410
Steel Sheeting Deadmen	246,000	LB	$ 3	$ 737,389
Excavation - Tie-Rods	3,677	CY	$ 15	$ 55,157
Tie-Rod	53,593	LB	$ 6	$ 321,559
Structural Fill - Tie-Rods	3,677	CY	$ 35	$ 128,700
Concrete Bulkhead Cap	103	CY	$ 650	$ 66,625
Concrete Slab	1,063	CY	$ 500	$ 531,345
Bollards, 61 ton/bitt	29	EA	$ 5,500	$ 161,794
12" Dia. Timber Piles (Fender)	86	EA	$ 3,000	$ 258,032
Timber Bracing				
12" X 12" Fender	665	BFM	$ 4.50	$ 2,992
8" X 12" Fender	867	BFM	$ 4.50	$ 3,902
Dredge/Placement of Material Behind Bulkhead	153,000	CY	$ 40	$ 6,120,000
Dredging Channel to South Terminal	62,963	CY	$ 50	$ 3,148,148
			Total South Terminal Extension:	$ 19,235,000

6.3.1.2 State Pier

The State Pier (Figure 6-2) is constructed with a solid fill core surrounded by a marginal wharf. This construction is typical of many old New England ports. The solid fill is contained within an old stone seawall. The marginal wharf is comprised of treated timber piles and superstructure. The marginal wharf extends seaward from the stone seawall and allows the berth to be dredged without undermining the seawall. Table 6-3 presents the cost estimate for the needed improvements identified for the State Pier.

Table 6-3
Cost Estimate for Improvements to State Pier at New Bedford Harbor
(Source: Childs Engineering Corporation)

	Description	Initial Construction Cost	Contingency @ 15%	Total Initial Construction Cost	30th Year	40th Year	Estimated Maintenance Cost (Present Worth Cost) 50th Year	60th Year	70th Year	80th Year	90th Year	100th Year	Total Cost of Alternatives
1	Timber Piles, Concrete Deck	$13,340,031	$2,001,005	$15,341,036			Replace					Replace	$41,512,087
	Timber Piles - Replace 20% every 10 years starting 30th year				$2,668,006	$2,668,006	$13,340,031	$ -	$ -	$2,668,006	$2,668,006	$13,340,031	
	Gangway and Float System - Replace 10% every 10 years starting at year 10				$390,000	$130,000	$1,560,000	$130,000	$130,000	$130,000	$130,000	$1,560,000	
2	Refurbish Timber Piles, Concrete Deck	$12,139,965	$1,820,995	$13,960,960			Replace					Replace	$38,151,902
	Timber Piles - Replace 20% every 10 years starting 30th year				$2,427,993	$2,427,993	$12,139,965	$ -	$ -	$2,427,993	$2,427,993	$12,139,965	
	Gangway and Float System - Replace 10% every 10 years starting at year 10				$390,000	$130,000	$1,560,000	$130,000	$130,000	$130,000	$130,000	$1,560,000	
3	Steel Piles, Concrete Deck	$20,347,152	$3,052,073	$23,399,225				Replace					
	Steel Piles - Replace 20% every 10 years starting 40th year				$ -	$4,069,430	$4,069,430	$20,347,152	$ -	$ -	$ -	$4,069,430	$36,715,443

Table 6-3 (continued)

	Description	Initial Construction Cost	Contingency @ 15%	Total Initial Construction Cost	Estimated Maintenance Cost (Present Worth Cost)								Total Cost of Alternatives
					30th Year	40th Year	50th Year	60th Year	70th Year	80th Year	90th Year	100th Year	
3	Gangway and Float System - Replace 10% every 10 years starting at year 10				$390,000	$130,000	$1,560,000	$130,000	$130,000	$130,000	$130,000	$1,560,000	
	Steel Bulkhead - Lightweight Fill - 1 Row Tiebacks	$31,058,195	$4,658,729	$35,716,924					Replace				
4	Sheet Piles - Replace 10% every 10 years starting 40th year				$ -	$3,105,820	$3,105,820	$3,105,820	$31,058,195	$ -	$ -	$ -	$44,535,654
	Gangway and Float System - Replace 10% every 10 years starting at year 10				$390,000	$130,000	$1,560,000	$130,000	$130,000	$130,000	$130,000	$1,560,000	
	Combi-Wall - 1 Row Tiebacks	$35,977,044	$5,396,557	$41,373,601					Replace				
5	Sheet Piles - Replace 10% every 10 years starting 40th year				$ -	$3,597,704	$3,597,704	$3,597,704	$35,977,044	$ -	$ -	$ -	$50,930,157
	Gangway and Float System - Replace 10% every 10 years starting at year 10				$390,000	$130,000	$1,560,000	$130,000	$130,000	$130,000	$130,000	$1,560,000	

Table 6-3 (continued)

	Description	Initial Construction Cost	Contingency @ 15%	Total Initial Construction Cost	30th Year	40th Year	Estimated Maintenance Cost (Present Worth Cost)						Total Cost of Alternatives
							50th Year	60th Year	70th Year	80th Year	90th Year	100th Year	
6	Soldier Piles, Concrete Lagging - 1 Row Tiebacks	$30,819,869	$4,622,980	$35,442,849					Replace				
	Sheet Piles - Replace 10% every 10 years starting 40th year				$ -	$3,081,987	$3,081,987	$3,081,987	$30,819,869	$ -	$ -	$ -	$44,225,830
	Gangway and Float System - Replace 10% every 10 years starting at year 10				$390,000	$130,000	$1,560,000	$130,000	$130,000	$130,000	$130,000	$1,560,000	
7	Cellular Cofferdam - Sand Backfill	$50,716,366	$7,607,455	$58,323,821					Replace				
	Sheet Piles - Replace 10% every 10 years starting 40th year				$ -	$5,071,637	$5,071,637	$5,071,637	$50,716,366	$ -	$ -	$ -	$70,091,276
	Gangway and Float System - Replace 10% every 10 years starting at year 10				$390,000	$130,000	$1,560,000	$130,000	$130,000	$130,000	$130,000	$1,560,000	
8	Cellular Cofferdam - Gravel Backfill	$51,588,891	$7,738,334	$59,327,225					Replace				
	Sheet Piles - Replace 10% every 10 years starting 40th year				$ -	$5,158,889	$5,158,889	$5,158,889	$51,588,891	$ -	$ -	$ 71,225,558	

Table 6-3 (continued)

	Description	Initial Construction Cost	Contingency @ 15%	Total Initial Construction Cost	30th Year	40th Year	Estimated Maintenance Cost (Present Worth Cost) 50th Year	60th Year	70th Year	80th Year	90th Year	100th Year	Total Cost of Alternatives
8	Gangway and Float System - Replace 10% every 10 years starting at year 10				$390,000	$130,000	$1,560,000	$130,000	$130,000	$130,000	$130,000	$1,560,000	
9	Diaphragm Cofferdam - Sand Backfill	$51,402,764	$7,710,415	$59,113,179					Replace				
	Sheet Piles - Replace 10% every 10 years starting 40th year				$ -	$5,140,276	$5,140,276	$5,140,276	$51,402,764	$ -	$ -	$ -	$70,983,593
	Gangway and Float System - Replace 10% every 10 years starting at year 10				$390,000	$130,000	$1,560,000	$130,000	$130,000	$130,000	$130,000	$1,560,000	
10	Diaphragm Cofferdam - Gravel Backfill	$52,275,289	$7,841,293	$60,116,582					Replace				
	Sheet Piles - Replace 10% every 10 years starting 40th year				$ -	$5,227,529	$5,227,529	$5,227,529	$52,275,289	$ -	$ -	$ -	$72,117,876
	Gangway and Float System - Replace 10% every 10 years starting at year 10				$390,000	$130,000	$1,560,000	$130,000	$130,000	$130,000	$130,000	$1,560,000	

The wharf structure is in poor condition according to recent inspections and must be replaced or a modified rebuild must be undertaken. The rebuild options include a repair/replace in kind, which would result in a low deck load capacity. The preferred alternatives would eliminate the wharf structure and replace it with solid fill behind a new bulkhead. A recent study suggested rebuild costs in the range of approximately $12.1 million to more than $52 million.

The immediate backland at State Pier is about 2.8 to 3.2 hectares (approximately 7 to 8 acres), which does not meet the landside criterion (see Table 6-1 above). This lack of space probably would result in material rehandling costs that would not be incurred at a larger site. The rehandling costs could result from offsite storage at other adjacent land facilities or perhaps from barge-based storage. There is covered space in the form of two small warehouses and the marine terminal building. The State Pier would be best described as a short-term, but immediately available, site. This also anticipates that no repairs are performed and a larger land-based unloading crane is employed inshore sufficiently of the wharf structure, which may require a higher-rated crane than would otherwise be needed to clear the low load bearing areas.

The Team believes the preferred option for New Bedford is the South Terminal. The site is the most desirable in terms of meeting the port criteria established by the Team. The South Terminal expansion cost is similar to the repair cost for the State Pier; however, the South Terminal has significantly more laydown area, which offsets any potential cost savings from the State Pier repair/rebuild.

6.3.2 Boston Harbor

The Team identified three possible locations in Boston Harbor that reasonably meet the established criteria. These include the North Jetty (Figure 6-3), Dry Dock #4 in the Boston Marine Industrial Park (Figure 6-4), and the former Coastal Oil site adjacent to Conley Terminal on the Reserved Channel (Figure 6-5). None of these facilities met all of the hard criteria discussed above, and demonstrated some level of deficiency in their current physical condition.

6.3.2.1 North Jetty

The North Jetty (Figure 6-3) is constructed with a solid fill core supported by a steel sheet pile bulkhead fronted by a marginal wharf. This construction was undertaken in the 1940s to meet the needs of the Department of Defense during World War II. The marginal wharf is comprised of steel h-piles supporting a reinforced concrete super structure. The wharf structure is currently in poor condition and must be replaced or rebuilt to be usable for offshore wind staging. A 1996 design suggested rebuild costs (in current dollars) of about $15 million. The immediate backland is about 2.8 to 3.2 hectares (approximately 7 to 8 acres) with an additional 4.0 m (10 acres) or more immediately adjacent.

The City has included the North Jetty rebuild in its application for a TIGER grant. Although the rebuild will correct current deficiencies, it will still leave the wharf with a deck capacity of only 2,930 kg/m^2 (approximately 600 lb/ft^2), which is insufficient for unit loading under certain situations. Depending on the developer’s operations, this capacity may require the use of a high capacity crane set up on the solid fill backlands.

Figure 6-3 North Jetty Port of Boston
(Source: Childs Engineering Corporation)

6.3.2.2 Dry Dock #4

The BRA has identified a 5.2 to 5.7 hectares (13 to 14 acre) parcel at the Dry Dock #4 site in the Marine Industrial Park in South Boston (Figure 6-4) for possible expansion. The existing dry dock is in very poor condition, but could be rebuilt to provide a two-sided solid fill pier with almost 549 m (1,800 feet) of berthing. Table 6-4 presents the cost estimate for the improvements to Dry Dock #4 identified to be necessary to support offshore wind farm development.

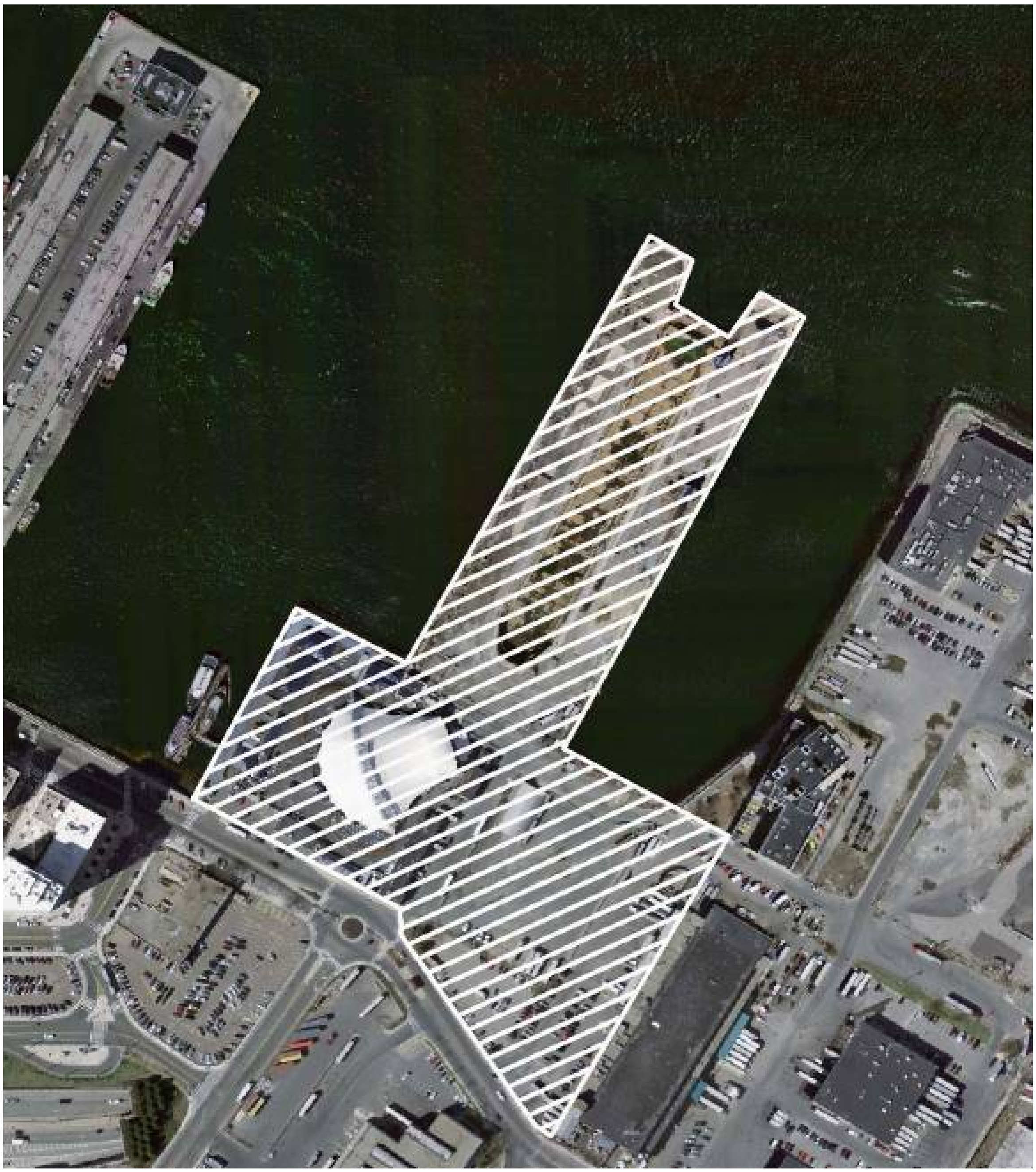


Figure 6-4 Dry Dock #4 at the Port of Boston

(Source: Childs Engineering Corporation)

Table 6-4
Cost Estimate for Improvements to Dry Dock #4 at the Port of Boston
(Source: Childs Engineering Corporation)

COST ESTIMATE		DATE PREPARED Nov-09	SHEET 1 OF 1
ACTIVITY AND LOCATION Boston Harbor Drydock #4 Parcel - South Boston	CEC JOB NUMBER 2178-09		IDENTIFICATION NUMBER
Install repair bulkhead, fender system, Fill drydock and pave Estimated in 2009 prices	ESTIMATED BY DLP		CATEGORY CODE NUMBER
	STATUS OF DESIGN _X_ PED ___ 35% ___ 65% __ 100% ___ FINAL ___ OTHER		JOB ORDER NUMBER

	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
ITEM DESCRIPTION	NO.	UNIT	UNIT COST	TOTAL	UNIT COST	TOTAL	UNIT COST	TOTAL
Soft Costs								
Engineering/Permits/Procurement	1	LS					$1,000,000	$1,000,000
Site Prep								
Site cleanup	1	LS					$250,000	$250,000
Bulkhead								
Sheeting- PZ27	3,500,000	LB					$3	$10,500,000
Mudslab Installation	6,000	CY					$200	$1,200,000
Wale-][MC 12x31	100,000	LB					$3	$300,000
Weep Drains @ 10' o.c.	200	EA					$150	$30,000
Tie- Rod	100,000	LB					$6	$600,000
Structural Fill- btween old and new sheets	10,000	CY					$35	$350,000
Concrete Bulkhead Cap	200	CY					$650	$130,000
Concrete Slab	1,050	CY					$500	$525,000
12" Dia.Timber Piles (Fender)	200	EA					$3,000	$600,000
Drydock fill								
Placement of Material in Drydock	116,665	CY					$30	$3,499,950
Pave surface	70,000	SF					$10	$700,000
						Total Drydock Parcel Repair:		$19,684,950

Table 6-4 (continued)

COST ESTIMATE	DATE PREPARED Oct-09	SHEET 1 OF 1
ACTIVITY AND LOCATION Boston Harbor Drydock 4 Repair Estimated Maintenance Costs Estimated in 2009 prices	CEC JOB NUMBER 2178-09 ESTIMATED BY DLP STATUS OF DESIGN _X_ PED ___ 35% ___ 65% __ 100% ___ FINAL ___ OTHER	IDENTIFICATION NUMBER CATEGORY CODE NUMBER JOB ORDER NUMBER

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT COST	TOTAL	UNIT COST	TOTAL	UNIT COST	TOTAL
Soft Costs								
Engineering/Permits/Procurement	1	LS					$500,000	$500,000
Bulkhead Annual								
Recoating and anode replacement	25	EA	1% of cost				$105,000	$2,625,000
Fender system repair etc								
Bulkhead Five Year								
Recoating and anode replacement	1	EA	5% of cost				$525,000	$525,000
Fender system repair etc								
Bulkhead Ten Year								
Recoating and anode replacement	1	EA	5% of cost				$525,000	$525,000
Fender system repair etc								
Bulkhead Fifteen Year								
Recoating and anode replacement	1	EA	5% of cost				$525,000	$525,000
Fender system repair etc								
Bulkhead Twenty Year								
Recoating and anode replacement	1	EA	5% of cost				$525,000	$525,000
Fender system repair etc								

Bulkhead cost base is $10,500,000
Anticpated 25 year life no salvage

Total Drydock Parcel Maintenance: $5,225,000

The dry dock would be filled with gravel, and new steel sheet piling would be installed around the deteriorated bulkheads. The estimated cost to rebuild the site is approximately $20 million.

This site would provide nominal laydown space, but the solid fill pier has very high ground capacity and the berth has “bonus” length. Although the site does not have covered space, there are such structures and warehouses in the Boston Marine Industrial Park that could be used or converted for use for this purpose.

Dry Dock #4 could accommodate the staging of offshore wind development with improvements at a reasonable cost. However, from a planning perspective, there are potentially permitting issues associated with these improvements due to Dry Dock #4’s proximity to Logan Airport. Tall equipment, such as cranes, as well as future installation vessels transporting assembled turbines in a vertical configuration, may require approvals from the FAA. Furthermore, the potential wind farm locations are much closer to New Bedford Harbor than Boston Harbor.

6.3.2.3 Coastal Oil Site

The Massachusetts Port Authority owns the former Coastal Oil Terminal in South Boston (Figure 6-5). The site is approximately 14.2 hectares (approximately 35 acres) and has a former oil tanker berth with a water depth in excess of 10.3 m (34 feet). The facility would require a new steel sheetpile bulkhead to be adequate for laydown. It also would need regrading and paving to “cap” any environmental contamination. The site does not have any covered space, and there is no covered space on the immediately adjacent parcel. The berth is a mooring dolphin-type structure seaward of an old seawall. The estimated cost for the repairs is approximately $20 million. Table 6-5 is the cost estimate for improvements to the Coastal Oil Terminal.

The Team believes the preferred option at the Port of Boston is Dry Dock #4. The site meets most of the established criteria. The rebuild cost is similar to the cost of repairs for the North Jetty. However, Dry Dock #4 has significantly more berthing space, which more than offsets any potential repair/rebuild cost savings.

Table 6-5
Cost Estimate for Improvements to the Coastal Oil Site at the Port of Boston
(Source: Childs Engineering Corporation)

COST ESTIMATE						DATE PREPARED Dec-09	SHEET 1 OF 1		
ACTIVITY AND LOCATION Boston Harbor Coastal Oil - South Boston				CEC JOB NUMBER 2178-09			IDENTIFICATION NUMBER		
Install repair bulkhead, fender system, Fill between existing and new sheet piling, grade and pave Estimated in 2009 prices				ESTIMATED BY DLP STATUS OF DESIGN _X_ PED ___ 35% ___ 65% __ 100% ___ FINAL ___ OTHER			CATEGORY CODE NUMBER JOB ORDER NUMBER		
ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE		
	NO.	UNIT	UNIT COST	TOTAL	UNIT COST	TOTAL	UNIT COST	TOTAL	
Soft Costs									
Engineering/Permits/Procurement	1	LS					$1,000,000	$1,000,000	
Site Prep									
Site cleanup	1	LS					$250,000	$250,000	
Bulkhead									
Sheeting- PZ27	1,700,000	LB					$3	$5,100,000	
Mudslab Installation	4,000	CY					$200	$800,000	
Wale-][MC 12x31	35,000	LB					$3	$105,000	
Weep Drains @ 10' o.c.	80	EA					$150	$12,000	
Tie- Rod	40,000	LB					$6	$240,000	
Structural Fill- between old wall and new sheets	30,000	CY					$35	$1,050,000	
Concrete Bulkhead Cap	100	CY					$650	$65,000	
Concrete Slab	1,050	CY					$500	$525,000	
12" Dia.Timber Piles (Fender)	80	EA					$3,000	$240,000	
Regrade and Pave									
Grade	80,000	SY					$15	$1,200,000	
Pave surface	900,000	SF					$10	$9,000,000	
						Total Coastal Oil Repair:		$19,587,000	

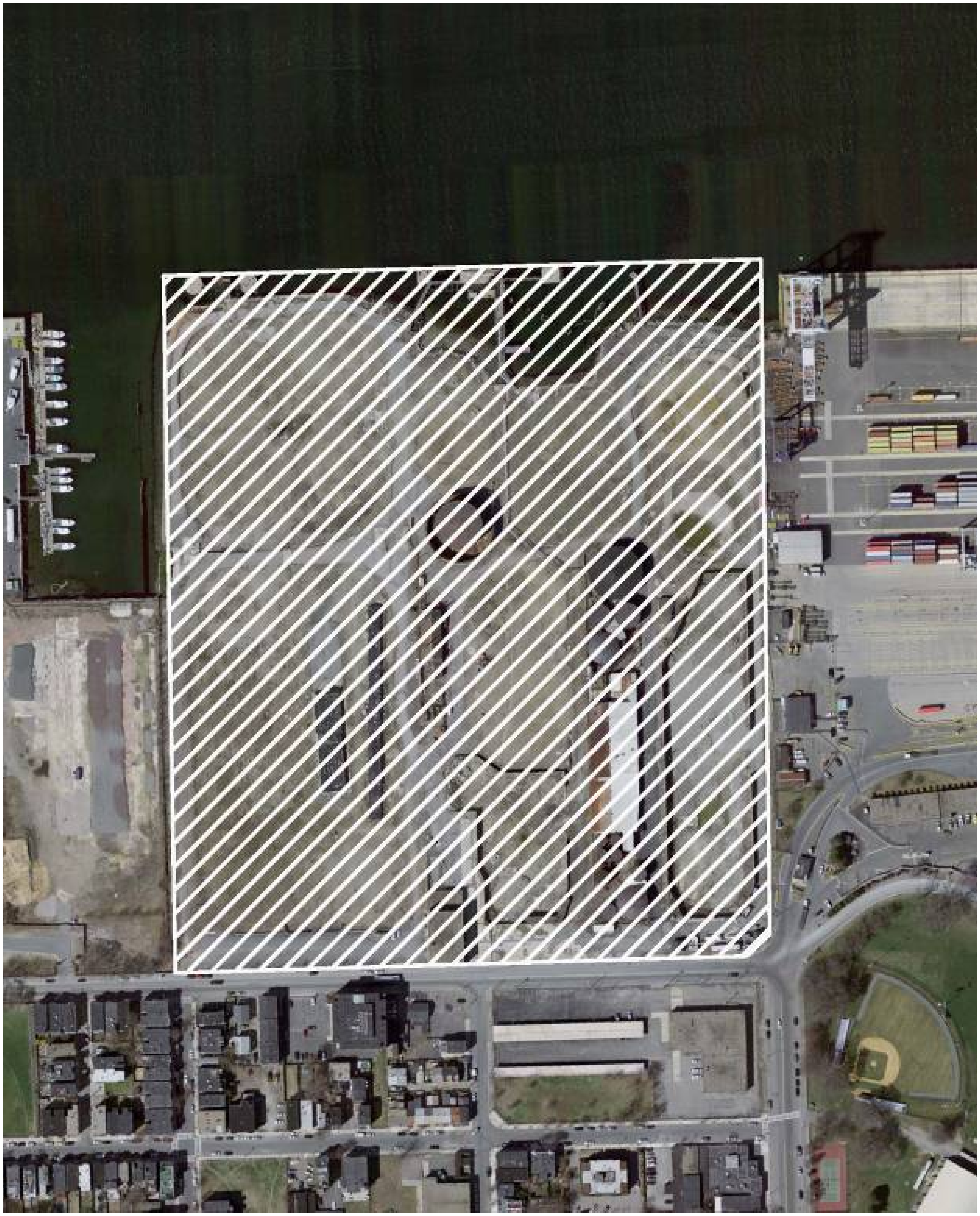


Figure 6-5 Coastal Oil Terminal Port of Boston
(Source: Childs Engineering Corporation)

6.4 Implications of Applying the Soft Criteria

The Team examined education and training needs required to support the offshore wind energy industry. See Appendix I for the questionnaire used to interview various educational and training institutions. More effective state support for renewable energy has encouraged investment in workforce training at many levels. The Massachusetts Maritime Academy (MMA) is nationally known for its mariner training programs, and a regional Marine Renewable Energy Center (MREC) at the University of Massachusetts/Dartmouth (UMass/Dartmouth) joins the resources of some of the region's leading academic institutions, community colleges, and trade unions to coordinate and plan appropriate training for this emerging industry. Given the relative proximity of the ports in this study to these educational resources, Massachusetts is well-positioned to assess the work force needs of each offshore wind energy developer and provide responsive, high-quality training.

Massachusetts has long been recognized as an international center for science, technology, and oceanography. There is considerable local and regional interest in developing technology and the necessary trade skills to harness renewable energy from the ocean. Since the late 1990s, when the idea of offshore wind energy projects first began to surface in Massachusetts, academic institutions and unions representing trade industries identified offshore renewable energy as an important field that would require new technologies and a corresponding demand for new training. Additional focus on Massachusetts as an emerging center for offshore construction occurred in 2004, when plans were developed for the first LNG deepwater port on the east coast of the United States, and the second such facility worldwide. The Northeast Gateway Deepwater Port was completed in 2007 and another similar facility is nearing completion. Both projects utilized local trade and construction workers to complete sub-sea pipelines and buoys.

A lengthy list of public and private academic institutions, including the Amherst and Dartmouth campuses of the University of Massachusetts system, Harvard University, the Massachusetts Institute of Technology, the Massachusetts Maritime Academy, and the Woods Hole Oceanographic Institute, (as well as other institutions in the region) have examined and will continue to explore numerous issues related to offshore renewable energy generation. These issues include energy production, facility design, transmission issues, and maritime training. These institutions, with evolving degree programs, unrivalled intellectual capital, and interest in furthering the development of offshore renewable energy, are an exceptional resource for policy makers, developers, builders, and maintenance firms.

State government, academic institutions, and local unions have all recognized the importance of offshore sites along the Massachusetts coast for both traditional and renewable sources of energy. At the state level, Governor Deval Patrick reversed the prior Administration’s opposition to the Cape Wind project and moved quickly to combine energy and environmental agencies in a cabinet-level secretariat with an emphasis on renewable energy. State agencies worked closely with the Massachusetts Renewable Energy Trust, part of a quasi-state agency funded through an excise tax on electricity consumption, and the Commonwealth’s Clean Energy Center to provide resources and expertise to move the Commonwealth toward the Patrick Administration’s 2020 goal of providing 2,000 MW of land- and ocean-based wind energy. With relatively shallow offshore waters and excellent wind resources, offshore wind energy became an increasing focus of renewable energy efforts. In a coordinated effort, the Patrick

Administration also pushed for passage of the Massachusetts Ocean Management Act, under which it has developed a plan that identifies sites within state waters for new offshore wind farm development, in addition to potential federal sites in adjacent waters that come under the jurisdiction of the U.S. Minerals Management Service.

The emerging field of offshore wind energy has already led to the development of a number of new technologies and applications, requiring a trained workforce to assemble, construct, operate, and maintain offshore wind turbines. Based on European experience, an eighty-turbine offshore wind energy project, for example, would typically need a number of trained individuals for the installation phase as presented in Table 6-6.

Table 6-6
Workers Required for Typical 80-Turbine Offshore Wind Energy Project
(Source: Thomsen 2009)

Turbine Installation	
Type of Worker	Number of Workers Required
Vessel officers and crew	25 people per shift per day
Installation crew	12 people per shift per day
Preassembly	12 people per shift per day
Harbor workers	12 people per shift per day
Project management	25 people to plan and execute all work
Crane and truck rental	25 people (e.g., crane operators, forklift/truck drivers)
Foundation Installation	
Vessel officers and crew	25 people per shift per day
Installation crew	18 people per shift per day (piling operations are more manpower intensive than turbine installation)
Preassembly	25 people per shift per day
Harbor workers	12 people per shift per day
Project management	25 people to plan and execute all work
Assistance from agents and port authorities	20 people
Crane and truck rental	25 people (e.g., crane operators, forklift/truck drivers)
Cable Installation	
Vessel officers and crew	25 people per shift per day
Diving crew	10 people
Installation crew	12 people per shift per day
Preassembly	12 people per shift per day
Harbor workers	12 people
Project management	25 people to plan and execute all work

Based on these figures, each phase of the construction process for offshore wind farms could require as many as 150 skilled workers, with another 80 workers for each additional daily shift.

European offshore wind developers have reported shortages among skilled workers in related trades, and potential offshore wind energy developers in the United States have described similar concerns. While the two short-listed Massachusetts ports have characteristics that make them suitable for the construction, operation, and maintenance of offshore wind energy facilities, they also have ready access to considerable education and training resources that are geared to offshore and underwater construction, seamanship, and technical trades and services. Given the relative proximity of these ports (as well as all of the Massachusetts ports considered in this study) to these education and training resources, Massachusetts is uniquely situated to respond to developers' needs for a variety of construction and operational technologies.

Recognizing that a wide variety of skill sets would be needed to construct, operate, and maintain offshore renewable energy facilities in Massachusetts, the MREC, an organization of industry, academia, government agencies, municipalities, public interest groups, and concerned individuals, was established at the UMass Dartmouth in 2006. MREC's goal is to foster the development of ocean-based renewable energy, including wave, tidal current and offshore wind, and is unique in that it brings together the knowledge and needs of science, technology, and training in order to successfully maximize renewable energy resources from the ocean. MREC seeks to develop a network of technology developers and energy users who will collectively define the needs of this nascent industry and bring together the required technology, capital, infrastructure, and human resources to implement ocean-based renewable energy in the most economically, environmentally, and socially sustainable manner for the region.

MREC has also proposed a National Offshore Renewable Energy Innovation Zone (NOREIZ) and is working with state and federal agencies to designate an area off of Nantucket and Martha's Vineyard for this purpose. The proposed project would provide demonstration and training sites for marine renewable energy, particularly offshore wind, and is envisioned as a critical asset for training, technology development, and small scale energy generation.

In addition to UMass/Dartmouth, MREC's university research consortium partners include:

- the University of New Hampshire (UNH);
- the University of Rhode Island (URI);
- the University of Maine (UMaine);
- the Massachusetts Institute of Technology (MIT);
- the Woods Hole Oceanographic Institution (WHOI);
- the Massachusetts Maritime Academy (MMA);
- Roger Williams University (RWU); and
- other schools within the University of Massachusetts system.

MREC corporate partners include:

- Battelle;
- Alden;
- Raytheon;
- National Grid;
- NStar;
- Lockheed/Martin;
- the New England Clean Energy Council; and

- the Ocean Renewable Energy Coalition.

Understanding that the offshore energy industry is evolving within the United States and New England, MREC joined forces with Cape Wind, Resolute Marine Energy, Ocean Renewable Power Company, Local 56 Pile Drivers Union, the MMA, the New Bedford Department of Workforce Development, and the community college system to form the Ocean Energy Training Task Force. The Task Force meets regularly to identify issues and to discuss how best to meet the needs of offshore energy developers, and draws on the expertise of each of its members.

Under the MREC/Task Force umbrella, significant education and training programs related to offshore renewable energy are being developed and some are currently offered. It is anticipated that these courses will evolve significantly to address future development needs. The Task Force, in discussions with the European Marine Energy Center (EMEC) and the New and Renewable Energy Center (NaREC) UK, have developed framework for education and training that encompasses three elements:

1) University level education to produce a cadre of researchers, engineers, and other professionals for the development of new technologies.

2) Construction skills training by unions and Workforce Investment Boards to support the construction and installation of ocean based turbines.

3) Operation and Maintenance (O&M) technician training and certification following the NaREC model of instruction at community colleges and training/certification at the MMA and MREC-developed ocean test sites.

At the University level, Oceanography and Ocean Engineering programs are in place with MREC Research University Consortium members. UMass/Dartmouth offers masters and doctorates in marine science and technology through the School for Marine Science and Technology (SMAST), has a range of sustainability courses that can be tailored to address ocean renewable energy, and offers a masters degree in public policy with concentrations in economic development, marine science, and technology policy. As with other MREC members, UMass/Dartmouth is very much interested in the national effort to establish a certificate program aimed at training oceanographic science and technology operations personnel to service ocean observatories, many of the skills that are transferable to offshore energy projects.

The MMA is well-known for its traditional courses in seamanship for maritime officers, which are essential to the construction and maintenance of offshore energy facilities. MMA also offers established training for power plant operations and has aggressively implemented renewable energy on campus with wind, solar, tidal, and geothermal projects. Located at the west end of the Cape Cod Canal, MMA will be a key asset in any training program that would require water access. As with other MREC partners, MMA will revise, as appropriate, existing energy-related courses to address ocean energy needs and issues.

Two MREC partners, Cape Cod Community College and Bristol Community College, have joined forces to provide clean energy workforce training, have a proven track record of providing targeted training to their local communities, and have offered training programs in the marine technology subject area. Bristol Community College currently has a grant with the National Science Foundation to offer certificates in environmental technology, marine technology and geographic information systems and offered a pilot tidal energy technician training program in

2009 that will be expanded in the future. The MMA is a partner in this effort and has tailored existing energy-related courses to address ocean energy, as appropriate.

At the construction skills level, Massachusetts trade unions have been very active in identifying offshore energy construction needs and developing appropriate training courses. For example, Local 56 of the Massachusetts Pile Drivers is a statewide organization that has been at the forefront of training workers for offshore energy. Targeting vocational technical school students, Local 56 either currently offers, or is planning to offer, training in the following areas:

- Four-year apprenticeships in pile driving and marine construction, including rigging, welding burning and fitting, and marine construction safety;
- Commercial diving training, for the inspection, trenching, and maintenance of sub-sea electrical cables;
- Pile driving and welding for wind turbine towers;
- Rigging and material handling for loading and unloading; and
- Rigging for tower, nacelle, and blade assembly.

Local 56 has a proven track record in responding to industry needs by providing high-quality training. Since January, 2007, Local 56 has offered training for commercial divers and pile drivers to work in the offshore natural gas industry, with 60 commercial divers working on four different offshore pipeline jobs along the Massachusetts coast. Its training programs have expanded to include underwater welding, with successful graduates completing over 60,000 hours on eight different construction contracts since May, 2007. Local 56 is currently working with the Occupational Safety and Hazards Administration (OSHA) and the Carpenters International Training Fund to develop a course on Marine Construction Safety.

Similarly, the International Brotherhood of Electrical Workers (IBEW) Local 103 has demonstrated its leadership in support of the renewable energy industry through the erection of a publicly visible 100 kilovolt (kV) wind turbine and the installation of a 5.4 kV solar roof at its headquarters and Apprentice Training Facility in Dorchester. As the IBEW increases its focus on renewable energy, it uses working non-fuel energy systems for training and will open its “Big Green Room” in 2010 to present a variety of different training tools that relate to hydro, wind, and solar generation technologies. The union’s strong commitment to safety, and current training certifications in tower climbing, working in confined spaces, and scuba proficiency, all have direct applications in the emerging offshore wind generation industry. Currently one half of IBEW local workers are trained in scuba and wind technology. In addition, the IBEW has been working with the MMA on wind generation construction and marine training.

With the state aggressively supporting the development of offshore wind energy through policy initiatives, expertise, and financial support, and with academic institutions and trade unions actively developing and improving training opportunities, Massachusetts is well situated to respond to a wide variety of technologies used to harness renewable energy in offshore waters. Given its broad geographic coverage, extensive research facilities, in-depth industry expertise, and a trained, flexible work force, Massachusetts is in a unique position to successfully meet the needs of the offshore wind energy industry.

Soft criteria also include regulatory considerations. Port facility upgrades may require Massachusetts environmental review if the project meets or exceeds certain thresholds established by the Massachusetts Environmental Policy Act (MEPA). A variety of federal, state and local permits also may be required, including, but not limited to:

- U.S. Army Corps of Engineers (USACE) Section 10 permit for structures in navigable waters;
- USACE Section 404 permit for discharge of dredged or fill materials into waters of the U.S.;
- Federal Aviation Administration (FAA) Determination of No Hazard;
- Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) permit;
- EPA Air Emission permit;
- Massachusetts Coastal Zone Management (MCZM) Consistency Determination;
- Massachusetts Department of Environmental Protection (MassDEP) Water Quality Certificate;
- MassDEP Chapter 91 License for work in, under, or over flowed or filled tidelands;
- Massachusetts Department of Transportation (MDOT) oversize/overweight vehicle permit;
- Local Conservation Commission Order of Conditions for alteration of “any bank, fresh water wetland, coastal wetland, beach, dune, flat, marsh, meadow, or swamp bordering on the ocean or on any estuary (a broad mouth of a river into which the tide flows.), creek, river, stream, pond, or lake, or any land under said waters or any land subject to tidal action, coastal storm flowage, or flooding”; and
- Local zoning, building or utility permits.

7.0 ECONOMIC AND TAX EFFECTS OF CONSTRUCTION AND OPERATING EXPENDITURES

Based on the criteria presented above, the New Bedford South Terminal and Boston Dry Dock #4 were selected for further evaluation and analysis. This section discusses the economic and fiscal effects of construction and operation of these ports to support a ROWEI 130-turbine wind farm. See Appendix J for a more detailed analysis of economic and tax effects.

7.1 Construction and Operating Period Economic Effects

Data in Table 7-1 show the estimated total direct, indirect, and induced economic effects of expenditures made to construct the New Bedford South Terminal port facility, Boston Dry Dock #4, and the ROWEI 130-turbine installation. These are one-time, non-recurring projected economic effects that are expected to accrue within the Massachusetts economy during a 3 to 5 year period that includes port facility construction and the ROWEI offshore wind turbine installation.

Table 7-1 also shows the annually recurring economic effects of maintaining a ROWEI and of handling, storing, and transshipping non-offshore wind related cargo at a multi-use South Terminal port facility in New Bedford. In the case of the Boston and New Bedford port facilities, economic effects during construction are shown for Suffolk and Bristol counties, respectively. The annually recurring economic effects of new non-offshore wind-related cargo operations at the South Terminal are shown for Bristol county as well as Massachusetts overall.

The measures of economic effects are:

- Output – which comprises business sales less the costs of materials and equipment produced outside Massachusetts;
- Employment – the full-time equivalent jobs expected to be held by Massachusetts residents;
- Income – the payroll and self-employment earnings of households; and
- GDP (Gross Domestic Product) – which measures the value added to the Massachusetts economy in terms of labor and proprietors' income, corporate profits, dividends, interest, rent and taxes.

The county-level economic effects in Table 7-1 are a subset of the Massachusetts totals and show the amounts of local and state direct, indirect, and induced economic effects that would accrue within communities in Bristol and Suffolk counties.

Table 7-1
Total Direct, Indirect, and Induced Economic Effects of Offshore Wind Installation and Related Port Facilities Construction and Operation
(Sources: FXM Associates, R/ECON™ Input Output Model, Tetra Tech Team, City of Boston, City of New Bedford, Cape Wind)

	Output (000 $)	Employment (Jobs)	Income (000 $)	GDP (000 $)
Construction Period Effects				
South Terminal Port Facility				
Bristol County	*$ 44,100*	*380*	*$ 19,200*	*$ 26,100*
Massachusetts	$ 65,500	540	$ 26,100	$ 36,200
Boston Port Facility				
Suffolk County	*$ 19,800*	*110*	*$ 9,100*	*$ 12,400*
Massachusetts	$ 30,100	190	$ 12,500	$ 17,200
Representative Offshore Wind Installation				
Massachusetts	$ 457,300	1700	$ 162,900	$ 200,100
Annual Operating Effects				
South Terminal Port Cargo Operations				
Bristol County	*$ 15,700*	*130*	*$ 5,900*	*$ 9,700*
Massachusetts	$ 20,200	170	$ 7,400	$ 11,900
ROWEI O&M				
Massachusetts	$ 27,500	110	$ 6,800	$ 11,000

7.2 Construction and Operating Period Fiscal Effects

The total direct, indirect, and induced tax effects shown in Table 7-2 correspond to the economic effects shown in Table 7-1. Local taxes include property and excise taxes paid to municipalities by workers in the jobs generated by the construction and operating period employment reflected in Table 7-1, as well as property and other local taxes by the companies employing those individuals. State taxes include income and sales taxes paid by individuals as well as payroll, income, and other taxes paid by the companies that employ those individuals. The taxes are thus proportional to the total direct, indirect and induced economic effects shown in Table 7-1. However, these totals do not represent all taxes paid by companies whose output is only partly affected by the changes in demand attributable to construction and operating periods of offshore wind energy installation and maintenance, port construction and terminal operation.

Table 7-2
Total Direct, Indirect, and Induced Tax Effects of Offshore Wind Installation and Related Port Facilities Construction and Operation
(Sources: FXM Associates and R/ECON™ Input Output Model)

	Local Taxes (000 $)	State Taxes (000 $)	Federal Taxes (000 $)
Construction Period Effects			
South Terminal Port Facility			
Bristol County	*$ 480*	*$ 440*	*$ 1,820*
Massachusetts	$ 1,190	$ 1,440	$ 7,280
Boston Port Facility			
Suffolk County	*$ 190*	*$ 220*	*$ 1,290*
Massachusetts	$ 500	$ 640	$ 3,540
Representative Offshore Wind Installation			
Massachusetts	$ 8,850	$ 10,090	$ 45,940
Annual Operating Effects			
South Terminal Port Operations			
Bristol County	*$ 300*	*$ 240*	*$ 730*
Massachusetts	$ 480	$ 500	$ 2,180
ROWEI O&M			
Massachusetts	$ 390	$ 430	$ 2,230

As shown in Table 7-2, nearly $9 million in taxes to be paid to municipalities throughout Massachusetts are estimated to be attributable to the direct, indirect and induced economic effects shown in Table 7-1 over the projected 3-year construction (assembly and installation) phase of the ROWEI. More than $10 million in taxes paid to the Commonwealth of Massachusetts and almost $46 million in federal taxes over this same 3-year period would be attributable to the economic effects of construction. Servicing and maintaining the ROWEI is projected to generate an annual amount of $390,000 in municipal tax receipts throughout Massachusetts, $433,000 in state taxes, and $2.2 M in federal taxes. The county-level tax totals in Table 7-2 are a subset of the Massachusetts totals and show the amounts of local, state and federal tax effects that would accrue within communities in Bristol and Suffolk Counties.

7.3 Summary

As can be seen from these projections, the economic and fiscal effects of port development and use are roughly comparable for both ports. Therefore, the selection of one port over the other is more likely to be determined by the balancing of the soft criteria.

8.0 SUMMARY AND RECOMMENDATION

There are no port facilities in Massachusetts that are currently ready to provide staging, installation, and operations and maintenance support to a commercial scale offshore wind farm development project in the region. However, if investment in targeted port upgrades is made, the opportunity to attract offshore wind developers exists.

Table 8-1 provides a summary of the side-by-side comparison between Dry Dock #4 at the Port of Boston and the South Terminal at the Port of New Bedford based on the hard and soft evaluation criteria developed for this study. With specifically targeted upgrades, both Dry Dock #4 and the South Terminal would have acceptable harbor access and the navigational parameters needed to accommodate wind turbine delivery and installation vessels (based on a comparison of port characteristics to the 1st Tier Hard Criteria).

For the most part, both ports also are capable of accommodating the assembly and installation of offshore wind turbines and foundations (based on a comparison of port characteristics to the 2nd Tier Hard Criteria). An exception at the present time may be Rail and Highway Access. The Boston Redevelopment Authority (BRA) has a “shovel-ready” design for modifications to expand the existing rail line to Dry Dock #4. New Bedford has submitted a TIGER application to extend the existing rail line to the State Pier, but not to the South Terminal (Mayor Scott Lang, 2009). Highway Access to both port areas is adequate. The Boston Haul Road currently has several bridges that would impose limitations on the transport of large turbine and/or foundation components. However, Massport and the BRA have plans to expand the freight roadway network at the Port. Despite the relative advantages and disadvantages associated with current rail/highway access at each port, neither port becomes a clear frontrunner based on these two criteria. Because rail and highway delivery of offshore wind generation components would be constrained by the weight and dimensions of the foundations and turbines, it is unlikely that this means of delivery would be used for these large primary components. And the distinction becomes less of an issue as the larger next generation wind turbine components currently in development will only be able to be transported by water.

Table 8-1
Comparison of the Two Short-Listed Ports

	Port of Boston Dry Dock #4	New Bedford Harbor South Terminal	Comments
1st TIER HARD CRITERIA			
Protected Harbor	●	●	Both ports are acceptable.
Shipping Channel Depth	●	●	Both ports are acceptable.
Overhead Clearance	●	●	Both ports are acceptable.
Horizontal Clearance	●	●	Both ports are acceptable.
24/7 Operational Ability	●	●	Both ports are acceptable.
Exclusive Use of Port Facility	●	●	Both ports are acceptable.
2nd TIER HARD CRITERIA			
Berth Length	●	●	Both ports are acceptable.
Shipping Vessel Water Depth	●	●	Both ports are acceptable.
Total Wharf and Yard Upland Area	●	●	Both ports are acceptable.

	Port of Boston Dry Dock #4	New Bedford Harbor South Terminal	Comments
Rail Access	●	⊙	BRA has a design to expand rail access to Dry Dock #4. New Bedford has submitted TIGER application to extend rail line to State Pier, but not to South Terminal.
Highway Access	⊙	●	Despite adequate highway access to port area, the Boston Haul Road currently has vertical/ horizontal limitations; however, a new freight roadway system is planned.
Proximity to Construction Site	⊙	●	South Terminal is closer to the planned offshore sites than Dry Dock #4 (as of January 2010).
SOFT CRITERIA			
Workforce Availability	●	●	
Education and Training Facilities	⊙	⊙	In U.S., education and training programs are now being developed for nascent offshore renewable energy industry. Given extensive research facilities, in-depth industry expertise, and trained, flexible work force, Massachusetts will be able to successfully meet education and training needs.
Political Climate/Community Acceptance	⊙	●	New Bedford has a Green Port initiative in place, has done study on South Terminal development, has submitted various proposals for infrastructure grants, and has the goal of strengthening its economy by focusing on renewable energy such as offshore wind. The BRA has emphasized a commitment to sustainability but may not be focused on the seaport. Dry Dock #4 currently has a tenant.
Regulatory Considerations	⊙	●	Required permits could include, but are not limited to: MEPA review; CZM Consistency Certification; USACE Section 404 and 10 Permits, FAA approval; Chapter 91 License/Permit; Water Quality Certification; NPDES Permit; Order of Conditions. Certain circumstances at each port may eliminate or reduce regulatory process. FAA approval at Dry Dock #4 may be problematic.

LEGEND:
- ● Acceptable / Most Supportive of offshore wind farm development
- ⊙ Qualified Acceptability / Degree of Supportiveness of offshore wind farm development
- ○ Unacceptable / Not Supportive of offshore wind farm development

The proximity of a port to prospective offshore wind farm sites is important in terms of minimizing cost and controlling transportation-related risk. These considerations indicate an advantage to the closer staging port. Based on available public information as of January 2010 regarding proposed offshore wind farm sites, the South Terminal at New Bedford Harbor is closer to these potential installation sites than is Dry Dock #4 at the Port of Boston.

A key soft criterion is Political Climate/Community Acceptance of the cities and towns associated with each port. The City of New Bedford has established a goal of strengthening its economy by focusing on supporting the renewable energy industry. New Bedford already has completed a study on development of the South Terminal as a port facility to support renewable energy technology companies (*Port of New Bedford Massachusetts, South Terminal Development, Renewable Energy Marine Park*, dated March 2009). The New Bedford HDC has received grant money from the Governor's Seaport Council for navigational dredging, identifying port infrastructure needs, and evaluating potential markets for the Port of New Bedford, among other projects. New Bedford has applied for a TIGER grant of approximately $36M for integrated intermodal transportation infrastructure improvements, which include expansion of the South Terminal. In Boston, the BRA has demonstrated its commitment to environmental sustainability by launching a pilot program to help small businesses improve their energy efficiency and sustainability practices. However, this initiative is not focused specifically on the seaport.

Another soft criterion, Regulatory Considerations, involves the environmental review and permitting processes that may be required for the port projects. Work in and around Massachusetts waters may require state environmental review, if one or more MEPA review thresholds is met or exceeded. Installing and operating an offshore wind farm also will require obtaining a number of federal, state, and local permits. MEPA review of a major port improvements project could take between six months and one year, depending on the type of MEPA review triggered and the amount and intensity of political and community support for the project. Permitting such a project may require a similar amount of time, depending on (among other factors) the complexities of the project, the number and length of public comment periods, and the duration of mitigation negotiations that must be conducted between the project proponent and the regulatory agencies.

Since some of the environmental impacts of the South Terminal site have already been assessed by the Commonwealth as part of the Superfund cleanup response for the site, MEPA review of the South Terminal expansion may be streamlined or limited. The permits required for this project are contingent on its projected impacts on regulated resources. The dredging component of the port expansion project may be covered under the State Enhanced Remedy CAD Cell Dredge Disposal Approval for the cleanup. However, other permits/approvals may still be required.

If the required upgrades to Dry Dock #4 at the Port of Boston can be defined as maintenance activities authorized under existing permits, the regulatory process may be circumvented or limited. Nevertheless, because of its proximity to Logan International Airport, obtaining FAA approval of crane heights at Dry Dock #4 could prove to be a lengthy process. The level of MEPA review required for the Dry Dock #4 improvements also would depend on which thresholds were exceeded, if any. Other permits/approvals may be required.

Determining the permits applicable to either project was not within the scope of this report. Additional research would be required to verify which, if any, permits would be needed. If support of renewable energy and immediate job creation are important political objectives in the Commonwealth, it would follow that the port project with the shortest regulatory track and the greatest political and community support would emerge as the best project to meet those objectives.

Upon review of the side-by-side comparison of the two short-listed ports presented in Table 8-1, it is seen that:

- Both ports and highlighted wharf areas are equally acceptable with regard to the 1st Tier Hard Criteria relating to navigation.
- The South Terminal at the Port of New Bedford displays a slight advantage over Dry Dock #4 at the Port of Boston with respect to the 2nd Tier Hard Criteria associated with Highway Access and Proximity to Construction Sites.

Both ports are equally acceptable with regard to the Soft Criteria relating to Workforce Availability and Education and Training Facilities. In addition, the comparison of the projected economic and fiscal impacts (Section 7) indicated that the two short-listed ports also were very comparable relative to these projections as well.

- The South Terminal at the Port of New Bedford is indicated to be advantageous relative to Dry Dock #4 with respect to the Soft Criteria of Political Climate/Community Acceptance and Regulatory Considerations.

Based on this comprehensive side-by-side comparison, the Team has concluded that the expansion of the South Terminal at the Port of New Bedford represents the best opportunity for a Massachusetts port facility to accommodate assembly and installation of offshore wind energy projects. In addition, the new facility will provide sufficient economic and fiscal benefits to Bristol County and the Commonwealth of Massachusetts to make the investment attractive and worthwhile. The political support, advanced planning effort, proximity to offshore sites, and absence of FAA obstacles have led the Team to recommend the South Terminal expansion.

9.0 PATH FORWARD – HIGH-LEVEL SOUTH TERMINAL BUSINESS PLAN

Based on the recommendation presented above, the Team prepared portions of a preliminary business plan for a multi-use cargo facility at the South Terminal in the Port of New Bedford (see Appendix K). Some specific objectives of this effort were to establish an initial path forward and identify:

(1) potential cargoes and revenues for the South Terminal facility, in addition to those associated with the staging, installation, and operations and management of a ROWEI;

(2) independent estimates of costs for facility upgrades;

(3) an appropriate governance model for multi-use terminal ownership and management; and

(4) preliminary standards of operation for the expanded facility.

Toward this end, the Team examined:

- prospective cargo demand;
- port governance/terminal management options;
- potential capital and operating costs;
- overall development feasibility; and
- potential economic effects associated with developing and operating a multi-use renewable energy terminal and general cargo facility at the South Terminal in the Port of New Bedford.

Sources for the analysis included: prior and ongoing studies (conducted by the New Bedford HDC and others); information obtained from offshore wind energy developers; and the relevant experience and related work of consultant team members and outside logistics experts. The following bullets summarize the findings of this effort:

- A new multi-use cargo facility at the South Terminal site represents the best option at the Port of New Bedford for servicing offshore wind energy development projects during the assembly and installation phases.
- A new multi-use port facility at the South Terminal can capture container, break-bulk (e.g., drums or crates), and bulk cargoes not now handled in New Bedford or other Massachusetts ports, and can generate economic development benefits and net operating income to the HDC with or without offshore wind energy development projects.
- The optimal model for governance of a new facility at the South Terminal would be ownership by the New Bedford HDC, which would lease offshore wind energy staging and other cargo handling, storage, and related facility operations to a qualified private operator.
- Capital costs for a new multi-use port facility at the South Terminal are estimated to total about $44 million ($44M) (in 2009 dollars). Approximately $32M of this total investment would be for land acquisition, bulkhead construction and dredging, and the buildings and site improvements that would be functionally necessary to attract and support offshore wind energy development projects (not including the Optional Fabrication Building for

offshore wind installation use). Approximately an additional $5M in capital expenditures would be for improvements necessary to attract and support new bulk, break-bulk, and container cargoes. Capital costs are shown in Table 9-1:

Table 9-1
South Terminal Capital Costs
(Source: FXM Associates, RECON™ Input Output Model)

SOUTH TERMINAL CAPITAL COSTS	Offshore Wind Installation	Non-Offshore Wind Cargoes
Bulkhead and Dredging	$ 19,990,977	$ 19,990,977
Site Acquisition	$ 2,100,000	$ 2,100,000
Backland Site Improvements (drainage, utilities, surfacing)	$ 6,000,000	$ 6,000,000
SUBTOTAL Basic Infrastructure	**$ 28,090,977**	**$ 28,090,977**
Buildings and structures (35,000 SF)	$ 3,500,000	$ 3,500,000
Crane		$ 3,000,000
Ground Equipment (fork lifts, trucks, etc.)		$ 1,500,000
Other Equipment & Fencing, Security	$ 485,000	$ 485,000
SUBTOTAL with Support Facilities & Equipment	**$ 32,075,977**	**$ 36,575,977**
Optional Fabrication Building (75,000 SF)	*$ 7,500,000*	*$ 7,500,000*
TOTAL with Fabrication Building	***$ 39,575,977***	***$ 44,075,977***

- Average net operating income to the HDC from a fully-developed South Terminal port facility is expected to total approximately $1.2M per year during a projected 3-year ROWEI and about $622,000 per year with full cargo operations. Projected operating revenues and costs are shown in Table 9-2 below:

Table 9-2
South Terminal Operating Income and Expenses
(Source: FXM Associates)

SOUTH TERMINAL OPERATING INCOME & EXPENSES	Offshore Wind Installation	Non-Offshore Wind Cargoes
Average Year Annual Operating Income		
Offshore Wind Energy Development (ROWEI)	**$ 1,500,000**	
Container Service		$ 280,000
Break Bulk Program		$ 240,000
Bulk Cargo		$ 432,500
Total Non-ROWEI Cargo		**$ 952,500**
Average Year Annual Operating Expenses		
HDC Personnel (contract/lessee management)	$ 140,000	$ 140,000
HDC Capital/maintenance reserve at 20% income	$ 190,500	$ 190,500
Average Year Annual Expenses	*$ 330,500*	*$ 330,500*
Average Year NET Operating Income		
Offshore Wind Energy Development (ROWEI)	**$ 1,169,500**	
Total Non-ROWEI Cargo		**$ 622,000**

- Based on the net operating income projected for the South Terminal, annual operating subsidies for either offshore wind energy development support or long term cargo operations are not anticipated to be required.

- The South Terminal can cover all of its operating expenses during the ROWEI use of the facility and annually thereafter based on non-ROWEI cargo operations. Approximately $12M of the capital costs for the new facility can be supported by annual net operating income combined with income from the 3 year ROWEI use of the facility. This leaves $32M of debt that would require financing from other sources.
- Construction of the South Terminal port facility is estimated to expand business output in Bristol County by approximately $44.1M over the projected 2-year construction period of the terminal, and provide 380 person years of employment and $19.2M in household income over the construction period. These projected economic impacts include total direct, indirect and induced economic effects within Bristol County. These effects are summarized in Table 9-3.

Table 9-3
Construction and Annual Direct, Indirect and Induced Economic Effects Associated with South Terminal Construction
(Source: FXM Associates)

	Output (000 $)	Employment (Jobs)	Income (000 $)
Construction Period Effects			
South Terminal Port Facility			
Bristol County	*$ 44,100*	*380*	*$ 19,200*
Massachusetts	$ 65,500	540	$ 26,100
Annual Operating Effects			
South Terminal Port Cargo Operations			
Bristol County	*$ 15,700*	*130*	*$ 5,900*
Massachusetts	$ 20,200	170	$ 7,400

- Construction of the South Terminal port facility is estimated to expand business output in Massachusetts overall (including Bristol County) by about $65.5M over the projected 2-year construction period of the terminal, and provide 540 person years of employment and $26.1M in household income over the construction period. These projected economic impacts include total direct, indirect and induced economic effects within Massachusetts over the construction period (see Table 9-3).
- The handling of cargoes not related to an offshore renewable wind energy installation (non-ROWEI), including container, break-bulk, and bulk cargoes, is estimated to expand business output in Bristol County by $15.7M annually, and provide 130 permanent jobs and $5.9M per year in new household income. These projected economic impacts include total direct, indirect, and induced economic effects within Bristol County estimated to recur annually following facility construction and do not include support of offshore wind energy projects (see Table 9-3).

- The handling of non-ROWEI container, break-bulk, and bulk cargoes at the South Terminal is estimated to expand business output in Massachusetts overall (including Bristol County) by approximately $20.2M annually, and provide 170 permanent jobs and $7.4M in new household income each year. These projected economic impacts include total direct, indirect, and induced economic effects within Massachusetts estimated to recur annually and do not include support of offshore wind energy projects (see Table 9-3).
- During the construction period for the South Terminal facility about $480,000 in local/municipal revenues within Bristol County communities would be attributable to the total projected direct, indirect and induced economic effects of construction. Within Massachusetts communities approximately $1.2M in municipal receipts (including Bristol County) would be attributable to the construction period economic effects (see Table 9-4).

Table 9-4
Construction and Annual Direct, Indirect and Induced Tax Effects
(Source: FXM Associates)

	Local Taxes (000 $)	State Taxes (000 $)	Federal Taxes (000 $)
Construction Period Effects			
South Terminal Port Facility			
Bristol County	*$ 480*	*$ 440*	*$ 1,820*
Massachusetts	$ 1,190	$ 1,440	$ 7,280
Annual Operating Effects			
South Terminal Port Operations			
Bristol County	*$ 300*	*$ 240*	*$ 730*
Massachusetts	$ 480	$ 500	$ 2,180

- During the construction period for the South Terminal facility about $1.4M in tax revenues to the Commonwealth of Massachusetts and approximately $7.3M in federal taxes would be attributable to the construction period economic effects (see Table 9-4).
- The handling of non-ROWEI container, break-bulk, and bulk cargoes at the South Terminal is expected to generate about $300,000 in new tax receipts annually for municipalities in Bristol County and $480,000 annually for municipalities statewide (including Bristol County) based on the projected annual economic effects attributable to cargo operations (see Table 9-4).
- The handling of non-ROWEI container, break-bulk, and bulk cargoes at the South Terminal is projected to generate about $500,000 in new tax receipts annually for the Commonwealth of Massachusetts and approximately $2.2M in federal taxes each year (see Table 9-4).

These components of a “path forward” relative to the development of an expanded multi-use cargo facility at the South Terminal address the key findings of preliminary business plan for port expansion. (Appendix K provides a more detailed financial analysis of port expansion and operation.) This study demonstrated that the South Terminal at the Port of New Bedford meets the necessary requirements and possesses a number of the advantageous characteristics needed to successfully support a developing offshore commercial wind farm. The study also identified some areas where this port could make modifications and improvements to its harbor or wharf facilities that would further enhance the port's ability to support offshore wind energy. The path forward would continue the process outlined here, more fully develop the elements that were addressed in this study, and consider other important aspects of the port's development that were not considered to be critical to the scope of this study.

10.0 REFERENCES

Aarsleff and Bilfinger Berger. 2009. Project information. Horns Rev 2. Offshore Windfarm Monopile Foundations.

Advanced Offshore Solutions. June 26, 2009. Crew Transfer Vessel Specification

Advanced Offshore Solutions. 26 June 2009. Installation Vessel Specification.

Applied Technology and Management, Inc. and Loria Emerging Energy Consulting, LLC. September 2007. Summary Report. RIWINDS. (Rhode Island Energy Independence 1) Phase I Siting Study.

Areva Multibrid. 2008. Areva Multibrid. Efficient. Reliable. Powerful. Product Brochure.

Areva Multibrid. Areva Multibrid. M5000 Technical data.

Barret, Chris. July 18, 2009. Deepwater gets tower approval from state. In: The Block Island Times.

Barrett, Chris and Ted. N. Grid. December 9, 2009. N. Grid, Deepwater in wind power deal. Providence Business News. http://www.pbn.com/detail/46643.html. Accessed February 2010.

BBC Chartering. July 27, 2009. BBC Elbe Specification.

BBC Chartering. July 29, 2009. BBC Konan Specification.

Beluga Group. July 22, 2009. F-Series Specification.

Beth Daley. July 20, 2009. Deep-water turbine farms could overshadow near-shore projects like Nantucket Sound`s, In: The Boston Globe.

Bluewater Wind. December 2006a. Atlantic North Offshore Wind Park.

Bluewater Wind. February 20, 2009b. Presentation on permitting under the MMS Interim Policy – Experience from the Mid-Atlantic. Held by Doug Pfeister at the Environment Business Council (EBC).

Bluewater Wind. Letter from Peter Mandelstam to Philadelphia Regional Port Authority dated September 15, 2009.

Bluewater Wind. Presentation on the Delaware Offshore Wind Park: Project Overview.

Childs Engineering Corporation. South Terminal Capital and Maintenance Costs Spreadsheets.

City of New Bedford. 2009. Implementation of Recommendations of Mayor`s Sustainability Task Force Report. Executive Order No.2009-01. Adopted on Earth Day, 2009.

City of New Bedford. 2009. Practical Solutions to Offshore Wind Energy Challenges. 2-page-handout.

City of New Bedford. June 20, 2009. Strategic Energy Planning. Energy Efficiency and Conservation Strategy Activity Worksheet.

City of New Bedford. Cost Estimating Table. PNB Support – Port Task. Budget Table for the Port of New Bedford Project Task in Support of Wind Energy Pilot Program. Spreadsheet.

City of New Bedford. Green Line Initiative Proposal Application to the Massachusetts Clean Energy Center.

City of New Bedford. Information Material: Port facility information.

City of New Bedford. Information Material: Terminal & contact information.

City of New Bedford. Port of New Bedford Port Infrastructure Assessment and Port Logistics Support. Draft Work Plan.

City of New Bedford. Report by the Sustainability Task Force. Sustaining New Bedford.

Clipper Windpower. October 19, 2009. Clipper Mariner Specification. Clipper Projects.

Clipper Windpower PLC. 2006. The Liberty 2.5 MW Wind Turbine. Brochure.

Cohen, Daniel. July 2008. Fishermen`s Energy of New Jersey, LLC.

Commonwealth of Massachusetts Partnership. November 10, 2006. CRADA Application..Large Scale Blade Test Facility Partnership. Submitted to National Renewable Energy Laboratory.

Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs. June 2009. Massachusetts Ocean Management Plan. Volume 1, 30.

Deepwater Wind. April 2009. Deepwater Wind announces appointment of Chief Development Officer. Paul M. Rich will head Deepwater Wind`s Rhode Island operations. Press release.

Durand & Anastas Environmental Strategies Inc. 2009. Profiles of East Coast Ports Outside of Massachusetts.

European Wind Energy Association. 2009. Oceans of Opportunity. Harnessing Europe`s largest domestic energy resource.

FXM Associates. 2009. Economic Effects of Offshore Wind Energy and Related Construction and Operating Expenditures.

FXM Associates. 2009. Port of New Bedford South Terminal Business Plan.

Gallagher, Paul. Fishermen`s Energy. Power from the Sea. Company Introduction. Presentation held in July 2008.

Garcia, Ketchen and Urban Harbors Institute, University of Massachusetts Boston, City of Gloucester. 2009. Harbor Plan and Designated Port Area Master Plan 2009

Garden State Offshore Energy. 2008. Fact Sheet http://www.gardenstatewind.com/pdf/factsheet.pdf. Accessed February 2010.

Garden State Offshore Energy. 2008. Frequent answers and questions.

Garden State Offshore Energy. 2008. Garden State Offshore Energy wins bid for NJ Offshore Wind Farm. 350 MW wind farm will generate clean energy and jobs for New Jersey.

GE Energy. 2005. 3.6 MW Offshore Series Wind Turbine. Brochure.

GE Energy. November 18, 2008. 5M, Repower Systems, Turbine Specification.

GE Energy. September 2005. Turbine Specification. 3.7 MW Offshore Series Wind Turbine.

Global Insight. April 2003. Economic Impact Analysis of the Cape Wind Off-Shore Renewable Energy Project.

Gusto MSC. MSC Gusto Jackup Maintenance Barge Description. NG-series self propelled jack-up units. Type NG-2750-WTM.

Heininger, Claire. March 2008. PSEG, 2 others apply to build wind farm off NJ coast. http://www.nj.com/news/index.ssf/2008/03/about_half_of_the_state.html. Accessed February 2010.

Infocast. 2009. US Offshore Wind Report.

ISO New England. July 2009. New England Wind Integration Study. Presentation held in July 2009 by John Norden and Bill Henson, ISO New England.

LEK Consulting and The Carbon Trust. July 2006. Policy Frameworks for Renewables.

Levitan & Associates, Inc. May 2007. ISO New England. Technical assessment of onshore and offshore wind generation potential in New England. Boston.

Maritime Danmark. November 04, 2009. Aarsleff to build 177 monopile foundations. Accessed at http://www.maritimedanmark.dk/?Id=6176 on November 16, 2009.

MARPRO Associates International. 2009. Potential Wind Turbine Delivery Ships.

MARPRO Associates International. 2009. Comparison of Selected Northeast ports for potential handling of Wind Power Offshore Energy Installations

MARPRO Associates International. 2009. Road ad Rail Access Ports of Massachusetts.

MARPRO Associates International. 2009. US East ad Gulf Coast Shipyard Construction an Repair Capacity And Availability Offshore Wind Turbine Delivery and Service Vessels.

Massachusetts Clean Energy Center. 2009. Strategic Options for Investment in Transmission in Support of Offshore Wind Development in Massachusetts. Summary Report with Expanded Technical Information. Analysis Group, Inc.

Massachusetts Executive Office of Energy and Environmental Affairs. 2010. Ocean Management Plan.

Massachusetts Maritime Academy. 2009. Practical Solutions to Offshore Wind Energy Challenges. Grant Application.

Massachusetts Port Authority. 2009. http://www.massport.com/ports/. Last accessed February 12, 2010.

Mayor Scott W. Lang. March 2009. Port of New Bedford, Massachusetts. South Terminal Development. Document prepared by the New Bedford Harbor Development Commission.

Monroe, Jeffrey, Captain. October 2009. Comparison of Selected Northeast Ports for Potential Handling of Wind Power Offshore Energy Installations (Draft).

Monroe, Jeffrey, Captain. October 2009. Comparison of Selected Northeast Ports for Potential Handling of Wind Power Offshore Energy Installations (Draft).

Multibrid Entwicklungsgesellschaft mbH. September 2005. M5000 Technical Data. Multibrid, Turbine Specification.

National Oceanic and Atmospheric Administration. Climatology Data. NOAA Buoy # 44009.

National Oceanic and Atmospheric Administration. Climatology Data. NOAA Buoy # 44025.

National Renewable Energy Laboratory/U.S. Department of Energy. April 2009. Economic Development Impacts in Colorado from Four Vestas Manufacturing Facilities. Wind Powering America Fact Sheet Series.

New Bedford Harbor Development Commission. June 2009. The harbor plan at a glance: Land Use.

New Bedford Harbor Development Commission. July 2009. Volume 3, Issue 1.New Bedford on the Waterfront.

New Bedford Harbor Development Commission. September 15, 2009. Integrated Intermodal Transportation Infrastructure Improvements.

Offshore Wind Collaborative Organizing Group. September 2005. A Framework for Offshore Wind Energy Development in the United States. Massachusetts Technology Collaborative, U.S. Department of Energy and General Electrics.

Papalexandrou. 2008. Economic analysis of offshore wind farms. KTH School of Energy and Environment, in partnership with Ecofys.

PB Americas, Inc. in association with Fitzgerald & Halliday, Inc. May 2007. Port of New Haven Strategic Land Use Plan, Prepared for the New Haven Port Authority.

Port Authority of New York and New Jersey. 2009. http://www.panynj.gov/port/. Last accessed October 27, 2009.

Port Authority of Portland Maine. http://www.portofportlandmaine.org. Accessed on 12/15/09.

Port of Baltimore. http://www.mpa.state.md.us. Accessed on 12/15/09.

Port of New Bedford, MA. The Nation`s #1 Fishing Port.

Port of Philadelphia. http://www.philaport.com. Accessed on 12/15/09.

Port of Portsmouth, New Hampshire. http://www.portofnh.org. Accessed on 12/15/09.

Port of Providence, RI. http://www.provport.com. Accessed on 12/15/09.

Port of Quonset Point/Davisville, RI. http://www.qdcri.com. Accessed on 12/15/09.

Port of Wilmington. http://www.portofwilmington.com. Accessed on 12/15/09.

Quirk, Daniel. Fore River Shipyard Factsheet.

Quonset Development Corporation. website accessed February 2010 http://qdcri.com/transportation/

Renewable Energy. August 2009. Progress in the City of New Bedford.

RE Power Systems. The 5-megawatt power plant with 126 rotor diameter. Product brochure.

Schachterle et al, Brown University, Providence, RI Public Works website accessed February 2010 http://www.providenceri.com/publicworks/hurricane/description1.html

Seafreeze Ltd. 2009. http://www.seafreezeltd.com/index.asp. Last accessed October 27, 2009.

Siemens AG. June 25, 2009. Presentation on UK Ports & Offshore Wind. Siemens` perspective by Chris Ehlers, MD Renewable Division Siemens.

Siemens. July 20, 2009. Technical Specification SWT-3.6-107 Wind Turbines. Siemens Power Generation, Turbine Specification.

Siemens. 2009. Oceans of Opportunities. Complete solutions for the entire life cycle of offshore wind farms. Product brochure.

Siemens. Technical Specification SWT-3.6-107 Wind Turbines. Accessed at www.power generation.siemens.com/products-solutions-services/p on July 7th 2009.

State of Rhode Island. April 2008. Rhode Island Energy Independence 1 Project. Request for Proposal Nr. 7067847.

Tetra Tech EC. November 2009. Conversations with Matthew Morrissey, Executive Director. New Bedford Economic Development Council (NBEDC).

Tetra Tech EC. 2009. Project Developer Interviews, conducted by Tetra Tech, dates July – September 2009.

Tetra Tech EC. 2009. Project Kickoff Meeting Minutes. June 23rd, 2009.

Tetra Tech EC. 2009/2010. Conversations with Vestas.

Tetra Tech EC. 2009/2010. Interviews with offshore wind developers, manufacturers and port authorities.

The Analysis Group, Inc., Tierney, Susan, Okie, Andrea and Carpenter, Stephen. 2009. The 2009 Summary Report - Strategic Options for Investments in Transmission in Support of Offshore Wind Development in Massachusetts.

The Glosten Associates. Project Kickoff Meeting Minutes. July 9, 2009.

The Glosten Associates. 2009. Vessel Requirements for Offshore Wind Farm Construction and Maintenance.

The Glosten Associates. 2009. Marine Vessels for Construction and Maintenance of Offshore Wind Farms.

Thomsen, Kurt. 2009. Various information regarding European port requirements and Offshore Wind Farm logistics. Contribution to the report.

University of Maine. 2009. College of Engineering News Update - AEWC Awarded $8M Grant for Offshore Wind. http://www.engineering.umaine.edu/blog/2009/10/21/news-update-aewc-awarded-8m-grant-for-offshore-wind/. Last accessed December 4, 2009.

U.S. Army Corps of Engineers. 2008. Boston Harbor Massachusetts Final Feasibility Report and Supplemental Environmental Impact Statement for Deep Draft Navigation Improvements.

U.S. Coast Guard. 2006. Northeast Gateway Deepwater Port Final Environmental Impact Statement Final Environmental Impact Report. DOT Docket Number: USCG-2004-22219. MEPA EOEA Number 12373/13474. Prepared by Environmental Resources Management (ERM) for USCG Deepwater Ports Standards Division (G-PSO-5). USCG, Washington DC.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) and National Ocean Service. 2009 (39th Edition). United States Coast Pilot 1. Atlantic Coast: Eastport, ME to Cape Cod, MA.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) and National Ocean Service. 2009 (39th Edition). United States Coast Pilot 2. Atlantic Coast: Cape Cod, MA to Sandy Hook, NJ.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) and National Ocean Service. 2009 (39th Edition). United States Coast Pilot 3. Atlantic Coast: Sandy Hook, NJ to Cape Henry, VA.

U.S. Department of Energy. April 2009. Wind Powering America Fact Sheet Series. Economic Development Impacts in Colorado from Four Vestas Manufacturing Facilities.

U.S. Department of the Interior. Mineral Management Service. 2008. Draft Environmental Assessment, Alternative Energy and Alternate Uses of Existing Facilities on the Outer Continental Shelf: Proposed Rule. http://www.mms.gov/offshore/RenewableEnergy/Assets/PDFs/Draft_EA-AEAU_Proposed_Rule-070308.pdf June 2008. Accessed February 2010

U.S. Department of the Interior. Mineral Management Service. 2009. Guidelines for the Minerals Management Service Renewable Energy Framework, July 2009. Accessed online January 2010 at http://www.mms.gov/offshore/ RenewableEnergy/PDFs/ REnGuidebook_03August2009_3_.pdf (cited as MMS 2009)

U.S. Department of the Interior Minerals Management Service. January 2009. Cape Wind Energy Project. Final Environmental Impact Statement. Volume 1 of 3. (MMS EIS-EA OCS Publication No. 2008-040.)

U.S. Department of the Interior. Minerals Management Service. January 21, 2009. Federal Register. Vol. 74, No. 12. Notices, p. 3635.

U.S. Department of the Interior. January 2009. Cape Wind. Final Environmental Impact Statement.

Van Hulle, F. and Cronin, A. September 2009. Oceans of Opportunity: Harnessing Europe's largest domestic energy resource, The European Wind Energy Association (EWEA).

Vestas. 2009a. Wind Systems A/S. V112-3.0MW. One Turbine for One World. Denmark.

Vestas. 2009b. Vestas celebrates ground-breaking for two manufacturing facilities in Colorado. Press release No. 2/2009 from Vestas Americas.

Vestas. November 2005. V90-3.0 MW: An Efficient Way to More Power. Turbine Specification.

Vestas. Offshore A/S. Functional Specification. 2008. Harbor Storage, Pre-Assembly and Load Out for Offshore Wind Turbine Installation.

Voskamp, Peter. Seven bids for a wind farm. Block Island Times. June 9, 2008. http://www.fishermensenergy.com/images/news/20080609%20Block%20Island%20Times%207%20Bid%20in%20RI.pdf Accessed February 2010.

Nautical Charts:

National Oceanic and Atmospheric Administration. March 1975. Designated Port Area: Gloucester Inner Harbor. NOAA National Ocean Survey Nautical Chart # 13281.

National Oceanic and Atmospheric Administration. November 1975. Designated Port Area: New Bedford - Fairhaven. NOAA National Ocean Survey Nautical Chart # 13229 Pg. G.

National Oceanic and Atmospheric Administration. January 1976. Designated Port Area: South Boston. NOAA National Ocean Survey Nautical Chart # 13272.

National Oceanic and Atmospheric Administration. January 1976. Designated Port Area: Salem Harbor. NOAA National Ocean Survey Nautical Chart # 13276.

National Oceanic and Atmospheric Administration. January 1976. Designated Port Area: Mystic River. NOAA National Ocean Survey Nautical Chart # 13272.

National Oceanic and Atmospheric Administration. January 1976. Designated Port Area: Beverly Harbor. NOAA National Ocean Survey Nautical Chart # 13276.

National Oceanic and Atmospheric Administration. January 1976. Designated Port Area: Chelsea Creek. NOAA National Ocean Survey Nautical Chart # 13272.

National Oceanic and Atmospheric Administration. January 1976. Designated Port Area: East Boston. NOAA National Ocean Survey Nautical Chart # 13272.

National Oceanic and Atmospheric Administration. April 1977. Designated Port Area: Mt. Hope Bay. NOAA National Ocean Survey Nautical Chart # 13221.

National Oceanic and Atmospheric Administration. January 1978. Designated Port Area: Weymouth Fore River. NOAA National Ocean Survey Nautical Chart # 13270.

National Oceanic and Atmospheric Administration. May 2008. Designated Port Area: Lynn. NOAA National Ocean Survey Nautical Chart # 13275.