Developments and Trends in the Global Offshore Wind Market

U.S. Offshore Wind Market and Supply Chain Workshop

Presented by Bruce Hamilton | Navigant
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Content of Report

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There are approximately 7 gigawatts (GW) of offshore wind installations worldwide.

<table>
<thead>
<tr>
<th>Region</th>
<th>Country</th>
<th>Total Capacity (MW)</th>
<th>Operational Projects</th>
<th>Installed Turbines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>U.K.</td>
<td>3,686</td>
<td>60</td>
<td>1,083</td>
</tr>
<tr>
<td></td>
<td>Denmark</td>
<td>1,274</td>
<td>17</td>
<td>517</td>
</tr>
<tr>
<td></td>
<td>Belgium</td>
<td>571</td>
<td>6</td>
<td>135</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>516</td>
<td>8</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>Netherlands</td>
<td>247</td>
<td>4</td>
<td>128</td>
</tr>
<tr>
<td></td>
<td>Sweden</td>
<td>212</td>
<td>6</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>Finland</td>
<td>32</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Ireland</td>
<td>25</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Spain</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Norway</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Portugal</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Asia</td>
<td>China</td>
<td>404</td>
<td>16</td>
<td>159</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>52</td>
<td>9</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>South Korea</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>7,033</td>
<td>105</td>
<td>2,279</td>
</tr>
</tbody>
</table>

- Majority of activity continues to center on northwestern Europe.
- Development in China continues to progress.
- In 2013, 1,720 MW were added globally.
- The European market will continue to grow rapidly over the next two years.
- New and expanding projects likely to contribute a record-setting 2,290 MW in 2014 alone (mostly in Germany and U.K.).

Note: Includes commercial and test projects. Individual phases of projects at a single site may be counted as separate projects. 
Source: Navigant analysis of data provided by NREL and BTM
The growth in average nameplate capacity of offshore wind turbines installed globally each year tapered off around 4 MW in 2013.

- Smaller turbines in Asia is the main reason for the drop in average size.
- Nearly two-thirds (64%) of turbines installed in 2013 were 3.6-MW models.
- 14% of installed turbines were larger (5 to 6.15 MW).
- Long-term trend toward larger turbines likely to continue.
- Beyond Cape Wind, LEEDCo and Galveston Offshore Wind, most U.S. projects plan to utilize larger (≥5MW) offshore wind turbines.

Note: Average turbine size is based on an annual capacity-weighted figure (each project’s turbine size is weighted against its share of annual installed capacity). While it has begun construction activities, Cape Wind (which plans to use 130 3.6-MW turbines) is included in the U.S. Planned category.

Source: Navigant analysis of data provided by NREL and BTM
Globally, offshore wind projects continue to trend further from shore into increasingly deeper waters.

- Trend toward greater distances helps reduce visual impacts and public opposition to offshore wind.
- Another benefit is that wind speeds and therefore capacity factors are generally higher farther from shore.
- But, it also requires advancements in foundation technologies and affects the logistics and costs of installation and maintenance.

Note: Multi-phase projects were combined and are reported at the latest year when turbines were added at the project site. Expansions or phases of existing projects sites currently under construction were omitted to avoid skewing the data.

Source: Navigant analysis of data provided by NREL and BTM
Globally, offshore wind projects continue to trend further from shore into increasingly deeper waters.

- Several projects currently under construction are continuing to push into more distant and deeper waters.
- Advanced-staged projects in the U.S. are planned for closer to shore than recent European projects.
- Two potential demonstration projects (UMaine and Oregon’s WindFloat) have proposed floating turbines at record-setting depths.
- Notably, some of the BOEM WEAs have average depths that exceed those of any currently operating commercial projects.

Note: Bubble size indicates projects’ relative capacities; several projects are labeled for scale. Multi-phase projects were combined to show cumulative project capacity. Chart does not include the proposed Principle Power WindFloat project off the coast of Oregon (365 meter depth, 15 miles from shore).

Source: Navigant analysis of data provided by NREL and BTM
Approaches to drivetrain configurations continue to diversify to improve reliability and reduce exposure to volatile supplies of rare earth metals.

- High O&M costs at sea have encouraged manufacturers and developers to continue seeking more robust drivetrain configurations.
- However, recent interest in direct-drive turbines has been somewhat tempered by limited supply and price volatility for several rare earth metals.
- As a result, several prototypes of machines employing alternate drivetrain designs are expected to be tested in 2014 and 2015.

**Global Offshore Wind Development and Technical Trends » Drivetrain Configuration**

**Offshore Wind Turbine Prototypes by Drivetrain Configuration and Year of First Offshore Deployment**

Note: Deployments after 2013 based upon wind turbine manufacturers’ announced schedules.

Source: NREL data
The general trend toward diversification of substructure types also continued in 2013.

- Industry seeks to address deeper waters, varying seabed conditions, increasing turbine sizes, and the increased severity of wind and wave loading.
- Monopiles will continue to dominate for the next 2-3 years due to the introduction of XL monopiles in Germany and Denmark.
- Jackets and tripiles have increased in the past three years, but still represent a small share of the total.
- To date, four full-scale prototype floating foundations have been installed globally.
Offshore wind power prices have been following a generally increasing trend.

- Cost increases are a function of several trends:
  - a movement toward deeper-water sites located farther offshore;
  - increased siting complexity; and
  - higher contingency reserves and greater uncertainty when working in the offshore environment.

- For projects installed in 2013 for which data was available, average reported capital cost was $5,186/kW.

Note: Data was not available for all projects. Capital costs were inflated to 2012 currency in original currency and converted to U.S. dollars using 2012 average exchange rates. BARD Offshore I was excluded due to a cost overrun of more than 1 billion Euros.

Source: NREL analysis
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2. **Offshore Wind Industry Survey Results**

3. **U.S. Offshore Wind Project Development Overview**
For the 2014 survey, we received partial or complete responses from 19 people in our offshore wind industry survey.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>2012 Survey</th>
<th>2013 Survey</th>
<th>2014 Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viewed</td>
<td>262</td>
<td>164</td>
<td>75</td>
</tr>
<tr>
<td>Started</td>
<td>123</td>
<td>42</td>
<td>26</td>
</tr>
<tr>
<td>Completed</td>
<td>53</td>
<td>30</td>
<td>19</td>
</tr>
<tr>
<td>Completion Rate*</td>
<td>43%</td>
<td>71%</td>
<td>73%</td>
</tr>
<tr>
<td>Drop Outs (After Starting)</td>
<td>70</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Average Time to Complete</td>
<td>22 minutes</td>
<td>26 minutes</td>
<td>27 minutes</td>
</tr>
</tbody>
</table>

*Completion rate for the purpose of this presentation is the number of completes per the number of surveys started.
Most survey participants fell outside of the prescribed categories. “Other” participant types included mostly consultants, as well as both governmental and non-governmental organizations.

How would you characterize your company's participation in offshore or onshore wind markets? (select all that apply)

### 2012 Survey
- Manufacturer: 15%
- Developer: 16%
- EPC or O&M: 9%
- Govt: 6%
- Trade Assn: 9%
- Other: 45%

### 2013 Survey
- Manufacturer: 9%
- Developer: 22%
- EPC or O&M: 6%
- Govt: 8%
- Trade Assn: 15%
- Other: 15%

### 2014 Survey
- Component or Material Supplier: 5%
- Wind turbine OEM: 5%
- Developer: 19%
- EPC or O&M: 10%
- Govt: 10%
- Trade Assn: 8%
- Other: 62%
Respondents from all survey years agree that monopiles will be the predominant foundation type in the next five years.

What type of foundation/substructure are you assuming in 5 years?

5-Year Prediction

Note: This table shows the mentions of each foundation type as a percent of total responses from each survey year. Only some of the survey respondents gave answers to this question, and respondents were allowed multiple answers.
Monopiles and jackets are expected to be the prevailing foundation types in 10 years.

What type of foundation/substructure are you assuming in 10 years?

10-Year Prediction

Note: This table shows the mentions of each foundation type as a percent of total responses from each survey year. Only some of the survey respondents gave answers to this question, and respondents were allowed multiple answers.
Floating turbines are expected to be the prevailing technology in 20 years.

**What type of foundation/substructure are you assuming in 20 years?**

### 20-Year Prediction

<table>
<thead>
<tr>
<th>Foundation Type</th>
<th>2012 Survey</th>
<th>2013 Survey</th>
<th>2014 Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monopile</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Jackets</td>
<td>20%</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Combination</td>
<td>30%</td>
<td>30%</td>
<td>30%</td>
</tr>
<tr>
<td>Floating</td>
<td>40%</td>
<td>60%</td>
<td>60%</td>
</tr>
<tr>
<td>Suction Piles</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Other</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Note: This table shows the mentions of each foundation type as a percent of total responses from each survey year. Only some of the survey respondents gave answers to this question, and respondents were allowed multiple answers.
Infrastructure, technology, and policy support are expected to be the dominant influences of future BOP cost trends.

What factors are expected to influence BOP cost trends in the near-term (2-4 years) and over the long-term (5-10 years)? (*Respondents typically did not distinguish between time frames)
Key technology trends include advancements in turbine size, foundations, and offshore wind infrastructure.

What are the key technology trends in offshore wind?

**Size:**

**Increasing turbine size and capacity**

- Turbines continue to increase in both size and reliability, but become lighter in weight
- This is, in turn, leading to larger blades and rotors

**Foundations:**

**Innovation in foundation type**

- The market is transitioning toward jacket foundations and floating foundations
- Other technological advancements include enhancements of drive train technologies

**Transmission:**

**Advancements in offshore wind cabling**

- The market will move toward higher-voltage array cable systems
- This will allow for better electrical layouts and interconnected offshore grids
Uncertain demand remains the most commonly-cited barrier for offshore wind manufacturers, as well as high capital investment requirements.

What are (or will be) the most significant barriers to entry for U.S. manufacturers to participate in the U.S. offshore wind industry?

- **High capital requirements for facility investment**: 33% (2012), 40% (2013), 33% (2014)
- **Uncertain lack of demand**: 20% (2012), 17% (2013), 17% (2014)
- **Development of dedicated offshore wind equipment**: 13% (2012), 20% (2013), 17% (2014)
- **Other**: 40% (2012), 60% (2013), 33% (2014)
Uncertain demand will be the most significant barrier for developers to enter into the offshore wind market.

*What are (or will be) the most significant barriers to entry for developers to participate in the U.S. offshore wind industry?*

### 2012 Survey
- Uncertain lack of demand: 23%
- Inability to obtain financing: 31%
- Need for offshore-specific technology: 20%
- Other: 20%

### 2013 Survey
- Uncertain lack of demand: 45%
- Inability to obtain financing: 11%
- Need for offshore-specific technology: 33%
- Other: 11%

### 2014 Survey
- Uncertain lack of demand: 40%
- Inability to obtain financing: 20%
- Need for offshore-specific technology: 20%
- Other: 20%
Lack of qualified labor and the need for offshore-specific technology are the most commonly cited barriers for service providers.

What are (or will be) the most significant barriers to entry for EPC contractors, operators, and other service providers to participate in the U.S. offshore wind industry?

2012 Survey
- Lack of qualified labor: 34%
- Need for offshore-specific technology: 45%
- Other: 21%

2013 Survey
- Lack of qualified labor: 42%
- Need for offshore-specific technology: 30%
- Other: 28%

2014 Survey
- Lack of qualified labor: 16%
- Need for offshore-specific technology: 53%
- Other: 32%
The majority of respondents believe the industry will stay with fixed price contracts in order to reduce risk premiums.

Do see any chance of moving the industry away from fixed price contracts in order to reduce risk premiums?
Reducing regulatory and policy uncertainty is the most commonly cited recommendation to reduce barriers for U.S. companies.

What should be done to reduce or eliminate the barriers to entry and create pathways to market for U.S. companies?

<table>
<thead>
<tr>
<th>Year</th>
<th>Educate U.S. companies on standards and requirements utilized by OEMs</th>
<th>Reduce regulatory and policy uncertainty</th>
<th>Provide incentives to stimulate demand</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>13%</td>
<td>19%</td>
<td>31%</td>
<td>37%</td>
</tr>
<tr>
<td>2013</td>
<td>12%</td>
<td>10%</td>
<td>37%</td>
<td>41%</td>
</tr>
<tr>
<td>2014</td>
<td>14%</td>
<td>17%</td>
<td>34%</td>
<td>34%</td>
</tr>
</tbody>
</table>
The most appropriate policies to encourage industry growth include financial incentives such as ITCs and cash grants, as well as state RPSs.

What types of policies are most appropriate to encourage growth of the U.S. offshore wind industry?

2012 Survey

- State-level RPSs w/ Offshore Wind Carve-Out Requirements: 12%
- Feed-In Tariffs: 30%
- Manufacturing Incentives: 25%
- Financial Incentives (e.g. PTC, ITC, Cash Grants): 10%
- Other: 10%

2013 Survey

- State-level RPSs w/ Offshore Wind Carve-Out Requirements: 19%
- Feed-In Tariffs: 21%
- Manufacturing Incentives: 27%
- Financial Incentives (e.g. PTC, ITC, Cash Grants): 20%
- Other: 13%

2014 Survey

- State-level RPSs w/ Offshore Wind Carve-Out Requirements: 19%
- Feed-In Tariffs: 19%
- Manufacturing Incentives: 7%
- Financial Incentives (e.g. PTC, ITC, Cash Grants): 31%
- Other: 24%
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3 » U.S. Offshore Wind Project Development Overview
In the U.S., according to Navigant’s analysis, 14 offshore wind projects, totaling 3.9 GW, have reached an advanced stage of development.

- Criteria for “Advanced-Stage” Projects:
  - Received approval for an interim limited lease or a commercial lease in state or federal waters
  - Conducted baseline or geophysical studies at proposed site with met tower erected and collecting data, boreholes drilled, or geological and geophysical data acquisition system in use
  - Signed power purchase agreement (PPA) with a power off-taker

Note: One potential project (the Deepwater Wind Energy Center) spans federal waters off the coasts of Massachusetts and Rhode Island; this map splits its estimated 1,000-MW capacity between the two states.

Source: Navigant analysis
Since last year’s DOE report, some potential U.S. offshore wind projects have achieved notable advancements, while others have emerged.

<table>
<thead>
<tr>
<th>Project Name (State)</th>
<th>Proposed Cap. (MW)</th>
<th>Status Notes</th>
<th>Target Compl. Date(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block Island Offshore Wind Farm (Deepwater) (RI)</td>
<td>30</td>
<td>Signed installation contract with ship-owner Bold Tern in February 2014 for construction in Q3 of 2016. Final approval from Rhode Island’s Coastal Resources Management Council is still pending. The developer also represents that it has complied with IRS guidance to be eligible to receive the Investment Tax Credit (ITC).</td>
<td>2016</td>
</tr>
<tr>
<td>Cape Wind Offshore (MA)</td>
<td>468</td>
<td>Received $600M loan financing commitment in February 2014, bringing estimated total of confirmed funds to at least $900M out of an estimated final cost of $2.6 billion. The developer also represents that it has complied with IRS guidance to be eligible to receive the Investment Tax Credit.</td>
<td>2016</td>
</tr>
<tr>
<td>Fisherman’s Energy Atlantic City Wind Farm (NJ)</td>
<td>25</td>
<td>DOE Advanced Wind Technology Demonstration Project grant recipient. Project is fully permitted; however, the New Jersey Board of Public Utilities’ March 2014 decision to disallow the project from using New Jersey’s offshore renewable energy credits (ORECs) has made the project’s completion less certain.</td>
<td>2016</td>
</tr>
<tr>
<td>Principle Power - WindFloat (OR)</td>
<td>30</td>
<td>DOE Advanced Wind Technology Demonstration Project grant recipient. BOEM received an unsolicited lease request from Principle Power and after an RFI found no competitive interest in the area. Principle Power has completed a geophysical survey of the lease request area and cable route.</td>
<td>2017</td>
</tr>
<tr>
<td>University of Maine (ME)</td>
<td>12</td>
<td>DOE Advanced Wind Technology Demonstration Project grant recipient. The team received its DOE grant for the potential installation of two additional 6-MW turbines. In January 2014, the project received approval from the Maine PUC for the term sheet of a 20-year PPA with Central Maine Power.</td>
<td>2017</td>
</tr>
<tr>
<td>Lake Erie Offshore Wind Project (Great Lakes) (OH) (Icebreaker)</td>
<td>18</td>
<td>DOE Advanced Wind Technology Demonstration Project grant recipient. Geotechnical surveys have been completed. In February 2014, the developer filed an application (currently pending) for a certificate of environmental compatibility with the Ohio Power Siting Board.</td>
<td>2017</td>
</tr>
<tr>
<td>Baryonyx Gulf Offshore Wind(^b)</td>
<td>18</td>
<td>DOE Advanced Wind Technology Demonstration Project grant recipient. The team will build the project on an existing lease from the Texas General Land Office. It is currently collecting environmental and meteorological data, with reports expected by the end of 2014.</td>
<td>2017</td>
</tr>
</tbody>
</table>

\(^a\) Dates shown are based on developer statements, Navigant analysis; they may change based on permitting, leasing, surveying, and other activities. 
\(^b\) Leasing and permitting requirements for projects in Texas state waters do not involve the Federal Energy Regulatory Commission (FERC) or the BOEM Minerals Management Service and may move more quickly than projects in federal waters. 

Source: Navigant analysis based on published project information, developer statements and media coverage.
Since last year’s DOE report, some potential U.S. offshore wind projects have achieved notable advancements, while others have emerged.

<table>
<thead>
<tr>
<th>Project Name (State)</th>
<th>Proposed Cap. (MW)</th>
<th>Status Notes</th>
<th>Target Completion Datea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dominion Virginia Power - Virginia Offshore Wind Technology Advancement Project (VA)</td>
<td>12</td>
<td>DOE Advanced Wind Technology Demonstration Project grant recipient. In September 2013, Dominion Virginia Power was the winning bidder in the second competitive lease sale for a U.S. offshore wind area. The team’s grant award is supporting the potential development of a pilot facility within that lease area. The team is currently conducting environmental studies and permitting efforts.</td>
<td>2017</td>
</tr>
<tr>
<td>Fisherman’s Energy: Phase II (NJ)</td>
<td>330</td>
<td>Received a met tower rebate from the state and began baseline surveys in August 2009. Has interim lease for initial assessment of wind farm feasibility.</td>
<td>2019</td>
</tr>
<tr>
<td>Galveston Offshore Wind (Coastal Point Energy) (TX)b</td>
<td>150</td>
<td>Has lease from Texas General Land Office and is collecting wind resources data via a met tower. The team plans to install a non-grid connected, 200-kW test turbine on the met tower foundation sometime in 2014.</td>
<td>2019</td>
</tr>
<tr>
<td>Garden State Offshore Energy Wind Farm (NJ)</td>
<td>350</td>
<td>In January 2014, Deepwater (along with other developers) encouraged the BOEM to delay its planned 2014 lease sales for New Jersey until after the state Board for Public Utilities clarified which developers could use ORECs to help finance their offshore wind projects.</td>
<td>2019</td>
</tr>
<tr>
<td>Baryonyx Rio Grande Wind Farms (North and South) (TX)c</td>
<td>1000</td>
<td>Received lease from Texas General Land Office in 2009. Army Corps of Engineers environmental studies underway. Site is same as that being pursued for the Gulf Offshore Wind Demonstration Project.</td>
<td>2020</td>
</tr>
<tr>
<td>Deepwater Offshore Wind Energy Center</td>
<td>1000</td>
<td>In August 2013, Deepwater was the winning bidder in the first competitive lease sale for a U.S. offshore wind area. They signed the lease in September 2013 and are marketing power to off-takers along the central Atlantic coast in the 13 to 14 cents/kWh range.</td>
<td>2020</td>
</tr>
<tr>
<td>NRG Bluewater’s Mid-Atlantic Wind Park (DE)</td>
<td>450</td>
<td>Received one of the first U.S. offshore leases (non-competitive) from BOEM in October 2012 as part of &quot;Smart from the Start&quot; program; however, Delmarva had canceled a PPA for 200 MW of the power. NRG placed the project on hold, but retains its development rights. It is unclear whether project will be developed by NRG or sold.</td>
<td>2020</td>
</tr>
</tbody>
</table>

a) Dates shown are based on developer statements, Navigant analysis; they may change based on permitting, leasing, surveying, and other activities.
b) Leasing and permitting requirements for projects in Texas state waters do not involve the Federal Energy Regulatory Commission (FERC) or the BOEM Minerals Management Service and may move more quickly than projects in federal waters.

Source: Navigant analysis based on published project information, developer statements and media coverage.
Navigant has projected expected construction and completion dates for each project based on developer statements and recent activities.

- Developers for three of the projects continue to compete to be the first commercial-scale offshore wind farm online in U.S. waters.
- It is unlikely that all 14 projects will achieve these targets, due to delays, cancelations, or other regulatory or market issues.
- Navigant expects that the initial growth of the U.S. offshore market would follow a trajectory like that shown to the left.
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