American Ports & Infrastructure for Offshore Wind

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The first port facility in North America expressly built to serve as a logistics hub for offshore wind farms, the New Bedford Marine Commerce Terminal, in New Bedford, Massachusetts, required a bulkhead capable of handling loads significantly greater than those imposed on other wharves in the United States. Designed to accommodate large crane cranes that will lift turbine components weighing hundreds of metric tons, the bulkhead features a system of cellular sheet-pile cofferdams capable of providing the support and flexibility required. By combining port construction with significant efforts to remediate existing contamination in New Bedford Harbor, the project boosts local economic prospects while helping to foster the nascent U.S. offshore wind industry.

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Recognizing the benefits that offshore wind energy could bring to New England, the Commonwealth of Massachusetts has been preparing for this industry for many years. Among these preparations has been the development of the New Bedford Marine Commerce Terminal, in New Bedford, Massachusetts. An ambitious, challenging effort, the terminal project entailed the creation of the first purpose-built marine terminal in New England having the capacity to stage and deploy offshore wind projects. Completed in 2016, the $113-million facility marks a significant milestone in the development of the infrastructure necessary to support the country’s nascent offshore wind industry.

On August 8, 2016, Massachusetts’s governor, Charlie Baker (R), signed into law an energy bill that would require the state’s utilities to draw on at least 1,600 MW of offshore wind capacity in the coming years, enough to power a third of the homes in Massachusetts. One month later, on September 6, the governor announced the future use of the New Bedford Marine Commerce Terminal by three offshore wind developers that were to compete to construct wind projects in federal wind energy areas beginning 14 mi south of Martha’s Vineyard. This industry, once it reaches maturity, is expected to deliver reliable, competitive, and clean power to metropolitan areas along U.S. coastlines, provide a measure of energy independence and security to regions that currently import most of their energy, and create hundreds of thousands of U.S. jobs in engineering, manufacturing, and construction.

Massachusetts has worked for more than 20 years to facilitate the development of renewable energy sources, including offshore wind. In 1997 it passed the Electric Industry Restructuring Act to divide energy generation and energy distribution into separate markets, aiming to make both markets more competitive. Around that same time, it created the Renewable Energy Trust Fund and implemented a surcharge of $0.0005 per kilowatt-hour on the retail sale of electricity to fund it. In 2008 legislation known as the Green Communities Act established the Massachusetts Clean Energy Center (MAsCEC), the steward of the Renewable Energy Trust Fund. In 2011, before developing the New Bedford Marine Commerce Terminal, MAsCEC completed work on the Wind Technology Testing Center, a massive facility in Charlestown for testing wind turbines (see “Testing Tomorrow’s Turbines,” Civil Engineering, July 2011, pages 64-71).

The Massachusetts Renewable Portfolio Standard, which took effect in 2003, mandates that utilities procure a certain percentage of electricity each year from such approved renewable energy sources as wind, the sun, and small-scale hydro-power facilities. For 2016 utilities were required to procure 11 percent of their electricity from renewable sources. This requirement will increase by 1 percentage point per year until it reaches 15 percent by 2020. As of the end of 2015, the total installed capacity from renewable sources in Massachusetts exceeded legislative mandates by a factor of 2, surpassing 1,000 MW.

Recognizing the direct relationship between greenhouse gases and global warming, as well as the threat that rising sea levels pose to the commonwealth’s coastlines, the Massachusetts legislature passed the Global Warming Solutions Act in 2008. The law commits the commonwealth to a 25 percent reduction of greenhouse gases from 1990 levels by 2020 and an 80 percent reduction by 2050. Meanwhile, a 2016 law entitled An Act Relative to Energy Diversity will further increase the amount of electricity that utilities must purchase from offshore wind and hydroelectric sources. ISO New England, Inc., the entity that operates the regional power system, has announced the possible retirement over the next several years of nuclear and fossil-fueled power plants having a combined capacity of more than 8,000 MW. Against this backdrop, the development of the offshore wind industry along U.S. shores could not be more timely.

Offshore wind represents a significant source of potential energy, one from which New England is well positioned to capitalize. According to the U.S. Department of Energy’s National Offshore Wind Strategy, released last September, U.S. offshore wind resources have a gross recoverable power...
Bathymetry after Terminal Construction

The United States has a “technical potential capacity” of 2,058 GW from offshore wind, nearly twice the electrical generating capacity of the entire country. In 2013 the six states served by the United States Department of Energy, estimated that these states have an offshore wind generation potential of 591 GW. The laboratory estimated that 79 percent of this offshore wind potential comes from average wind velocities higher than 9 m/s, which is approximately 1.4 to 2.1 times higher than 87 percent of the offshore wind resources estimated for the rest of the country. In view of the fact that retail electricity prices in New England in 2013 were 14.1 cents per kilowatt-hour, 33 percent higher than the national average, commercial-scale offshore wind presents a viable and attractive option for electric power generation in New England. Assuming continued reductions in the cost of the technologies used to harness wind energy, New England could realistically generate a significant portion of its electricity from offshore wind.

Offshore wind energy in New England has progressed from the theoretical to the actual. In January 2015 the U.S. Bureau of Ocean Energy Management auctioned leases in the federal wind energy area south of Martha’s Vineyard mentioned above. In 2016 Deepwater Wind, of Providence, Rhode Island. The five turbines for the wind farm were mentioned above. In 2016 Deepwater Wind, of Providence, Rhode Island. The five turbines for the wind farm were mentioned above. In 2016 Deepwater Wind, of Providence, Rhode Island. The five turbines for the wind farm were mentioned above. In 2016 Deepwater Wind, of Providence, Rhode Island. The five turbines for the wind farm were mentioned above. In 2016 Deepwater Wind, of Providence, Rhode Island. The five turbines for the wind farm were mentioned above.

Future commercial-scale projects will involve wind turbines, towers, and foundation components weighing hundreds of metric tons. In the near future many of these items will be imported from Europe because at present no U.S. manufacturing facilities have the ability to build the large primary components required by offshore wind farms operating on a commercial scale. Thus, for now, these primary offshore components will have to be transported by international cargo vessels. The assembly of wind turbines at sea requires specialized, highly mobile installation vessels that can create a stable platform in the open ocean and provide the heavy crane capacity needed to lift the large components into place. Offshore wind farms must be assembled and erected on an exacting season-to-season basis, with the potential for maximum flexibility in transporting heavy components around the terminal site, made land-side heavy-lift capacity a prominent element in the design of the New Bedford Marine Commerce Terminal.

In 2010 STUDY COMMISSIONED by MassCEC listed Boston’s Dry Dock 4 and New Bedford Harbor’s South Terminal as the top candidates for terminals for supporting offshore wind energy development. The two sites were selected because of their locations in protected harbors, their shipping channel depths, the absence of physical restrictions on overhead clearance, the potential berth lengths they offered, and the available upland areas. Ultimately, the study recommended New Bedford over Boston for the following reasons:

- New Bedford is closer to the federal wind energy areas south of Martha’s Vineyard.
- The City of New Bedford viewed the proposed terminal and the offshore wind industry as keys to its economic future and had adopted formal measures to support the growth of this industry.
- As a designated Superfund site with a clearly defined plan for navigational dredging, New Bedford Harbor offered a more straightforward permitting process than would have been the case in Boston, where multiple state and federal agencies would have had jurisdiction.
- Given the business site’s proximity to Boston Logan International Airport, the Federal Aviation Administration would have had authority over matters pertaining to overhead clearance.

In 2010 MassCEC hired its design team for the New Bedford Marine Commerce Terminal. Participants included Apex Companies, LLC, of Rockville, Maryland, which would provide civil and environmental engineering services; CLE Engineering, Inc., of Marion, Massachusetts, which would serve as the structural engineer; and GZA GeoEnvironmental, Inc., of Norwood, Massachusetts, which would provide geotechnical engineering services. In 2011 LeMessurier Consultants, Inc., of Boston, was brought on board as the owner’s adviser Cashman-Wecks NB, a joint venture comprising Cashman Dredging, Inc., of Quincy, Massachusetts, and Weeks Marine, Inc., of Cranford, New Jersey, served as the contractor.

A major challenge associated with the design and construction of the New Bedford Marine Commerce Terminal, one must consider the project’s three governing conditions: heavy-lift capacity, heavy-lift capacity, heavy-lift capacity. To understand the challenges associated with the design and construction of the New Bedford Marine Commerce Terminal, one must consider the project’s three governing conditions: heavy-lift capacity, heavy-lift capacity, heavy-lift capacity. The terminal’s heavy-lift capacity would be needed to receive, prepare, and stockpile components weighing several hundred metric tons in a manner that would make it possible to deploy them to construction sites under favorable weather conditions. The complex logistical challenges associated with moving heavy components on a commercial scale required that the entire terminal’s quayside and upland areas be engineered to support heavy cargo vessels without the use of load-spreading appurtenance, or “dunnage.” Such an approach was required to maximize operational flexibility.

Geologically, New Bedford Harbor is underlain by relatively shallow bedrock. More than 20,000 years ago, the Laurentide ice sheet scoured the bedrock there, fracturing it and entraining large pieces of rock within dense deposits of glacial lodgement till. Above these glacial till deposits, glacial outwash and marine deposits were laid down during the glacial retreat. Situated above these outwash and marine deposits is a layer of silty, organic marine sediment that became heavily contaminated with polychlorinated biphenyls (PCBs) after World War II. In 1983 the U.S. Environmental Protection Agency (EPA) designated New Bedford Harbor as a Superfund site under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and placed it under its oversight.
Environmental Response, Compensation, and Liability Act.

The presence of this contamination, which is still found in nearly the entire harbor environment, provides opportunities as well as challenges during the development of the New Bedford Marine Commerce Terminal. The commonwealth and the design team for the terminal project recognized that constructing an entirely new port facility along the coast would prove challenging from a regulatory perspective. However, building the new terminal in New Bedford Harbor meant that development could proceed in a manner that addressed the environmental contamination. For this reason, once New Bedford Harbor had been selected as the home for the Massachusetts offshore wind port, the commonwealth and the design team entered into discussions with environmental regulatory officials to begin developing a process that would be responsive to the project’s circumstances. New Bedford Harbor’s designation as a Superfund site meant that the commonwealth and the design team worked in tandem with the appropriate federal and state agencies to develop the regulatory process for the terminal project.

Ships entering New Bedford Harbor must pass through the hurricane protection barrier constructed by the U.S. Army Corps of Engineers in the 1960s. The 3.5 mi long barrier includes a 130 ft wide gate within the 29 ft deep, 350 ft wide federal navigation channel. To enable deep-draft vessels to reach the New Bedford Marine Commerce Terminal, the project included the dredging of an 825 ft diameter turning basin and a 500 ft wide channel leading to the terminal. In this way, ships entering the harbor through the hurricane barrier would have to pass to the north of the terminal, change direction by means of the turning basin, and then approach the terminal to the south.

The design team’s assessment of the project site to the south of the existing South Terminal included the following:

- Gathering information from land-side and waterside borings;
- Engaging land-side and waterside remote sensing programs;
- Analyzing side-scan sonar, vibracores, peat cores, and bottom material obtained by grab samplers within the dredge footprint;
- Gathering historical information on dredging at the South Terminal;

so-called state-enhanced remedy provision was incorporated into the record of decision to allow special handling and disposal of dredge sediments from the navigation channel that contained contamination at a level below a certain threshold. Approximately 2.5 million cu yd of the sediment would not be suitable for disposal in the open water, would not be covered by the Superfund project, and would require dredging in order to maintain the shipping channels at the Superfund site at their federally mandated depths. Using the state-enhanced remedy provision as a guide, the commonwealth and the design team worked in tandem with the appropriate federal and state agencies to develop the regulatory process for the terminal project.

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Although the procedures at existing European terminals can work well, European colleagues impressed upon MassCEC and the design team that these measures limited the flexibility of land-side logistics and would not be favored in the case of a new, purpose-built European terminal. A new U.S. terminal could be designed more efficiently, but it would also have to contend with the prohibition on European-flag installation vessels. Limiting the transfers to land-side cranes increases the radius of the “picks,” driving up the size of the crane and counterweight necessary for such picks and subsequently increasing the peak loads under the tracks of the crane on the seaward side of the bulkhead. These considerations led MassCEC and the design team to consider loading criteria in modeling going beyond the basic 4,100 psf originally suggested by the offshore wind industry.

The cost of designing for heavy loads also led MassCEC to investigate options for concentrated heavy-lift platforms that would involve stationary cranes at various locations along the bulkhead. However, these options were complicated by the presence of the so-called jack-up barges (also known as spud barges) that would be parked at the quayside during loading operations. Used to deliver the turbine components from the terminal to the wind farm, the barges employ multiple “legs” that are lowered to the ocean floor to jack up, or elevate, the barge above the water’s surface and create a stable platform for construction. These legs, however, are raised in the air when the barges are in shallow water, so the presence of the barges at the quayside was a challenge. The stakeholder engagement process also revealed that existing offshore wind developers had various methods for using a staging port, that the logistics of offshore wind installation and the logistics of staging ports are continually evolving, and that the primary criterion that garnered consensus among stakeholders was maximum flexibility at the site.

Discussions with offshore wind component manufacturers provided guidance on the size and weight of future components that may need to be loaded or unloaded. The stakeholder engagement process also revealed that existing offshore wind developers had various methods for using a staging port, that the logistics of offshore wind installation and the logistics of staging ports are continually evolving, and that the primary criterion that garnered consensus among stakeholders was maximum flexibility at the site.

The design team minimized the size of the relieving platform to create a straight quayside and protect the sealed wastewater edges of the cellular caissons. Furthermore, the study’s findings gave MassCEC confidence that the cellular caisson structure, which offered advantages with regard to constructability, would be able to accommodate future loading patterns, even if heavier. This process, 4,100 psf became the “uniform load” and governed the caisson design with regard to hoop tension, shearing, and sliding. Meanwhile, the maximum pressure under the crane tracks in a loaded condition, or “point load,” governed the design of the pile-supported structure and the soil bearing capacity.

For high bearing capacities in the upland areas, the design team specified 3 ft of dense, graded aggregate over at least 7 ft of heavily compacted fill. This dense, graded aggregate cap made it possible to leave in place sediment contaminated with less than 50 ppm of PCBs. The cap also strengthened the bearing capacity of the sediment so that the cranes would be able to move freely at the site without damage.

**Image Description:**

The image shows a diagram titled “Typical Steel Cell for 32 ft Dredging.” The diagram illustrates various components of a steel cell, including:

- **Cell Structure:** The main cell structure is depicted with labeled parts such as cell walls, header, and footer.
- **Dimensions:** The cell dimensions are indicated, with emphasis on the height and depth suitable for 32 ft of dredging.
- **piles and Anchoring:** The diagram includes piles, some labeled as driven piles and grouted piles, with details on their specifications.
- **Grouting:** The process of grouting piles is represented, showing the concrete used to fill the piles to achieve the required load-bearing capacity.
- **soil Conditions:** The soil conditions are noted, including the depth to the bedrock and the required filter layer.
- **Dredge Operations:** The diagram highlights the dredging operations, including the header for outgoing barges and the channel leading to it.

**Legend:**

- A. Remove all organic and unstable soils to depth determined by owner’s field representative.
- B. Toe of sheet piles on rocky material. Exclude minimum.
- C. Locate piles in this area to have driving shoes.
- D. 3 in. diameter extra-heavy steel pipe 4 ft long.
- E. 24 in. x 5.8 in. wall pipe pile 450 ton rock socket 4 ft into sound rock. Grouted piles to be filled with 4,000 psi concrete.
- F. Rock sockets for piles to be minimum 6 in. larger than outer diameter of pile.
- G. Predrill rock sockets through loose and soft rock materials to sound rock as determined by engineer in field. Socket to penetrate 4 ft minimum into sound rock layer. Fill void to top with 4,000 psi grout or concrete.

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The design team also had to consider the dredging of the new channel and turning basin from environmental, geo-
technical, and logistical points of view and to coordinate the
dredging and construction of the new terminal. The design and
construction requirements resulted in the development of three
dredge prism basins in the project. The material in the bottom
dredge prism was considered to be environmentally and geotechnically unsuitable for reuse as
filling material or upland fill. Material in the bottom prisms
was considered to be environmentally and geotechnically suitable for reuse as
upper fill. The intermediate material of dredge prism was considered to be
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