ECE 333 – GREEN ELECTRIC ENERGY

8. Wind Status

George Gross
Department of Electrical and Computer Engineering
University of Illinois at Urbana-Champaign
Wind power rebounded in 2016: 8,203 MW of new capacity was added – approximately 95.4% of the wind resource capacity added in 2015; the added capacity represents

- circa 27% of the US 2016 capacity additions
- a 11% increase in the cumulative wind capacity in 2015
2016 WIND STATUS

- The cumulative US wind capacity by the end of 2016 reached 82.1 GW

- TX remains the leading state in cumulative wind capacity:
  - TX added more capacity than every other state in 2016 with 2,611 MW
  - TX has more than nearly three times as much installed wind capacity than any other state
2016 WIND STATUS

- Overall, wind power ranked as the third largest source of new generation capacity in 2016 – behind solar and natural gas.

- AWEA reports wind energy is off to a good start in 2017, with approximately 21 GW of wind power capacity was under construction or at an advanced stage of development.
CAUSAL FACTORS OF 2016 DEVELOPMENTS

- Wind projects had to start construction by the end of 2016 in order to qualify for the PTC at 100% of its nominal value.

- Wind sector employment increased from 88,000 at the end of 2015 to 101,000 at the end of 2016.
1998 – 2016 INSTALLED US WIND CAPACITY ADDITIONS

US CUMMULATIVE WIND CAPACITY

1998 – 2015 US CAPACITY ADDITIONS

GW


ECE 333 © 2002 – 2016 George Gross, University of Illinois at Urbana-Champaign, All Rights Reserved.
PERCENTAGE OF WIND IN TOTAL ADDED CAPACITY IN 2000–2016

### 2016 Wind Capacity Addition and Cumulative Wind Total

<table>
<thead>
<tr>
<th>Annual Capacity in MW</th>
<th>Cumulative Capacity in MW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>China</strong></td>
<td><strong>168,732</strong></td>
</tr>
<tr>
<td><strong>United States</strong></td>
<td><strong>82,143</strong></td>
</tr>
<tr>
<td><strong>Germany</strong></td>
<td><strong>50,018</strong></td>
</tr>
<tr>
<td><strong>India</strong></td>
<td><strong>28,700</strong></td>
</tr>
<tr>
<td><strong>Brazil</strong></td>
<td><strong>23,074</strong></td>
</tr>
<tr>
<td><strong>France</strong></td>
<td><strong>14,543</strong></td>
</tr>
<tr>
<td><strong>Turkey</strong></td>
<td><strong>12,066</strong></td>
</tr>
<tr>
<td><strong>Netherlands</strong></td>
<td><strong>11,900</strong></td>
</tr>
<tr>
<td><strong>United Kingdom</strong></td>
<td><strong>10,740</strong></td>
</tr>
<tr>
<td><strong>Canada</strong></td>
<td><strong>9,257</strong></td>
</tr>
<tr>
<td><strong>Rest of the World</strong></td>
<td><strong>75,576</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>486,749</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Annual Capacity in MW</strong></th>
<th><strong>Cumulative Capacity in MW</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>China</strong></td>
<td><strong>23,370</strong></td>
</tr>
<tr>
<td><strong>United States</strong></td>
<td><strong>8,203</strong></td>
</tr>
<tr>
<td><strong>Germany</strong></td>
<td><strong>5,443</strong></td>
</tr>
<tr>
<td><strong>India</strong></td>
<td><strong>3,612</strong></td>
</tr>
<tr>
<td><strong>Brazil</strong></td>
<td><strong>2,014</strong></td>
</tr>
<tr>
<td><strong>France</strong></td>
<td><strong>1,561</strong></td>
</tr>
<tr>
<td><strong>Turkey</strong></td>
<td><strong>1,387</strong></td>
</tr>
<tr>
<td><strong>Netherlands</strong></td>
<td><strong>887</strong></td>
</tr>
<tr>
<td><strong>United Kingdom</strong></td>
<td><strong>736</strong></td>
</tr>
<tr>
<td><strong>Canada</strong></td>
<td><strong>702</strong></td>
</tr>
<tr>
<td><strong>Rest of the World</strong></td>
<td><strong>6,727</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>54,642</strong></td>
</tr>
</tbody>
</table>

LEADING NATIONS IN WIND ENERGY CONSUMPTION IN 2016

2016 US WIND POWER PROJECTS STATUS

Note: numbers within states represent cumulative installed wind capacity and, in brackets, annual additions in 2016.


ECE 333 © 2002 – 2016 George Gross, University of Illinois at Urbana-Champaign, All Rights Reserved.
2016 WIND CAPACITY ADDITIONS BY OFF–TAKE CATEGORY

- **IOU**: 2,283 MW (28%)
- **POU**: 2,014 MW (25%)
- **Direct Retail**: 2005 MW (24%)
- **Merchant**: 1,816 MW (22%)
- **Power Marketer**: 81 MW (1%)

US WIND Manufacturer Status

- The manufacturing supply chain continued to adjust to swings in demand for wind equipment
- Of the 8,203 MW of wind installed in 2016, 43% (3,530 MW) used turbines from Vestas, 42% (3,415 MW) from GE Wind, and 10% (829 MW) from Siemens
- Other suppliers included Gamesa (318 MW), Nordex (93 MW), Vensys (15 MW), and Goldwind (1.5 MW)
US WIND MANUFACTURER STATUS

- In 2016, domestic nacelle assembly capability was about 11.7 GW, and the US had the capability to produce approximately 8 GW of blades and 7 GW of towers annually.
- US exports of wind–powered generating sets has been declining from $488 million in 2014 to $151 million in 2015 and $17 million in 2016.
- The sharp decrease in exports since 2014 may indicate that the fast-rising US wind market absorbed much of the local production of wind turbine equipment.
US WIND MANUFACTURER SITES

Figure includes wind turbine and component manufacturing facilities, as well as other supply chain facilities, but excludes corporate headquarters and service-oriented facilities. The facilities shown here are not intended to be exhaustive. Those facilities designated as "Turbines" may include turbine and/or nacelle assembly and in some cases the manufacturing of towers, nacelle components, blades or other components.

INTERCONNECTION QUEUES

Wind represents about 34% of all electricity capacity within these queues in 2016.

OFFSHORE WIND POWER

- Offshore wind is typically **faster and steadier** than onshore wind.
- Offshore wind entails higher construction and **maintenance costs** than onshore wind.
- Offshore wind may be an unwelcome sight for local residents and impacts the marine life.
In December 2016, Deepwater Wind completed the commissioning of the first commercial offshore wind project in the US.

As of June 2017, a total of 26 offshore wind projects totaling more than 24.1 GW are in various stages of development in the US.
2016 US OFFSHORE WIND PROJECT PIPELINE BY STATE

2016 US OFFSHORE WIND PROJECT PIPELINE BY PROJECT STATUS

Offshore wind turbines currently need to be in relatively shallow water and the maximum distance from the shore depends on the nature of the seabed.

Capacity factors tend to increase as turbines move further offshore into deeper waters.

*Image Source: National Renewable Energy Laboratory*
NREL issued a report discussing US offshore wind potential, with its key conclusion being that US could get about 54 GW of new offshore wind by 2030.

Offshore wind has a significant advantage that the supply is located relatively close to the high-density load regions in urban areas.

The leading offshore wind producers are Great Britain, Denmark, and Holland.
US POPULATION DENSITY AND RENEWABLE RESOURCE LOCATIONS

Source: http://www.census.gov/popest/data/maps/2009/PopDensity_09.jpg
BLOCK ISLAND WIND FARM

- First commercial US offshore wind farm

- Installed capacity: 30 MW (5 turbines)

- 5 6-MW Halidae turbines produced by GE

- 21 miles submarine power cable

- PPA initial price: 24.4 ¢/kWh
PROJECT KEY CHARACTERISTICS

- Absence of economies of scale
- Large investment
- Uncompetitive prices
- Imported technology
- Long delays from September 2008 start date
- Major breakthrough for offshore wind in the US
UK ministry approved the proposal for *East Anglia* One offshore wind farm, comprising 240 turbines with a cumulative capacity of 1,200 MW

The project will be more than double the size of the *London Array*, the largest offshore wind farm currently in existence
East Anglia One is located about 45 km from the Suffolk coast and will have up to 4 submarine DC cables for interconnection with the National Grid’s transmission network.

The project area will cover roughly 300 km² and will be able to generate energy to supply 820,000 British households.