ECE 333 – GREEN ELECTRIC ENERGY

11. Wind Status

George Gross

Department of Electrical and Computer Engineering

University of Illinois at Urbana–Champaign
The US Department of Energy publishes every two years the Land-Based Wind Market Report. The text of the 2021 edition has been prepared by the staff of Lawrence Berkeley National Laboratory and is available at https://emp.lbl.gov/wind-technologies-market-report

The data on the developments on wind energy presented in ECE 333 make extensive use of the information presented in the 2021 edition of the Land-Based Wind Market Report.
Wind power grew at a record pace in 2020: 16,836 MW of new capacity was added – an 84% increase over the wind capacity added in 2019; the added capacity

- is circa 42% of the 2020 US capacity additions – the largest single technology share
- increases the 2019 cumulative wind capacity by 15%
- keeps US as the second largest wind nation
The cumulative US wind capacity by the end of 2020 reached 121.98 GW.

TX remains the leading state in cumulative wind capacity:

- TX added more capacity in 2020 – 4,138 MW – than every other state.
- TX share is above 25% of the total US installed wind capacity.
Overall, wind ranked as the largest source of new US generation capacity added in 2020, ahead of solar with 8,542 MW and followed by natural gas with 6,259 MW.

EIA reports wind energy continues at a steady pace in 2021, with approximately 12.2 GW of wind projects scheduled to come online in 2021.
QUARTERLY DEVELOPMENT STATUS OF US WIND PROJECTS: 2016 – 2020

under construction at the end of quarter

advanced development at the end of quarter

2020 US WIND POWER PROJECTS
STATUS

Note: numbers within states represent cumulative installed wind capacity and the annual additions in 2020 within the brackets.
2020 WIND CAPACITY ADDITIONS BY OFF–TAKE CATEGORY

- **IOU**: 7,521 MW (45%)
- **POU**: 2,406 MW (14%)
- **Merchant**: 2,007 MW (12%)
- **Direct retail**: 4,496 MW (27%)
- **Power marketer**: 406 MW (2%)

IMPORTANT ECONOMIC INCENTIVES

- A critically important incentive in all wind projects is the production tax credit \((PTC)\), whose level and duration is subject to Congressional actions.

- The initial \(PTC\) in 2016 was set 0.015 \$/kWh for the first 10 years of operation of all projects placed in service by that year, with 20% \(PTC\) haircuts in each subsequent year.
IMPORTANT ECONOMIC INCENTIVES

- For example, wind projects whose construction started by January 1, 2017 (2018) can get 80 (60) % of the full PTC during the first ten years of operation.

- In December 2019, Congress extended the PTC’s construction start deadline through 2020 and restored its level to 60% from 40% in 2019.

- The Internal Revenue Service annually sets a multiplier to adjust the PTC for inflation.
In May 2020, pandemic-related supply chain disruptions led the IRS to extend the original 4-year safe–harbor window for projects that started construction in 2016 or 2017 to 5 years.

Those projects that started construction in 2016 (2017) had until the end of 2021 (2022) to be placed into service and to receive 100% (80%) of the full PTC during the first 10 years of operations.
IMPORTANT ECONOMIC INCENTIVES

- At the end 2020, Congress again extended the PTC at the 60% level for another year; under the new PTC legislation, wind projects whose construction is begun before December 31, 2021, qualify for the PTC.

- In June 2021, the IRS extended the so-called safe-harbor window to 6 years for projects that started construction in 2016–2019 and to five years for those that initiated construction in 2020.
US WIND DEVELOPMENTS IN 2020

- Wind installed power capacity exceeds the US hydro capacity since 2016; moreover, wind became in 2018 the largest capacity RER in the US.

- Added wind capacity in 2020 was 16,836 MW and the total installed wind capacity at the end of 2020 was 121,985 MW.

US WIND DEVELOPMENTS IN 2020

- The Biden Administration announced a targeted 30-GW offshore wind capacity by 2030
- Bureau of Ocean Energy Management (BOEM) created 5 new wind energy areas in the New York Bight
- Vineyard Wind 1 became the first fully approved US commercial offshore wind energy project
1998 – 2020 ANNUAL INSTALLED US WIND CAPACITY ADDITIONS

1998 – 2020 US ANNUAL AND CUMULATIVE INSTALLED WIND CAPACITY


cumulative capacity

added capacity

GW

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140

16.84

121.98

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US CUMMULATIVE WIND CAPACITY

2020: TOP 20 US STATES IN INSTALLED WIND CAPACITY

2020 US WIND ELECTRICITY GENERATION

million MWh

53% of total US wind generation

rest of US
TOP 5 US STATES WITH INSTALLED WIND CAPACITY IN 2020

Total capacity in GW

<table>
<thead>
<tr>
<th>State</th>
<th>Total Capacity in GW</th>
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<tbody>
<tr>
<td>TX</td>
<td>32.7</td>
</tr>
<tr>
<td>IA</td>
<td>11.37</td>
</tr>
<tr>
<td>OK</td>
<td>9.34</td>
</tr>
<tr>
<td>KS</td>
<td>7.03</td>
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<tr>
<td>IL</td>
<td>6.40</td>
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Annual capacity in GW

<table>
<thead>
<tr>
<th>State</th>
<th>Annual Capacity in GW</th>
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<tbody>
<tr>
<td>TX</td>
<td>3.94</td>
</tr>
<tr>
<td>IA</td>
<td>1.74</td>
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<tr>
<td>OK</td>
<td>0.54</td>
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<tr>
<td>KS</td>
<td>0.47</td>
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<tr>
<td>IL</td>
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</table>

2020: TOP 20 US STATES OF WIND GENERATED ENERGY SHARE

1998 – 2020 US CAPACITY ADDITIONS BY RESOURCE TYPE CATEGORY


GW

other non-renewable

other renewable

wind

coal

gas

solar

SHARE OF WIND OF THE TOTAL ADDED ANNUAL CAPACITY: 2000 – 2020

% of wind of the total US added capacity

WIND ENERGY REDUCES US GHG EMISSIONS

source: American Clean Power WPA Executive Summary p. 5; available at https://cleanpower.org/resources/types/reports/

189 million metric tons of CO₂ avoided in 2018 (2019), equivalent to the emissions of 43 (42) million cars

201 (198) million metric tons of CO₂ avoided in 2018 (2019), equivalent to the emissions of 43 (42) million cars
US WIND ENERGY IMPACTS: WATER CONSUMPTION SAVINGS

Source: https://cleanpower.org/facts/wind-power/

95 (103) billion gallons of water avoided in 2018 (2019), equivalent to 308 (312) gallons per person in US.
2005 – 2020 GLOBAL WIND CAPACITY

GW

<table>
<thead>
<tr>
<th>2020 capacity in MW</th>
<th>cumulative capacity in MW</th>
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<tbody>
<tr>
<td><strong>China</strong></td>
<td><strong>Chinese</strong></td>
</tr>
<tr>
<td>52,000</td>
<td>288,320</td>
</tr>
<tr>
<td><strong>United States</strong></td>
<td><strong>United States</strong></td>
</tr>
<tr>
<td>16,836</td>
<td>121,985</td>
</tr>
<tr>
<td>Brazil</td>
<td>62,850</td>
</tr>
<tr>
<td>2,297</td>
<td>27,250</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1,979</td>
</tr>
<tr>
<td>Germany</td>
<td>1,668</td>
</tr>
<tr>
<td>1,532</td>
<td>23,937</td>
</tr>
<tr>
<td>Spain</td>
<td>1,400</td>
</tr>
<tr>
<td>1,318</td>
<td>17,948</td>
</tr>
<tr>
<td>France</td>
<td>1,224</td>
</tr>
<tr>
<td>1,119</td>
<td>17,750</td>
</tr>
<tr>
<td>Turkey</td>
<td>11,538</td>
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<td>11,538</td>
<td>119,572</td>
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**rest of world**

**total**

92,910

742,357

LEADING NATIONS IN WIND ENERGY CONSUMPTION IN 2020

2020 US WIND ENERGY INDUSTRY
MANUFACTURING FACILITIES

US WIND MANUFACTURER STATUS

- The manufacturing supply chain continued to adjust to swings in demand for wind equipment.

- Of the 16,836 MW of wind capacity installed in 2020, 8,923 MW or 53% used turbines from GE Wind, 5,724 MW or 34% used Vestas and 1,515 MW or 9% deployed SGRE equipment.
imports from countries besides the top 10 totaled $407 m

**US WIND MANUFACTURER STATUS**

- *Nordex Acciona* and *Goldwind* supplied 3% and 1%, respectively, of the remaining capacity.

- Despite the sizeable imports wind technology equipment, the *US* has big domestic wind manufacturing capability; in 2020, domestic nacelle assembly capability was able to supply 15 GW of installed wind capacity, 9.4 GW of the blades and 10.3 GW of the towers.
AVERAGE WIND TURBINE FEATURES

TURBINE SPECIFIC POWER TRENDS


commercial year of operation
The specific power of a turbine is the ratio of its nameplate capacity to the area swept by the rotor.

\[
\text{turbine specific power} = \frac{\text{nameplate capacity}}{\text{rotor swept area}}
\]

The average specific power of the US turbine fleet decreased from 394 W/m\textsuperscript{2} – the 1998 – 1999 projects – to 224 W/m\textsuperscript{2} of the 2020 projects, as the increase in the average rotor swept area outpaced the average nameplate capacity increase over this period.
OFFSHORE WIND POWER

- Offshore wind is, typically, faster and steadier than onshore wind.
- Offshore wind entails, in general, higher construction/maintenance costs than onshore wind; moreover, the transmission part development poses a huge challenge.
- Offshore wind may be an unwelcome sight for local residents and may impact marine life.
2020 STATUS OF US OFFSHORE WIND POWER

- The US offshore wind energy project development and operational pipeline grew significantly with a potential capacity of 35.3 GW at the end of 2020.

- The pipeline experienced a 24% increase in 2020 from the 28.5 GW potential capacity in 2019.
2020 STATUS OF US OFFSHORE WIND POWER

- In December 2016, the Deepwater Wind completed the commissioning of the first commercial offshore wind project in the US.

- At the end of 2020, the many US offshore wind projects are in various stages of development.
EAST COAST OFFSHORE WIND PROJECTS AND LEASE AREAS

Source: America Clean Power WPA Executive Summary p. 4; available at https://cleanpower.org/resources/types/reports/
2020 US OFFSHORE WIND PROJECT PIPELINE BY PROJECT STATUS

2020 US OFFSHORE WIND PROJECT STATUS BY STATE

US POPULATION DENSITY AND RENEWABLE RESOURCE LOCATIONS

Source: http://www.census.gov/popest/data/maps/2009/PopDensity_09.jpg
NREL issued a report that discusses US offshore wind potential, with its key conclusion being that by 2030 US could harness 54 GW of offshore wind.

US offshore wind has a significant advantage in that the supply may be located relatively close to the high-density load regions in urban areas.

The leading global offshore wind producers are Great Britain, China, Germany and Denmark.
BLOCK ISLAND WIND FARM

- First commercial US offshore wind farm
- Installed capacity: 30 MW (5 turbines)
- Farm has five 6–MW GE Haliade turbines
- 21 miles submarine power cable
- PPA initial price: 24.4 ¢/kWh
BLOCK ISLAND KEY CHARACTERISTICS

- Absence of economies of scale
- Large investment
- Uncompetitive prices
- Imported technology
- Long delays from the September 2008 start date
- Major breakthrough for offshore wind in the US
In 2020, the global offshore wind energy industry installed 5.5 GW of capacity.

Much of the added global generating capacity can be attributed to 2.1 GW of new deployments in the Chinese market, followed by 1.5 GW commissioned in the Netherlands, 714 MW in the UK, 706 MW in Belgium, 315 MW in Germany and the remaining 107 MW in the r.o.t.w.
2020 GLOBAL OFFSHORE WIND STATUS

annual installed capacity (MW)

United Kingdom  China  Belgium
Germany  Denmark  Netherlands
Other Europe  United States  Other Asia

global cumulative capacity (MW)

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.
DISTANCE FROM PORT & WATER DEPTH OF OFFSHORE WIND PROJECTS


average distance port (km)

average water depth (m)

Capacity (MW) ≤ 10 200 400 600 800 ≥ 1,000

2001 2020
c.f.s OF OFFSHORE WIND PROJECTS

LARGEST OFFSHORE WIND FARM

- **Hornsea One** is the largest offshore wind farm with 174 turbines for a cumulative capacity of 1,218 MW.

- The completed project is more than double the size of the *London Array*, the second largest offshore wind farm that was implemented.
LARGEST OFFSHORE WIND FARM

- **Hornsea One** is located about 120 km from the Yorkshire coast and will use 220-kV submarine AC cables to interconnect with the National Grid's transmission grid.

- The project area covers roughly 407 km² with the ability to generate energy to supply over a million British households.
The *Hornsea One* will not be the world’s largest wind farm for too long a time as the title will be given to the *Dogger Bank Wind Farms, UK*

The world’s largest offshore wind farm will have, upon completion, a nameplate capacity of 3.6 $GW$. 
In the competition for the turbine selection, GE won with its Haliade-X model over the competing Siemens Gamesa Renewable Energy proposed turbine. The Haliade-X 12–MW turbine is considered to be the world’s largest commercial wind turbine with its 107–m blade.
ROTOR TRANSPORT HAS ITS CHALLENGES

DRAMATIC DELIVERY OF HUGE WIND TURBINE BLADE IN CHINA