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National Renewable Energy Laboratory

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Data and Methodology
Data Sources

This update draws data from the U.S. Department of Energy’s (DOE’s) National Renewable Energy Laboratory’s (NREL’s) internal offshore wind database, which is built on internal research and a wide variety of data sources, including peer-reviewed literature, press releases, industry news reports, manufacturer specification sheets, and global offshore wind project announcements. For the database, NREL has verified and sourced data from the following publications:

- The 4C Offshore Wind Database (4C Offshore 2021)
- 4C Offshore Vessel Database (4C Offshore 2021)
Scope and Pipeline Definitions

• This work defines the offshore wind project pipeline as potential offshore wind development indicated by developer announcements or by areas made available for offshore wind development by regulatory agencies.

• The scope of this report covers the global fleet of projects in the pipeline through December 31, 2020.

• This report also covers recent developments and events in the United States through May 31, 2021, projects that have been completed before May 31, 2021.

• Any estimates of capacities and project dates are shown as reported by project developers or state/federal agencies.

• All dollar amounts are reported in 2020 U.S. dollars, unless indicated otherwise.

• In this analysis, the U.S. pipeline capacity includes the sum of project-specific capacities and the undeveloped lease area potential capacities based on a project density of 3 megawatts (MW)/km2.

• For further discussion on methodology and data sources, please refer to the “2019 Offshore Wind Technology Data Update” (Musial et al. 2020)
## Project Pipeline Classification System

<table>
<thead>
<tr>
<th>Step</th>
<th>Phase Name</th>
<th>Start Criteria</th>
<th>End Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Planning</td>
<td>Starts when a developer or regulatory agency initiates the formal site control process</td>
<td>Ends when a developer obtains control of a site (e.g., through competitive auction or a determination of no competitive interest in an unsolicited lease area (United States only))</td>
</tr>
<tr>
<td>2</td>
<td>Site Control</td>
<td>Begins when a developer obtains site control (e.g., a lease or other contract)</td>
<td>Ends when the developer files major permit applications (e.g., a Construction and Operations Plan for projects in the United States)</td>
</tr>
<tr>
<td>3</td>
<td>Permitting = Site Control + Offtake Pathway</td>
<td>Starts when the developer files major permit applications (e.g., a Construction and Operations Plan and an offtake agreement for electricity production)</td>
<td>Ends when regulatory entities authorize the project to proceed with construction and certify its offtake agreement</td>
</tr>
<tr>
<td>4</td>
<td>Approved</td>
<td>Starts when a project receives regulatory approval for construction activities and its offtake agreement</td>
<td>Ends when sponsor announces a “financial investment decision” and has signed contracts for construction work packages</td>
</tr>
<tr>
<td>5</td>
<td>Financial Close</td>
<td>Begins when sponsor announces a financial investment decision and has signed contracts for major construction work packages</td>
<td>Ends when the project begins major construction work</td>
</tr>
<tr>
<td>6</td>
<td>Under Construction</td>
<td>Starts when construction is initiated</td>
<td>Ends when all wind turbines have been installed and the project is connected to and generating power to a land-based electrical grid</td>
</tr>
<tr>
<td>7</td>
<td>Operating</td>
<td>Commences when all wind turbines are installed and transmitting power to the grid; COD marks the official transition from construction to operation</td>
<td>Ends when the project has begun a formal process to decommission and stops feeding power to the grid</td>
</tr>
<tr>
<td>8</td>
<td>Decommissioned</td>
<td>Starts when the project has begun the formal process to decommission and stops transmitting power to the grid</td>
<td>Ends when the site has been fully restored and lease payments are no longer being made</td>
</tr>
<tr>
<td>9</td>
<td>On Hold/Cancelled</td>
<td>Starts if a sponsor stops development activities, discontinues lease payments, or abandons a prospective site</td>
<td>Ends when a sponsor restarts project development activity</td>
</tr>
</tbody>
</table>
U.S. Offshore Wind Data
Percentages of U.S. Offshore Wind Energy Pipeline for 2019 and 2020 by Classification Category

2019 Pipeline – 25,821 Megawatts (MW)
- Lease Area with Site Control 61%
- Projects Permitting with Site Control & Offtake Agreement 23%
- Unleased Wind Energy Areas 8%
- Under Construction 0.04%
- Installed 0.1%

2020 Pipeline – 35,324 MW
- Lease Area with Site Control 33%
- Projects with Site Control & Negotiating Offtake Agreement 31%
- Unleased Wind Energy Areas 34%
- Fully Approved Projects with Offtake and Interconnect 2%
- Installed 0.1%
U.S. Project Pipeline Classification by State

- New York
- Massachusetts
- Maryland
- Delaware
- New Jersey
- Rhode Island
- New York
- North Carolina
- Ohio
- Virginia
- Maine
- Connecticut

- Operating
- Under Construction
- Financial Close
- Approved
- Permitting
- Site Control
- Planning
- Total Pipeline

- 42 MW
- 0 MW
- 0 MW
- 800 MW
- 11,652 MW
- 10,779 MW
- 12,051 MW
- 35,324 MW

Pipeline Classification
U.S. Project Pipeline by State

- New York
- Massachusetts
- New Jersey
- North Carolina
- Virginia
- Connecticut
- Maryland
- Delaware
- Rhode Island
- Ohio
- Maine

**U.S. Offshore Wind Pipeline (MW)**

- **Planning***
- **Site Control***
- **Permitting**
- **Approved**
- **Operating**

- New York: 12 MW Operating
- Rhode Island: 30 MW Operating
U.S. Atlantic Coast Offshore Wind Energy Pipeline and Call Areas
U.S. West Coast Offshore Wind Call Areas
Hawaiian Offshore Wind Call Areas
Industry Forecasts for U.S. Offshore Wind Energy Deployment to 2030 Including the National Goal
New York Bight Wind Energy Areas (WEAs)
U.S. Offshore Wind State Procurement Targets and Timelines

RFP = request for proposals
Global Offshore Wind Data
Global Cumulative Offshore Wind Deployment and Annual Capacity Additions in 2020

Global Cumulative Offshore Wind Deployment

Annual Capacity Additions
Global Offshore Wind Installations in 2020

- China: 2,174.0 MW
- Netherlands: 1,502.5 MW
- United Kingdom: 714.0 MW
- Belgium: 706.0 MW
- Germany: 315.0 MW
- Other: 85.8 MW
- United States: 12.0 MW
- Denmark: 9.5 MW

5,519 MW of New Installed Capacity in 2020
Global Cumulative Offshore Wind Installation by Country
Offshore Wind Capacity Under Construction by Country as of 2020

- **China**: 16,591.4 MW
- **United Kingdom**: 3,689.0 MW
- **Taiwan**: 1,127.2 MW
- **Denmark**: 605.0 MW
- **Vietnam**: 539.3 MW
- **France**: 480.0 MW
- **Netherlands**: 382.7 MW

Total: 23,415 MW of Under Construction Capacity in 2020
Developer-Announced Offshore Wind Capacity through 2026 for Projects with Financial Closure
Estimated 2026 Cumulative Offshore Wind Capacity by Country Based on a Developer-Announced Commercial Operation Date

145,460 MW has been announced through 2026.
Total Global Pipeline by Status

The chart illustrates the distribution of global pipeline capacity by status. The pipeline is categorized into various stages, including operating, under construction, financial close, approved, permitting, site control, planning, and total pipeline. The chart shows a significant portion of the pipeline capacity is under construction, with a total of 23,415 MW. The planning stage has 11,652 MW, and the operating stage has 32,906 MW. The total global pipeline capacity is 307,815 MW, with Asia leading at 152,904 MW.
Industry Forecasts for Global Offshore Wind Energy Deployment to 2030

[Data and charts related to offshore wind energy deployment from 2020 to 2030, showing cumulative installed capacity and annual projected additions by region.]
Global Floating Offshore Wind Data
Total Global Floating Offshore Wind Energy Pipeline

Pipeline Classification

- Operating
- Under Construction
- Financial Close
- Approved
- Permitting

- Europe
- Asia
- United States

Global Floating Offshore Pipeline (MW)

- 26,078 MW
- 26,529 MW

Pipeline Breakdown:
- Operating: 79 MW
- Under Construction: 48 MW
- Financial Close: 104 MW
- Approved: 142 MW
- Permitting: 79 MW
- Planning: 26,078 MW
- Total Pipeline: 26,529 MW
Global Floating Offshore Wind Energy Projects by Depth, Country, and Project Size
Cumulative Floating Offshore Wind Capacity by Country Based on Announced Commercial Operation Date through 2026

3,688 MW has been announced through 2026.
2020 Offshore Wind Technology Trends
Fixed-Bottom Offshore Wind Energy Project Depths and Distances to Shore
Distance From Shore for Global Operating and Future Offshore Wind Energy Projects

Distance to Shore (km)

Commercial Operation Date

Operating

Announced

Global Capacity-Weighted
Rolling 5 Year
Mean Project Distance to Shore
Rest of the World
Capacity-Weighted
Rolling 5 Year
Mean Project Distance to Shore
Asian Capacity-Weighted
Rolling 5 Year
Mean Project Distance to Shore
Projects in Rest of the World
Asian Projects
Water Depth for Global Operating and Future Projects

- Global Capacity-Weighted Rolling 5 Year Mean Project Depth
- Rest of the World Capacity-Weighted Rolling 5 Year Mean Project Depth
- Asian Capacity-Weighted Rolling 5 Year Mean Project Depth
- Projects in Rest of the World
- Asian Projects

Diagram showing water depth over time with categories for operating and announced projects.
Offshore Wind Substructure Technology Used in Operating Projects

- Monopile: 24,614.0 MW
- Jacket: 3,543.8 MW
- Unreported: 1,509.3 MW
- High-Rise Pile Cap: 1,333.6 MW
- Tripod: 1,060.0 MW
- Gravity Base: 735.5 MW
- Semisubmersible: 39.8 MW
- Spar: 34.3 MW
- Rock-Anchored Concrete Rings: 30.0 MW
- Barge: 6.0 MW
- Multipile: 0.6 MW

32,906 MW of Global Operating Substructure Capacity in 2020
Announced Offshore Wind Substructure Technology Market Share

- Monopile: 38,356.2 MW
- Jacket: 16,012.3 MW
- Semisubmersible: 8,787.5 MW
- Gravity Base: 5,284.0 MW
- High-Rise Pile Cap: 2,905.9 MW
- Spar: 2,279.4 MW
- Barge: 532.0 MW
- Tripod: 99.2 MW
- Tension-Leg Platform: 60.2 MW

Total: 74,317 MW of Global Announced Substructure Capacity in 2020
Global Floating Substructure Market Share

- **Semisubmersible**: 8,827.3 MW
- **Spar**: 2,313.7 MW
- **Barge**: 537.0 MW
- **Tension-Leg Platform**: 60.2 MW

11,738 MW of Installed and Announced Capacity in 2020
Average Offshore Wind Turbine Capacity, Hub Heights, and Rotor Diameters

2020 Capacity – Weighted Averages
Turbine Capacity: 7.58 MW
Rotor Diameter: 156.24 m
Hub Height: 100.32 m
Comparison of Offshore Wind Turbine Prototypes with Commercial Offshore Turbine Growth
Offshore Wind Turbine Manufacturer Market Share in Operating Projects

- Siemens: 18,142.7 MW
- Gamesa: 1,181.8 MW
- Vestas: 6,132.5 MW
- Senvion: 1,416.2 MW
- Goldwind: 1,312.5 MW
- Envision Energy: 1,037.2 MW
- Adwen: 1,020.0 MW
- GE Energy: 580.5 MW
- MingYang: 551.5 MW
- CSIC: 420.0 MW
- Bard: 400.0 MW
- Sewind: 221.0 MW
- Sinovel: 159.0 MW
- Doosan Heavy Industries: 103.5 MW
- Other: 227.5 MW

Global Operating Turbine OEM Capacity in 2020: 32,906 MW
Offshore Wind Turbine Manufacturer Market Share for Announced Projects

- Siemens: 23,180.2 MW
- Gamesa: 10,642.2 MW
- Vestas: 7,576.4 MW
- GE Energy: 3,409.0 MW
- Sewind: 2,520.0 MW
- MingYang: 1,947.9 MW
- Goldwind: 1,200.0 MW
- Doosan Heavy Industries: 960.0 MW
- CSIC: 600.0 MW
- Sinovel: 500.0 MW
- DEC: 325.9 MW
- Hitachi Ltd: 300.0 MW
- Envision Energy: 205.0 MW
- Unison: 200.0 MW
- Yinhe: 63.9 MW

Total: 53,631 MW of Global Announced Turbine OEM Capacity in 2020
Distribution Voltage of Array Cable Versus Year of First Power

![Diagram showing the distribution voltage of array cable versus year of first power. The graph includes different data points for turbines of varying power capacities (less than 4 MW, 4 to 7 MW, 7 to 10 MW, and more than 10 MW) over the years 2000 to 2030. The largest turbine in a wind power plant is also indicated.]
Number of Wind Farms Versus Length of AC Export Cable Length

- Europe
- Asia
- United States
- Other

AC Export Cable Length (km)

Number of Wind Power Plants

0-10
10-20
20-30
30-40
40-50
50-60
60-70
70-80
80-90
90-100
100+
Status Quo and Future Potential Integrated U.K. Network Designs

Image from National Grid Electricity System Operator, Offshore Coordination Project

Status Quo

Capex Cost: £29 billion
Total Assets: 330
Total Landing points: 105

Future Potential Integrated

Capex Cost: £27 billion (-8%)
Total Assets: 40% reduction
Total Landing points: 60

Capex Cost: £23 billion (-18%)
Total Assets: 70% reduction
Total Landing points: 30
Analysis of Global Wind Turbine Installation Vessel (WTIV) Capabilities

Image from Bocklet et al. (2021)
2020 Offshore Wind Cost Trends
Global Levelized Cost of Energy Estimates for Fixed-Bottom Offshore Wind

![Graph showing Levelized Cost of Energy (2020 USD/Megawatt-Hours [MWh]) over Commercial Operation Date from 2019 to 2035, with various data sources and scenarios represented by different lines and markers.](image-url)
Capital Expenditures for Global Offshore Wind Energy Projects

Operating

Announced

- Installed
- Under Construction
- Financial Close
- Contracted
- Approved
- Permits
Global Offshore Wind Power Plant Operational Expenditures

![Graph showing annual operational expenditures from 2020 to 2030 for different sources: Wood Mackenzie (2021), International Energy Agency (2019), Wiser et al. (2021). The expenditures decrease over time, with Wood Mackenzie projecting the highest and Wiser et al. the lowest.](image-url)
Adjusted Strike Prices from U.S. and European Offshore Wind Procurements

Beiter et al. (2021) for U.S. projects
Global Levelized Cost of Energy Estimates for Floating Technology

![Graph showing levelized cost of energy estimates for floating technology across different operation dates and sources. The graph includes data from NREL and DNV, as well as expert surveys, with estimates trending downward over time.]
Notice
Notice

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