What Next in Wind Power

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Beyond 33 Percent: California’s Renewable Future - Emerging Renewable Technologies

UC Davis Policy Institute for Energy, Environment and the Economy
&
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10 December 2014
Wind Power: Industry Status

- End of 2013
  - Global: 318 GW
  - U.S.: 61.1 GW
  - California: 5.8 GW

- U.S. slowdown in 2013
  - 2012: +13.13 GW
  - 2013: +0.27 GW
  - Driven by policy uncertainty (PTC)
  - 2014: +1.25 GW (first 3 qrts)
Wind Power: Technology Status

- Rotor: 3 blade, upwind of tower, horizontal axis, active pitch for power regulation, 80 – 150 m diameter
- 1.0 – 6.0 MW
- Geared and direct drive
- DFIG or full conversion (AC-DC-AC) for partial or full variable speed
- Advance power electronics for grid support. LVRT and ZVRT
- Steel tubular tower
- Blades: aeroelastically tailored, fiberglass, some carbon fiber
- Advanced airfoils
- Active yaw control

Source: Vestas
California Wind Resource

- California wind maps. Developed by AWS Truepower for CEC
- Mean annual wind speed at 30, 50, 70, 100 m heights at 200 m spatial resolution
- Maps indicate limited onshore resource except for several areas: San Gorgonio, Tehachapi, Altamont, Solano
Wind Power: Emerging Technology – Large Diameter Rotors

- Wind turbine rotors are becoming larger
- Example:
  - Ca. 2002
    - GE 1.5 MW
      - 65 m, 452 W/m²
      - 70 m, 390 W/m²
      - 77 m, 322 W/m²
  - Present
    - GE 1.6 MW
      - 100 m, 204 W/m²
- Intended for lower wind sites (IEC Class III), making wind energy economical at these sites
- Widely deployed in higher, low turbulence wind sites

<table>
<thead>
<tr>
<th>Rotor diameter (m)</th>
<th>77.0</th>
<th>82.5</th>
<th>100.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine specific power (W/m²)</td>
<td>322</td>
<td>281</td>
<td>191</td>
</tr>
<tr>
<td>Turbine capacity factor, wind speed at hub height = 5.5 m/s (Wind Power Class I)</td>
<td>22.6%</td>
<td>25.2%</td>
<td>33.0%</td>
</tr>
</tbody>
</table>

Source: U.S. DOE, Wiser & Bolinger (2014)
Wind Power: Energy Price Comparison
U.S. DOE, Wiser & Bolinger (2014)
Why Offshore Wind?

• Terrestrial wind power sites saturated
• Excellent wind resource
  – High wind speeds
  – Low turbulence
  – Near load centers
• Remotely located
• No road transportation constraints
  – Larger turbines
• Local economic benefits
  – Jobs
  – Infrastructure
  – Taxes
### California Offshore Wind Potential & Operating Environment

Source: Schwartz et al, 2010

#### Bathymetry Depth (m)

- **> 300**
- **100 – 300**
- **60 – 100**
- **30 – 60**
- **0 – 30**

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#### GW by Depth (m)

<table>
<thead>
<tr>
<th>Region</th>
<th>0-30</th>
<th>30-60</th>
<th>&gt;60</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>4.4</td>
<td>10.5</td>
<td>573.0</td>
<td>587.8</td>
</tr>
<tr>
<td>Pacific Northwest</td>
<td>15.1</td>
<td>21.3</td>
<td>305.3</td>
<td>341.7</td>
</tr>
</tbody>
</table>

Source: Elliott et al, 2011

Source: NREL
Statoil Hywind

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine rated capacity</td>
<td>2.3 MW</td>
</tr>
<tr>
<td>Turbine weight</td>
<td>138 tons</td>
</tr>
<tr>
<td>Draft hull</td>
<td>100 m</td>
</tr>
<tr>
<td>Nacelle height</td>
<td>65 m</td>
</tr>
<tr>
<td>Rotor diameter</td>
<td>82.4 m</td>
</tr>
<tr>
<td>Water depth</td>
<td>200 - 220 m</td>
</tr>
<tr>
<td>Displacement</td>
<td>5300 m³</td>
</tr>
<tr>
<td>Mooring</td>
<td>3 lines</td>
</tr>
<tr>
<td>Diameter at water line</td>
<td>6 m</td>
</tr>
<tr>
<td>Diameter of submerged body</td>
<td>8.3 m</td>
</tr>
</tbody>
</table>

November 2013: The Crown Estate approved lease for 30MW Hywind project 20-30 kilometers off Scotland

Source: Statoil
Principle Power

Source: Banister, Principle Power, July 2014

- Principle Power WindFloat-1 (2 MW) installed off northern Portugal in October 2011; still producing today
- Generated and delivered over 10 GWh of energy to Portuguese grid
- Technical availability 93%
- Performed through extreme weather events, including waves over 15 m
- Energy output consistent with onshore turbine under same wind conditions
- WindFloat-2 (6 MW) projected for installation off Oregon Coast. Total installation 5 WF-2
Principle Power Project Site
Source: Banister, Principle Power, July 2014

- Lease application filed with BOEM on 14 May 2013
- Lease issuance target Q2 2015
- Commissioning target before end 2017
- Approx. 18 miles offshore
- Project will be in about 350+ meters (1,200 ft) of water
- Generally sandy/silly bottom
Marine Development Parties in CA

Selected agencies

- Bureau of Ocean Energy Management
- California Governor’s Office
- California Energy Commission
- California Public Utilities Commission
- California Fish and Wildlife
- U.S. Fish and Wildlife
- National Oceanic and Atmospheric Administration
  - National Marine Fisheries Services
  - National Marine Sanctuaries
  - Office of Ocean and Coastal Resource Management
- California State Lands Commission
- California State Parks
- National Park Service
- U.S. Defense Department
  - Army
  - Navy
  - Air Force
  - Coast Guard
- Ocean Protection Council
- California Coastal Commission
- Federal Energy Regulatory Commission
- County agencies
Final Observations - Offshore Wind Power

- **Great Opportunity**
  - Bountiful energy resource
  - Near load centers
  - Benefits from extensive onshore technical and regulatory experience
  - Leverage experience from other industries
    - Oil and gas industry

- **Great Challenge**
  - Young industry
  - Costs are currently high
  - Lack of established infrastructure
    - Coastal facilities
    - Ships
  - Cost challenges
    - Larger turbines
    - Deep water / floating platforms
    - Maintenance
  - New environmental considerations
  - Complex regulatory process with limited experience