Offshore Wind Energy Market Overview

BOEM Offshore Renewable Energy Workshop

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Support from Navigant Consulting, Inc., Bruce Hamilton
All Offshore Wind Projects are in Europe and Asia, with European Nations Leading Deployment

- Portugal: 2 MW
- Sweden: 212 MW
- Norway: 2 MW
- Finland: 32 MW
- Germany: 516 MW
- UK: 3,686 MW
- Denmark: 1,274 MW
- Netherlands: 247 MW
- Ireland: 25 MW
- Belgium: 571 MW
- Spain: 5 MW
- Channel Islands: 2 MW

Cumulative MW Installed:

Europe (incremental)
Asia (incremental)
Cumulative Total

Pre-2000
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

Incremental MW Installed:
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
4200
4400
4600
4800
5000
5200
5400
5600
5800
6000
6200
6400
6600
6800
7000
7200
7400
7600
7800
8000

Europe (incremental) Asia (incremental) Cumulative Total
Offshore Wind Drivers & Developments in Asia


**Japan** – 50 MW installed. 2 operating 2MW floating turbines, larger OSW specific turbine under development, the government plans to phase out nuclear power by 2040, which previously provided over 30% of the country’s electricity. New feed-in tariffs for wind announced in 2012 ~25 cents/kWh and indications that the domestic market for floating OSW may be as high as 1,000 MW.

**South Korea** – 5 MW offshore demonstration project (Jeju Island) in operation, plus a government target of 2 GW in operation by 2019.

**Taiwan** – Launched the *Thousand Wind Turbines Promotion* program, targeting 3 GW installed by 2030.
Reported Capital Costs for Global OSW

Costs have risen but seems to have stabilized

Source: Navigant Consulting, Inc
Physical Siting Considerations / Cost Drivers

- Water depth
- Distance to shore
- Wind resource and losses
- Project size
- Geotechnical / geophysical soil conditions
- Wave climate – sheltered vs. open ocean
- Extreme climate conditions – e.g. tropical storms, installation windows
- Environmental impacts and long term mitigation
- Availability of grid connections/load proximity
- Supply chain – where the equipment comes from and how this changes over time
- Turbine reliability and repair timelines
- …
Wide Distance and Water Depth Deployments

Clearly the close, shallow sites are the first to go. Deeper projects farther from shore will then be developed and resulting in higher cost.

Source: Navigant Consulting, Inc
Expected plant capacity factors (efficiency of the turbines) has steadily increased – more experience, better wind resource, more reliable operation and maintenance.
## Expected Costs

<table>
<thead>
<tr>
<th></th>
<th>Land-Based</th>
<th>Offshore</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Installed capital cost</strong></td>
<td>$1,400–$2,900/kW</td>
<td>$4,500–$6,500/kW</td>
</tr>
<tr>
<td><strong>Annual operating expenses</strong></td>
<td>$9–$18/MWh</td>
<td>$15–$55/MWh</td>
</tr>
<tr>
<td><strong>Capacity factor</strong></td>
<td>18%–53%</td>
<td>30%–55%</td>
</tr>
<tr>
<td><strong>Discount rate</strong></td>
<td>6%–13%</td>
<td>8%–15%</td>
</tr>
<tr>
<td><strong>Operational life</strong></td>
<td>20–30 years</td>
<td>20–30 years</td>
</tr>
<tr>
<td><strong>Range of LCOE</strong></td>
<td>&lt;$60–&gt;$100/MWh</td>
<td>&lt;$168–&gt;$292/MWh</td>
</tr>
</tbody>
</table>

Balance-of-station (BOS) costs dominate ICC for offshore wind projects.

There are three primary BOS contributors:

- **Support structure**
- **Electrical infrastructure**
- **Assembly, transport, and install**

Component contribution can vary significantly from one project to another.

Majority of Global Offshore Wind Developments are in Europe

~ 15,600 MW Approved

<table>
<thead>
<tr>
<th>Country</th>
<th>Proposed Capacity (MW) Approved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poland</td>
<td>4,500 MW</td>
</tr>
<tr>
<td>Germany</td>
<td>3,723 MW</td>
</tr>
<tr>
<td>France</td>
<td>2,303 MW</td>
</tr>
<tr>
<td>Italy</td>
<td>384 MW</td>
</tr>
<tr>
<td>Greece</td>
<td>498 MW</td>
</tr>
<tr>
<td>UK</td>
<td>1,416 MW</td>
</tr>
<tr>
<td>Belgium</td>
<td>1,015 MW</td>
</tr>
<tr>
<td>Sweden</td>
<td>265 MW</td>
</tr>
<tr>
<td>Norway</td>
<td>31 MW</td>
</tr>
<tr>
<td>Denmark</td>
<td>36 MW</td>
</tr>
<tr>
<td>Finland</td>
<td>768 MW</td>
</tr>
<tr>
<td>Estonia</td>
<td>700 MW</td>
</tr>
<tr>
<td>Estonia</td>
<td>700 MW</td>
</tr>
</tbody>
</table>
The total global offshore wind project pipeline exceeds 200 GWs

(Total US Generating capacity is about 1000 GW)
The global market for offshore wind turbines is expected to become increasingly fragmented.

Installed Capacity: ~4,550 MW
- Siemens: 59%
- Vestas: 32%
- REpower: 5%
- Sinovel: 2%
- Others: 1%

Projected Near-Term Capacity*: ~16,600 MW
- Siemens: 38%
- Vestas: 12%
- RePower: 5%
- Alstom: 11%
- Sinovel: 7%
- BARD: 5%
- China Energy: 2%
- WinWind: 1%
- Others: 1%

Turbines from Siemens and Vestas represent a combined 91% of capacity installed to date.

A number of OEMs have developed strong pipelines, reducing projected Siemens/Vestas share to 43% of near term market.

OEMs gaining share tend to be either 1) offering turbine models in the 5 MW+ class or 2) are well positioned to take advantage of growth in the Chinese market.

*Includes projects under construction and approved projects that have announced a turbine manufacturer.

Source: Navigant Consulting, Inc

Note: Some capacities are estimated based on what could be supported in the leased area; developers have not necessarily confirmed final design plans. This map splits the estimated 1,000-MW capacity for Deepwater ONE between Massachusetts and Rhode Island. The U.S. Virgin Islands Project (USVI) does not appear on this map.
Current wind vision has estimates of ~20 GW by 2030, 80 GW by 2050.
Growth Trajectory for U.S. Offshore Wind Markets

- Represent 15 defined projects totaling 4.5 GW with others still possible
- Unlikely all of these will be completed within this time horizon
## US Off Shore Lease Zones and Markets

<table>
<thead>
<tr>
<th>WEA</th>
<th>Status</th>
<th>Area (sq. km)</th>
<th>Estimated OSW potential (GW)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA</td>
<td>Announced</td>
<td>3,007</td>
<td>9.0</td>
</tr>
<tr>
<td>RI-MA</td>
<td>Awarded</td>
<td>667</td>
<td>2.0</td>
</tr>
<tr>
<td>NY</td>
<td>Scoping</td>
<td>329</td>
<td>1.1</td>
</tr>
<tr>
<td>NJ</td>
<td>Announced</td>
<td>1,434</td>
<td>4.3</td>
</tr>
<tr>
<td>DE</td>
<td>Scoping</td>
<td>418</td>
<td>1.3</td>
</tr>
<tr>
<td>MD</td>
<td>Announced</td>
<td>323</td>
<td>1.0</td>
</tr>
<tr>
<td>VA</td>
<td>Awarded</td>
<td>457</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Total (GW)</strong></td>
<td></td>
<td><strong>20</strong></td>
<td></td>
</tr>
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</table>

Assumes an average capacity density of 3 MW per square kilometer based on standard spacing metrics developed in Musial et al. 2013a and Musial et al. 2013b

~20 MW of potential capacity in identified lease areas

Other lease areas under consideration, including west coast
Offshore Wind Resource is Near Population Centers
Map of Annual Average Wind at 80-m

United States - Wind Resource Map
Credit: Dr. H. J. Dagher

55 million people in NE
18% of US population
Highest electricity costs
Coastal states generally have high electricity prices, making offshore wind more competitive.
Over the long term, wind can compete head to head in a subsidized energy market.

In the near term, wind costs competitive with future cost of natural gas.

Even without the subsidies (PTC), wind still competes quite well against the subsidized NG and provides huge hedge against NG price volatility.
Externalities can Significantly Impact Costs

Levelized Cost of Electricity (2010) vs. CO2 Price

- Coal PC
- Coal IGCC
- Coal IGCC w/CCS
- Gas CC
- Nuclear
- Wind Class 6
- Wind Class 4
- Wind Offshore Class 6
## U.S. Federal Policy to Support OSW

<table>
<thead>
<tr>
<th>DOE National Offshore Wind Strategy</th>
<th>Federal Tax Credits &amp; Deductions</th>
<th>Bureau of Ocean Energy Management Initiatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>• DOE Offshore Wind Initiative</td>
<td>• Production Tax Credit</td>
<td>• Smart from the Start</td>
</tr>
<tr>
<td>• Advanced Technology Program &amp; Grants</td>
<td>• Investment Tax Credit</td>
<td>• Rules Revisions</td>
</tr>
<tr>
<td>• DOE Guaranteed Loan Program</td>
<td>• Accelerated Depreciation Deduction</td>
<td>• Research Studies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Competitive Auction Lease Process</td>
</tr>
</tbody>
</table>
## State Policy to Support OSW

<table>
<thead>
<tr>
<th>Policy Options</th>
<th>Jurisdictions where Used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Barrier: High Cost</strong></td>
<td>Delaware</td>
</tr>
<tr>
<td>Renewable Portfolio Standard (RPS)</td>
<td>✓</td>
</tr>
<tr>
<td>Incorporate PPAs into competitive situations</td>
<td>✓1</td>
</tr>
<tr>
<td>RPS with offshore carve out</td>
<td></td>
</tr>
<tr>
<td>Green certificates with premium prices for offshore installations</td>
<td>✓2</td>
</tr>
</tbody>
</table>

1. Delaware statute directed all-resource competitive bid & Delmarva to negotiate a PPA with Bluewater Wind approved by four Delaware state agencies in 2009 (~$14/MWh).
2. DE offshore wind RECs count 3.5 times in meeting Delmarva’s renewable energy purchase requirements.
3. Maine legislation authorized bidding process for pilot offshore projects and PPAs; U.Maine team signed term sheet with PUC.
4. The Maryland Offshore Wind Energy Act of 2013 established Offshore Wind Renewable Energy Credits (ORECs) for up to 200 MW and requires consideration of broad range of economic and ratepayer benefits.
5. Massachusetts statute requires PPAs for 7% of load and approved Cape Wind PPA for $18.70/MWh with a 3.5%/year escalator.
6. NJ statute requires 1100 MW Ocean RECs at a cost-effective rate based on a comprehensive net benefits analysis.
8. Rhode Island issued an RFP for an offshore wind project to produce 15% of the state’s electricity demand and subsequently signed a Joint Development Agreement with Deepwater Wind. Approved initial 30MW Pilot PPA for $24.40/MWh.

*Source: Navigant Consulting, Inc*
Where is the industry going?

...however, speed of cost reduction will be determined by deployment rate
How do we reduce costs?

Risk Reduction

- Increase demand side market certainty through consistent long-term policy
- Increase regulatory certainty
- Get steel in the water to help develop investor confidence
- Mature design tools, practices, and standards through IEC, API, AWEA and class societies for U.S. Specific conditions
- Industry-wide focus on risk identification and management
- Improve understanding of metocean conditions and develop forecasting methods to provide
How do we reduce costs? Technology Innovation

DOE’s ATD FOAs will bring next generation of technology to U.S.
Projects announced in Dec 2012 will receive $4M for initial planning and design phases. Three will be selected to complete the follow-on design and deployment phases by 2017.
How do we reduce costs?

Economies of scale, local manufacturing and installation expertise, stable market, and streamline projects.
Marketing Summary

• European markets dominate so far.

• Asian markets promise lower costs; but yet undemonstrated

• The U.S. offshore wind industry is ready to begin deployment

• Stable, coordinated policy is needed to offset high initial costs and drive deployment

• A robust project pipeline is needed to encourage investment in technologies and infrastructure that will lower cost of energy

• Cost are high for first adopters and must be reduced through risk reduction, new technology, and increasing scale (turbine, project, and national deployment)

• Expanded market reports starting to be produced – DOE funded, Navigant Consulting Offshore Wind Market Report due out in September.
Carpe Ventem

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