U.S. Offshore Wind Generation and Transmission Needs

PRESENTED TO
Offshore Wind Transmission, USA Conference

PRESENTED BY
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Agenda

- Global Context for U.S. Wind Generation
  - Onshore vs. Offshore

- U.S. Offshore Wind Generation
  - Potential
  - Policy Commitments
  - Development Efforts

- Cost and Value of U.S. Offshore Wind Generation

- Implications for Offshore Transmission
  - Offshore transmission investment need
  - Offshore grids vs. gen-ties to individual plants

- Takeaways
Global Context for U.S. Wind Generation

The U.S. has significant wind generation ... but little offshore wind because of abundant low-cost onshore wind resources (though often far from major load centers)

U.S. Position Relative to Global **Offshore Market**

The installed global offshore wind capacity has reached 18.8 GW by the end of 2017 (up from 12.9 GW at the end of 2016) ... mostly in Europe and China

<table>
<thead>
<tr>
<th>Total Offshore Wind Capacity</th>
<th>Commissioned (as of end of 2016 [MW])</th>
<th>Under Construction (as of end of 2016)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom</td>
<td>5,097 (6,836 as of end of 2017)</td>
<td>1,966</td>
<td>7,062</td>
</tr>
<tr>
<td>Germany</td>
<td>3,877 (5,355 as of end of 2017)</td>
<td>1,483</td>
<td>5,360</td>
</tr>
<tr>
<td>China</td>
<td>1,092 (2,848 as of end of 2017)</td>
<td>1,994</td>
<td>3,086</td>
</tr>
<tr>
<td>Denmark</td>
<td>1,271</td>
<td>0</td>
<td>1,271</td>
</tr>
<tr>
<td>Netherlands</td>
<td>520</td>
<td>600</td>
<td>1,120</td>
</tr>
<tr>
<td>Belgium</td>
<td>712</td>
<td>165</td>
<td>877</td>
</tr>
<tr>
<td>Sweden</td>
<td>202</td>
<td>0</td>
<td>202</td>
</tr>
<tr>
<td>Japan</td>
<td>38</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>United States</td>
<td>30</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>Other</td>
<td>75</td>
<td>80</td>
<td>155</td>
</tr>
<tr>
<td><strong>Total (end of 2016)</strong></td>
<td><strong>12,913</strong></td>
<td><strong>6,300</strong></td>
<td><strong>19,213</strong></td>
</tr>
<tr>
<td><strong>Total (end of 2017)</strong></td>
<td><strong>18,814</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

U.S. Relative to Global Offshore Market: 2018-22

U.S. offshore wind development is expected to increase significantly, but still account for only a modest share of the global industry.

U.S. Offshore Wind Quality

Highest-quality U.S. offshore wind:
- East and Northeast
- Northern California and Oregon

Enormous “Technical Potential” of U.S. Offshore Wind

Considering technological, land-use, environmental limits, the U.S. is estimated to offer 2,000 GW (7,200 TWh) of offshore wind potential.

- More than double total installed U.S. generation
- Best quality: MA, ME, CA, NY, NJ, OR, RI
- Lower quality but shallow water and long coast lines: TX, LA, NC, SC, FL, MI, VA

BOEM Issued 17 GW Worth of Offshore Wind Leases

Individual BEOM Lease Sales:

- **Rhode Island/Massachusetts** (July 2013)
  - Commercial Lease OCS-A 0486
  - Commercial Lease OCS-A 0487
- **Virginia** (September 2013)
  - Commercial Lease OCS-A 0483
- **Maryland** (December 2014)
  - Commercial Lease OCS-A 0489
  - Commercial Lease OCS-A 0490
- **Massachusetts** (March 2015)
  - Lease OCS-A 0500
  - Lease OCS-A 0501
- **New Jersey** (February 2016)
  - Lease OCS-A 0498
  - Lease OCS-A 0499
- **New York** (December 2016)
  - Lease OCS-A 0512
- **North Carolina** (March 2017)
  - Lease OCS-A 0508

Currently Proposed U.S. Offshore Wind Projects

28 projects “under development” (23,735 MW)
18 projects with site control (14,785 MW) ... mostly in North Atlantic

Examples of Current U.S. Offshore Wind Initiatives

Examples of state initiatives:
- **RI**: 30 MW block island (operational)
- **MD**: 368 MW by 2020-22 (procured)
- **MA**: 1,600 MW by 2027 (mandate, 400-800 MW bid); 5,000 MW by 2035 (bill)
- **CT**: 200 MW RFP for offshore wind (including storage and fuel cells)
- **NY**: 800 MW (mandate); up to 2,400 MW by 2030 (goal)
- **NJ**: 1,100 MW (mandate); 3,500 MW by 2030 (goal)
- Proposed projects also in: CA, GA, ME, NC, OH, TX, VA, (plus BC and ON in Canada)

Examples of developer initiatives:
- **US Wind**: 248 MW (MD) and others
- **Deepwater Wind**: Revolution Wind 400 MW (MA, RI, CT); 120 MW (MD) and others
- **Ørsted**: Ocean Wind with 1,000 MW by 2020-25 (NJ); Baystate Wind 400-800 MW (MA)
- **Avangrid Renewables**: Vineyard Wind 400-800 MW (MA); Kitty Hawk 1,500 MW (NC)
- **Equinor (Statoil)**: Empire Wind 600 MW (up to 1,500 MW) for NYC & LI
- Others include: GE, RES, Neptune Wind, Virginia Power, Georgia Power, ...
The Cost of Offshore Wind in the U.S. vs. Europe

Compared to $55/MWh (€46.6) for 1,610 MW (six wind farms) in most recent German auction (approved April 2018), U.S. prices are expected to remain near $100/MWh in near term.

- 2016 Block Island (RI): 30 MW at $244/MWh
- 2020-22 Maryland: 368 MW at $132/MWh
- 2023 MA: up to 800 MW est. at $90-110/MW (later today!)

The Value of Offshore Wind in the U.S.

LBNL estimated the total market value of offshore wind generation based on historical market prices for energy, capacity, and RECs in various U.S. wholesale power markets:

- Highest value in New England at $110/MWh
- New York: $100/MWh
- Mid-Atlantic (PJM): $70/MWh
- South of PJM: $40-55/MWh

Implications for Offshore Transmission

U.S. offshore wind development will require substantial offshore transmission infrastructure

- Even the 8,000 MW of committed off-shore wind development in MA, NY and NJ will require about **600-1,200 miles of offshore transmission** plus onshore reinforcements
  - For example: to integrate 8,000 MW with single 220kV HVAC gen-ties for every 400 MW of wind plants (30-60 miles offshore) would require 20 landing points with associated onshore grid interconnections reinforcements
  - Off-shore grids to integrate multiple wind plants—such as used in Germany, the Netherlands, Belgium and proposed by Atlantic Wind in NJ and Anbaric, Bluewater, and Ørsted in MA—would create scale economies and reduce the number of necessary landing points
- Integrating 15,000-24,000 MW of already proposed offshore wind plants will almost certainly require the development of some (networked) **offshore grids** and approximately **3,000 miles** of offshore transmission lines
Offshore Transmission Needs for NJ, NY, MA

**MA, RI, CT:** 40 to 90+ miles from interconnections with on-shore grid

<table>
<thead>
<tr>
<th>State</th>
<th>Owner</th>
<th>Approximate Total Cable Route Length (Miles)</th>
<th>Approximate Land Cable Route Length</th>
<th>Approximate Submarine Cable Route Length</th>
<th>Substation Improvement for a 1,000 MW Project</th>
<th>Proximity of Potential Converter Station Parcel</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brayton Point</td>
<td>MA National Grid</td>
<td>45 – 95</td>
<td>&lt;1</td>
<td>45 – 95</td>
<td>$10M</td>
<td>Close</td>
<td>Tier 1</td>
</tr>
<tr>
<td>Canal</td>
<td>MA NSTAR</td>
<td>60 – 100</td>
<td>10</td>
<td>50 – 90</td>
<td>$2.5M</td>
<td>Close</td>
<td>Tier 1</td>
</tr>
<tr>
<td>Kent County</td>
<td>RI National Grid</td>
<td>51 – 96</td>
<td>1</td>
<td>40 – 95</td>
<td>$2.5M</td>
<td>Close</td>
<td>Tier 1</td>
</tr>
<tr>
<td>Carver</td>
<td>MA NSTAR</td>
<td>65 – 105</td>
<td>20</td>
<td>45 – 85</td>
<td>$2.5M</td>
<td>Not Close</td>
<td>Tier 2</td>
</tr>
<tr>
<td>Oak Street</td>
<td>MA NSTAR</td>
<td>50 – 60</td>
<td>10</td>
<td>45 – 60</td>
<td>$2.5M</td>
<td>Not Close</td>
<td>Tier 2</td>
</tr>
<tr>
<td>Millstone</td>
<td>CT Northeast Utilities</td>
<td>60 – 120</td>
<td>&lt;1</td>
<td>60 – 120</td>
<td>$2.5M</td>
<td>Close</td>
<td>Tier 3</td>
</tr>
<tr>
<td>Montville</td>
<td>CT Northeast Utilities</td>
<td>65 – 130</td>
<td>&lt;1</td>
<td>65 - 130</td>
<td>$2.5M</td>
<td>Close</td>
<td>Tier 3</td>
</tr>
</tbody>
</table>

**New York:** wind energy area located 14-30 miles offshore
- Limited by shipping lanes emanating from New York City
- Limited interconnection opportunities with on-shore grid

**New Jersey:** wind areas in southern NJ, approx. 17 miles from shore
- Beyond Oyster Creek, the onshore grid in southern NJ is fairly weak, likely requiring
  - (1) significant reinforcements of the on-shore grid at local landing points or
  - (2) build off-shore connections to more robust but more distant landing points (e.g., in northern NJ)

Offshore Gen-Ties vs. Offshore Grids

Advantages of **gen-ties** to individual offshore wind plants:
- Offshore wind plant and transmission can be perfectly synchronized and integrated in development effort of individual companies
- Development of individual wind plants does not depend on common offshore transmission infrastructure becoming available in time
- More cost effective for limited wind development and short distances to shore

Advantages of **off-shore grids** to integrate multiple wind plants:
- More cost effective for large-scale wind development that are far offshore or in locations with few onshore landing points (or sensitive shoreline)
- Reduced risk that gen-ties of first several wind plants inefficiently use up available rights-of-ways, blocking subsequent developments
- Better coordination with and reinforcement of onshore grid
- Added offshore redundancy due to meshed configuration
- Open access to enable more competition between wind developers
- Competition between experienced transmission developers
Choosing between Gen-ties and Offshore Grids?

Factors favoring offshore grids to serve multiple wind plants

- Large size of total development commitment with sizable individual steps
  - Greater than 1400 MW and procured within a few years?
- Several plants close to each other but long distances from shore or from sufficiently-robust onshore transmission nodes
  - Greater than 40 miles?
- More efficient use of right-of-way
  - Few landing points with robust on-shore transmission
  - Difficult permitting of landing points and onshore interconnection study process
- Network benefit (offshore redundancy and reinforcement of on-shore grid)
- Create level playing-field for wind developers through open access to offshore hubs
- Create competition between experienced offshore transmission developers

Factors favoring gen ties to individual offshore wind plants

- Modest total development and small incremental steps
  - 200-400 MW plants only?
- Modest distance from shore
  - Less than 40 miles?
- Many landing points with robust on-shore transmission infrastructure
  - 4-8 for every 1,600 MW of total development?
- Long distance between offshore locations to be interconnected
- Easy permitting of landing points and interconnection study process
- Wind developers have significant offshore transmission experience
Takeaways

The U.S. is relying less on offshore wind resources to meet clean energy goals than some parts of Europe, but is poised to make significant investments in the next decade

- **U.S. Onshore Wind**: Abundant low-cost, high-quality locations (many greater than 50% capacity factor) ... but often far from major load centers

- **U.S. Offshore Wind**: 30 MW installed with 8,000 MW of existing state-level commitments and 24,000 MW of proposed projects
  - Closer to major load centers and higher-priced wholesale power markets

The U.S. will likely require 600-1,000 miles (up to 3,000 miles) of offshore transmission infrastructure to integrate proposed projects

- **Gen-ties** to individual offshore wind plants that are within 30 miles from shore (and far from other plants) can be cost effective

- **Offshore grids** with open access can offer significant cost and competitive advantages for interconnecting large amounts of wind generation
  - This is particularly the case with plants far from shore and relatively close to each other
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Johannes (Hannes) Pfeifenberger is an economist with a background in power engineering and over 20 years of experience in the areas of public utility economics and finance. He has published widely, assisted clients and stakeholder groups in the formulation of business and regulatory strategy, and submitted expert testimony to the U.S. Congress, courts, state and federal regulatory agencies, and in arbitration proceedings.

Hannes has extensive experience in the economic analyses of wholesale power markets and transmission systems. His recent experience includes the analysis of transmission benefits, reviews of RTO capacity market and resource adequacy designs, testimony in contract disputes, cost allocation, and rate design. He has performed market assessments, market design reviews, asset valuations, and cost-benefit studies for investor-owned utilities, independent system operators, transmission companies, regulatory agencies, public power companies, and generators across North America.

Hannes received an M.A. in Economics and Finance from Brandeis University and an M.S. in Power Engineering and Energy Economics from the University of Technology in Vienna, Austria.

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