U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

# 2018 Offshore Wind Technologies Market Report


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## BNOW Webinar


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# Report Contents

- Data and Project Classification
- U.S. Offshore Wind Market Assessment
- Global Offshore Wind Development
- Offshore Wind Technology Trends
- Cost and Pricing Trends

Full Presentation and report available at:
https://www.energy.gov/eere/wind/2018-wind-market-reports#offshore

# 2018 Market Report Data Sources

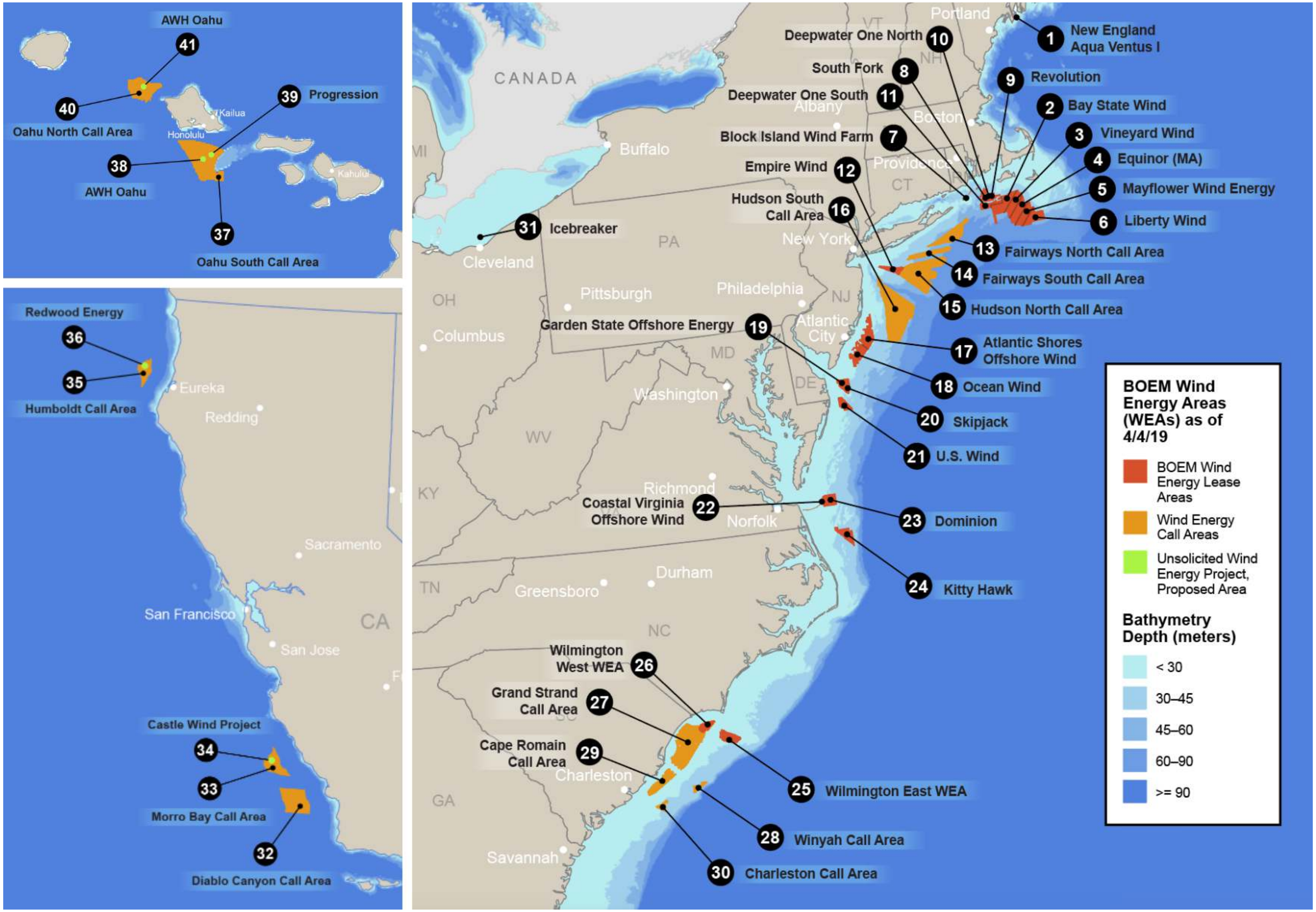
- NREL's Offshore Wind Database (OWDB) is built from internal research using peer-reviewed literature, press releases, industry news reports, manufacturer specification sheets, subscription-based industry databases, and global offshore wind project announcements.
- The data in this report—both globally and domestically—are derived from the OWDB.
- Data gaps were filled using the best judgment of the authors and industry subject matter experts that were consulted.
- The OWDB is verified against the following sources:
  - The 4C Offshore Wind Database
  - BOEM
  - The WindEurope Annual Market Update
  - Bloomberg New Energy Finance's (BNEF's) Renewable Energy Project Database
  - The University of Delaware's Special Initiative on Offshore Wind (SIOW).

# Offshore Wind Pipeline Criteria for Market Report

| Step | Phase Name | Start Criteria | End Criteria |
|---|---|---|---|
| 1 | Planning | Starts when a developer or regulatory agency initiates the formal site control process | Ends when a developer obtains site control to a site (e.g., through competitive auction or a determination of no competitive interest in an unsolicited lease area [United States only]) |
| 2 | Site Control | Begins when a developer obtains site control (e.g., a lease or other contract) | Ends when the developer files major permit applications (e.g., a construction and operations plan for projects in the United States) or obtains an offtake agreement |
| 3 | Permitting = Site Control + Offtake Pathway | Starts when the developer files major permit applications (e.g., construction and operations plan or an offtake agreement for electricity production) | Ends when regulatory entities authorize the project to proceed with construction and certify its offtake agreement |
| 4 | Approved | Starts when a project receives regulatory approval for construction activities and its offtake agreement | Ends when sponsor announces a "financial investment decision" and has signed contracts for construction work packages |
| 5 | Financial Close | Begins when sponsor announces a financial investment decision and has signed contracts for major construction work packages | Ends when project begins major construction work |
| 6 | Under Construction | Starts when offshore construction is initiated[10] | Ends when all turbines have been installed and the project is connected to and generating power for a land-based electrical grid |
| 7 | Operating | Commences when all turbines are installed and transmitting power to the grid; COD marks the official transition from construction to operation | Ends when the project has begun a formal process to decommission and stops feeding power to the grid |
| 8 | Decommissioned | Starts when the project has begun the formal process to decommission and stops transmitting power to the grid | Ends when the site has been fully restored and lease payments are no longer being made |
| 9 | On Hold/Cancelled | Starts if a sponsor stops development activities, discontinues lease payments, or abandons a prospective site | Ends when a sponsor restarts project development activities |

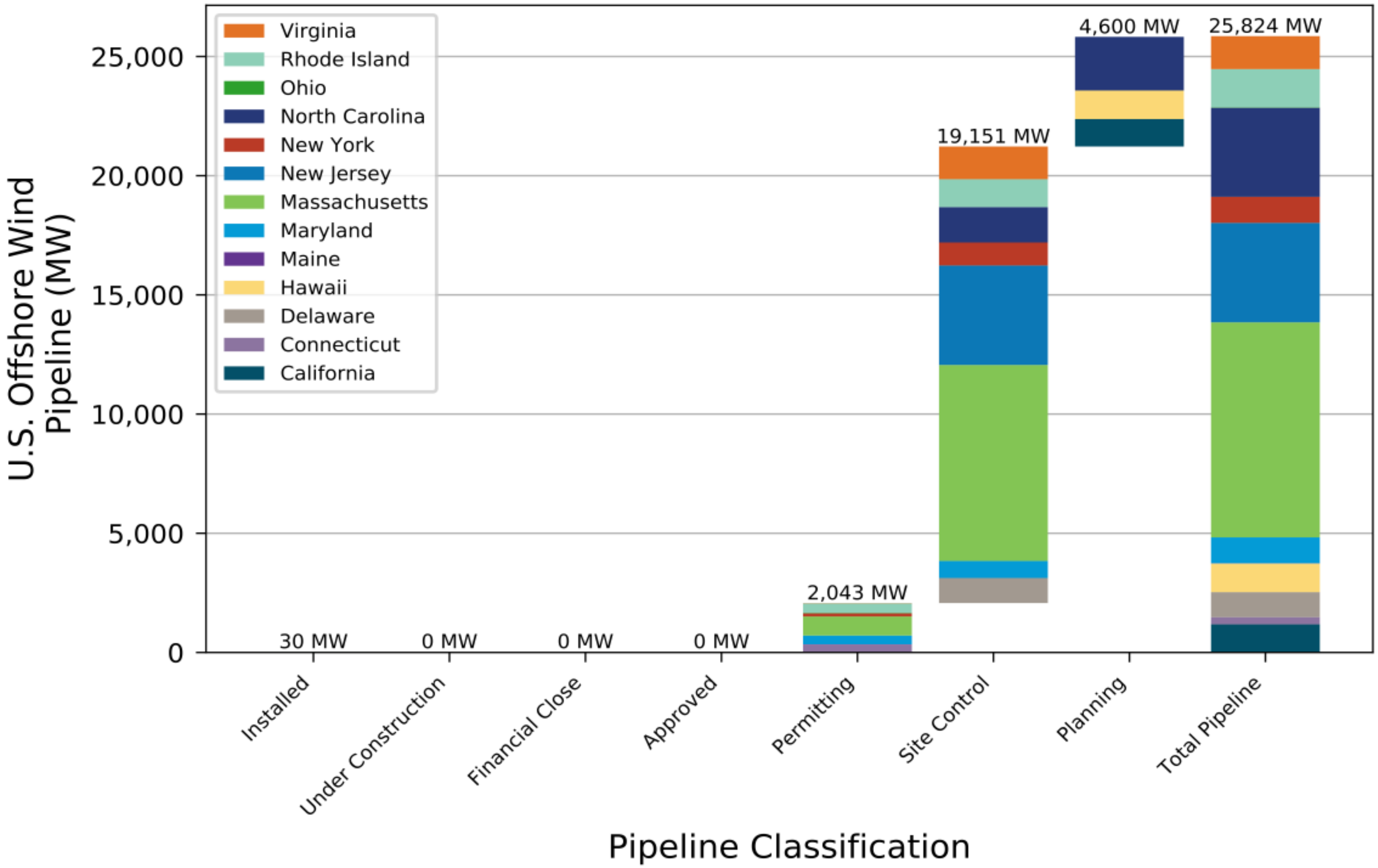
# U.S. Offshore Wind Market Assessment

# U.S. Offshore Wind Development Activity

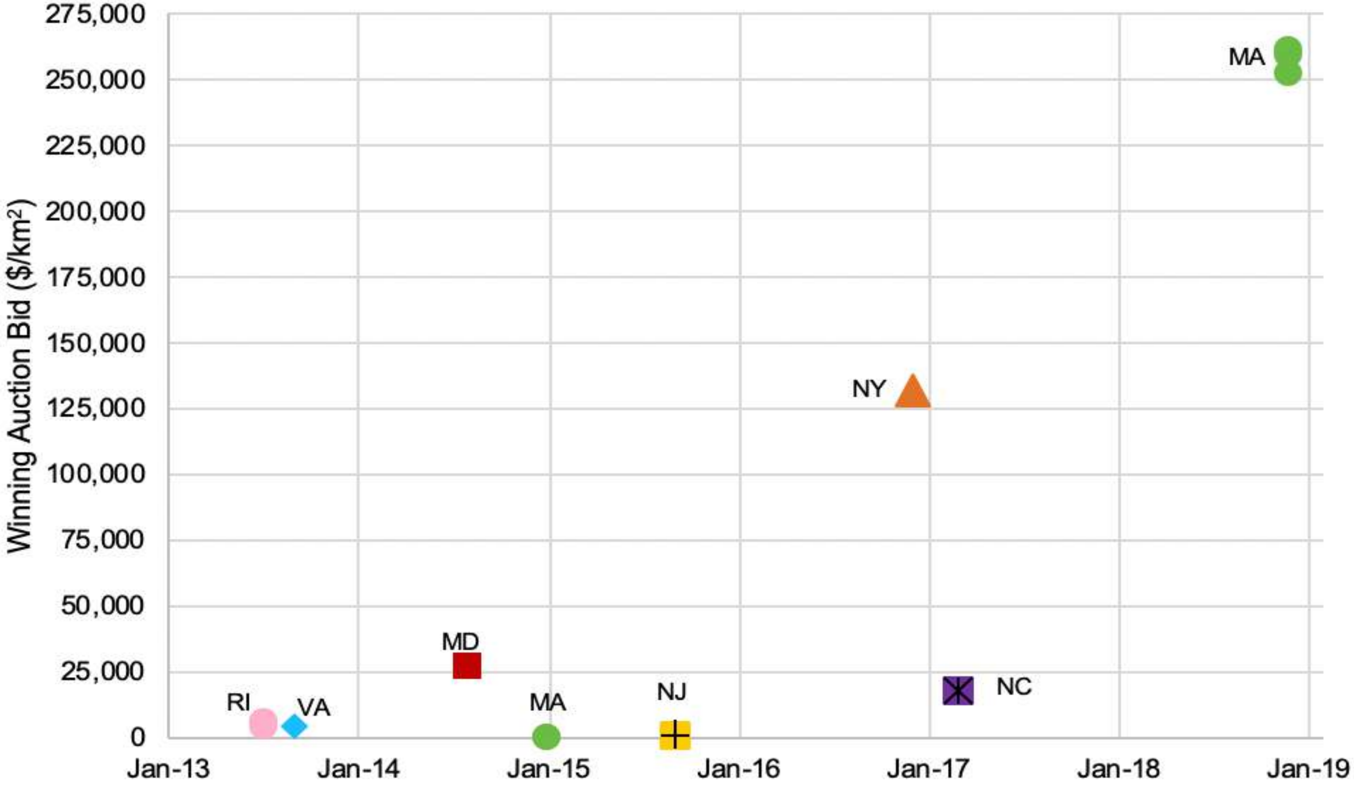


# U.S. Offshore Wind Pipeline Calculated at 25,824 GW

The 2018 U.S. pipeline is 25,824 MW, growing by 1.4% relative to 2017. Changes were caused by cancellation of the 24-MW Nautilus Offshore Wind Project (New Jersey), expansion of South Fork from 90 MW to 130 MW, the addition of the150-MW Redwood Coast Offshore Wind Project (California), and the proposed size increase of Castle Wind (California) from 765 MW to 1,000 MW.



# The Auction Prices of U.S. Lease Areas Increased in 2018




- Three Massachusetts lease areas were auctioned in December 2018. Each sold for at least \$135 million (\$258,000/km$^2$), more than tripling the previous record of \$42 million (\$132,255/km$^2$).
- Increased lease sale prices may indicate the offshore wind market is maturing.
- Higher lease prices could increase the delivery price of offshore wind.

# U.S. Offshore Wind Market Is Driven by State Policies

- In 2018 and early 2019, new targets were established or upgraded in New Jersey (3.5 GW), Massachusetts (3.2 GW), Maryland (1.2 G.W), Connecticut (2.3 GW), and New York (9.0 GW).
- In 2018, offshore wind request for proposals were issued in New York (800 MW) and New Jersey (1,100 MW).
- As of June 2019, state policy commitments call for 19,968 MW of offshore wind capacity by 2035–almost four times the aggregate state-level targets identified at the end of 2017.

**2018 Summary Table of U.S. State Policy Commitments**

| State | 2018 Capacity Commitment (MW) | Offshore Wind Solicited (MW) | Contract Type | Target Year | Statutory Authority | Year Enacted | RPS Goal | State RPS Year |
|---|---|---|---|---|---|---|---|---|
| MA | 1,600 | 1600 | PPA | 2027 | An Act to Promote Energy Diversity (H.4568) | 2016 | 35% | 2030 |
| | 1,600 | - | PPA | 2035 | An Act to Advance Clean Energy (H.4857) | 2018 | | |
| RI | 400 | 400 | PPA | - | - | - | 31% | 2030 |
| NJ | 3,500 | 1,100 | OREC | 2030 | Executive Order 8 AB No. 3723 | 2018 | 50% | 2030 |
| MD | 368 | 368 | OREC | 2030 | Maryland Offshore Wind Energy Act | 2013 | 24% | 2020 |
| | 400 | - | OREC | 2026 | Senate Bill 516 | 2019 | | |
| | 400 | - | | 2028 | | | | |
| | 400 | - | | 2030 | | | | |
| NY | 2,400 | 930 | OREC | 2030 | Case 18-E-0071 Order Establishing Offshore Wind Standard and Framework for Phase 1 Procurement | 2018 | 50% | 2030 |
| | 6,600 | - | TBD | 2035 | Climate Leadership and Community Protection Act | 2019 | | |
| CT | 300 | 300 | PPA | 2020 | House Bill 7036 (Public Act 17-144) | 2017 | 44% | 2030 |
| | 2,000 | - | TBD | 2030 | House Bill 7156 | 2019 | | |
| VA | - | 12 | Utility Owned | 2028 | Virginia Energy Plan | TBD | - | - |
| TOTAL | 19,968 MW | 4,710 MW | | | | | | |

# BOEM Issued Calls for Information and Nominations in the New York Bight and Along the California Coast

- Calls for Information and Nominations (Call Areas) are used to assess commercial offshore wind interests in federal ocean areas and receive feedback from a variety of local stakeholders.

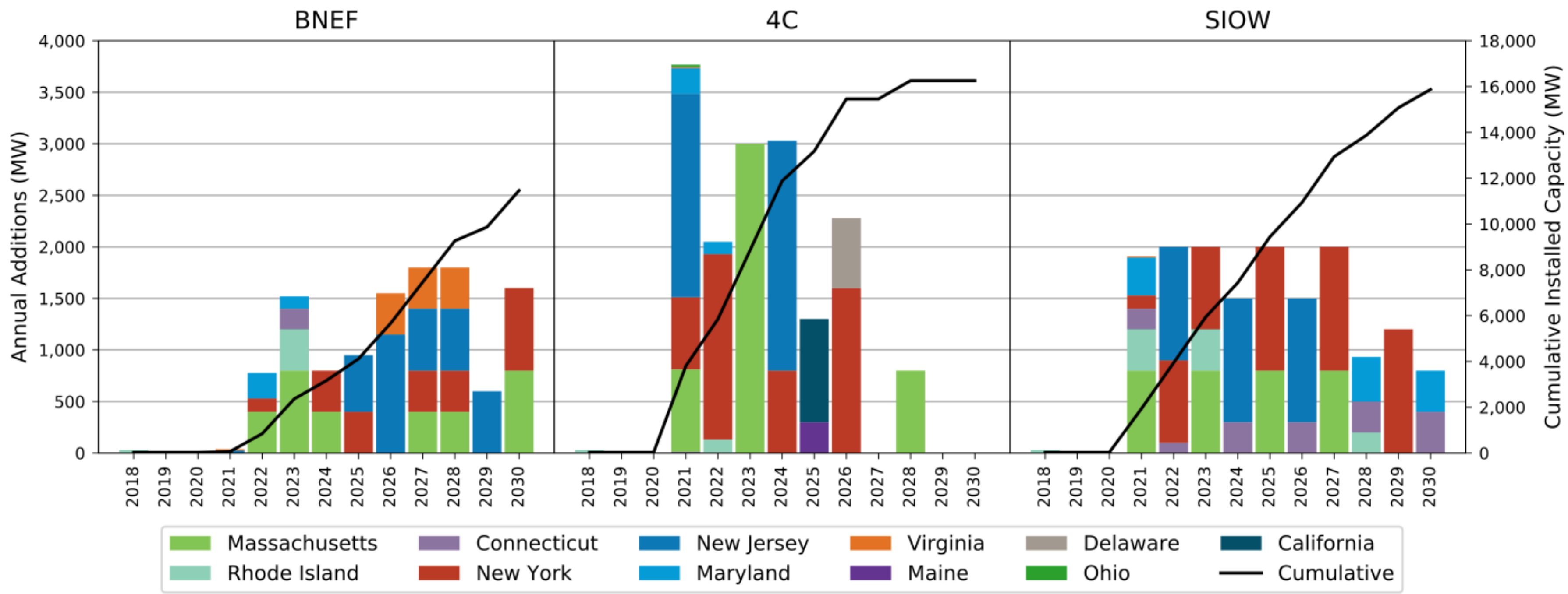
- BOEM identified four Call Areas in the New York Bight (off the states of New York and New Jersey) and found there was commercial interest in all sites. These additional lease areas are essential for supporting the states' offshore wind procurement policy goals.

- The three California Call Areas total approximately 2,784 $km^2$ and could potentially deliver a generating capacity of up to 8.4 GW. In response to the California call, BOEM received 14 nominations indicating interest in developing some portions of each Call Area.

**New Offshore Wind Call Areas in 2018**

| State | Name | Call Period |
|---|---|---|
| NY | Fairways North Call Area | 4/11/2018–7/30/2018 |
| NY | Fairways South Call Area | 4/11/2018–7/30/2018 |
| NY/NJ | Hudson North Call Area | 4/11/2018–7/30/2018 |
| NY/NJ | Hudson South Call Area | 4/11/2018–7/30/2018 |
| CA | Humboldt Call Area | 10/19/2018–1/28/2019 |
| CA | Morro Bay Call Area | 10/19/2018–1/28/2019 |
| CA | Diablo Canyon Call Area | 10/19/2018–1/28/2019 |

# U.S. Market Predicted To Grow to at Least 10 GW by 2030



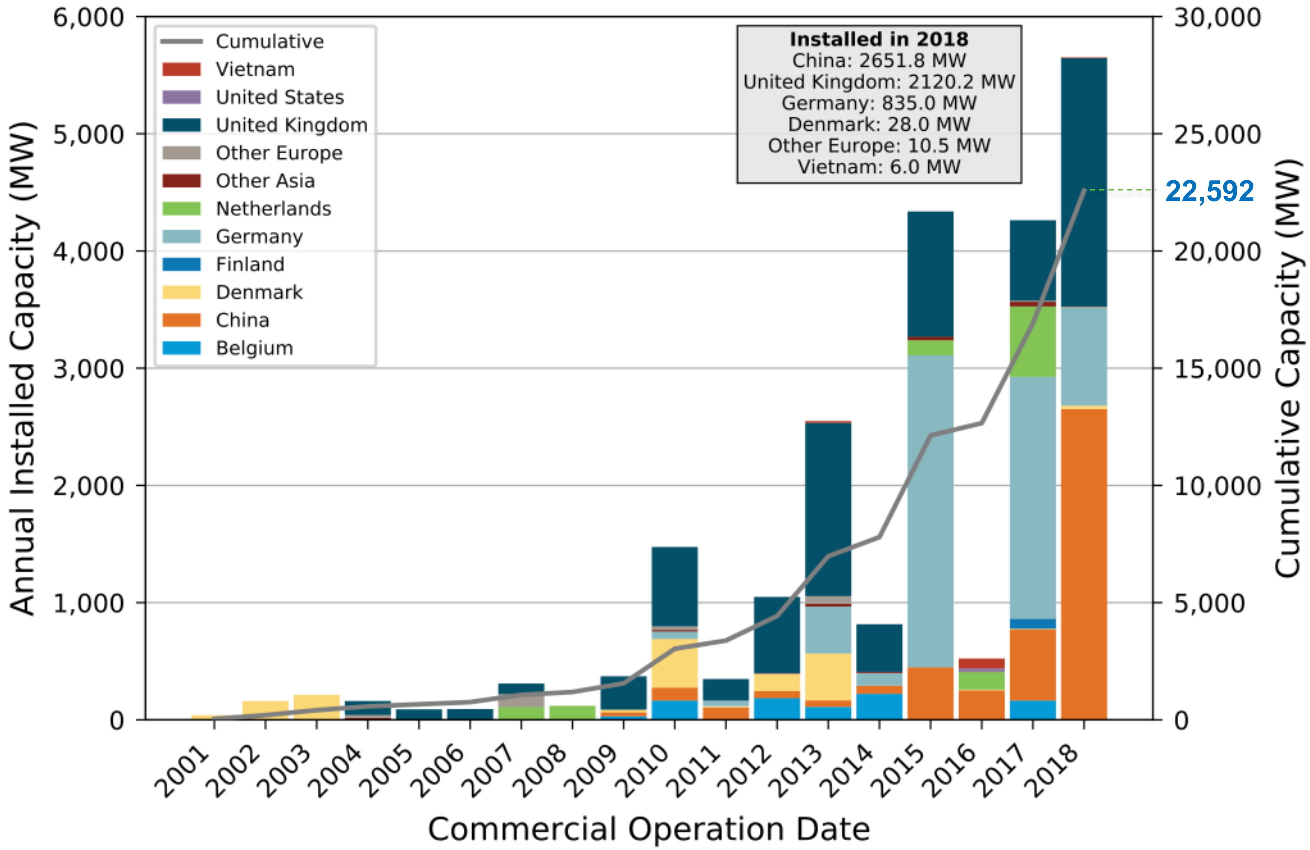

- Forecasts estimate the U.S. offshore wind market will cumulatively deploy between 4 and 13 GW by 2025, and 11 to 16 GW by 2030.

- The size and speed of build-out are uncertain and depend on state policies, regularity of future procurements, availability of installation vessels and specialized ports, land-based and offshore electrical infrastructure, and evolving market demand.

# Overview of Global Offshore Wind Development

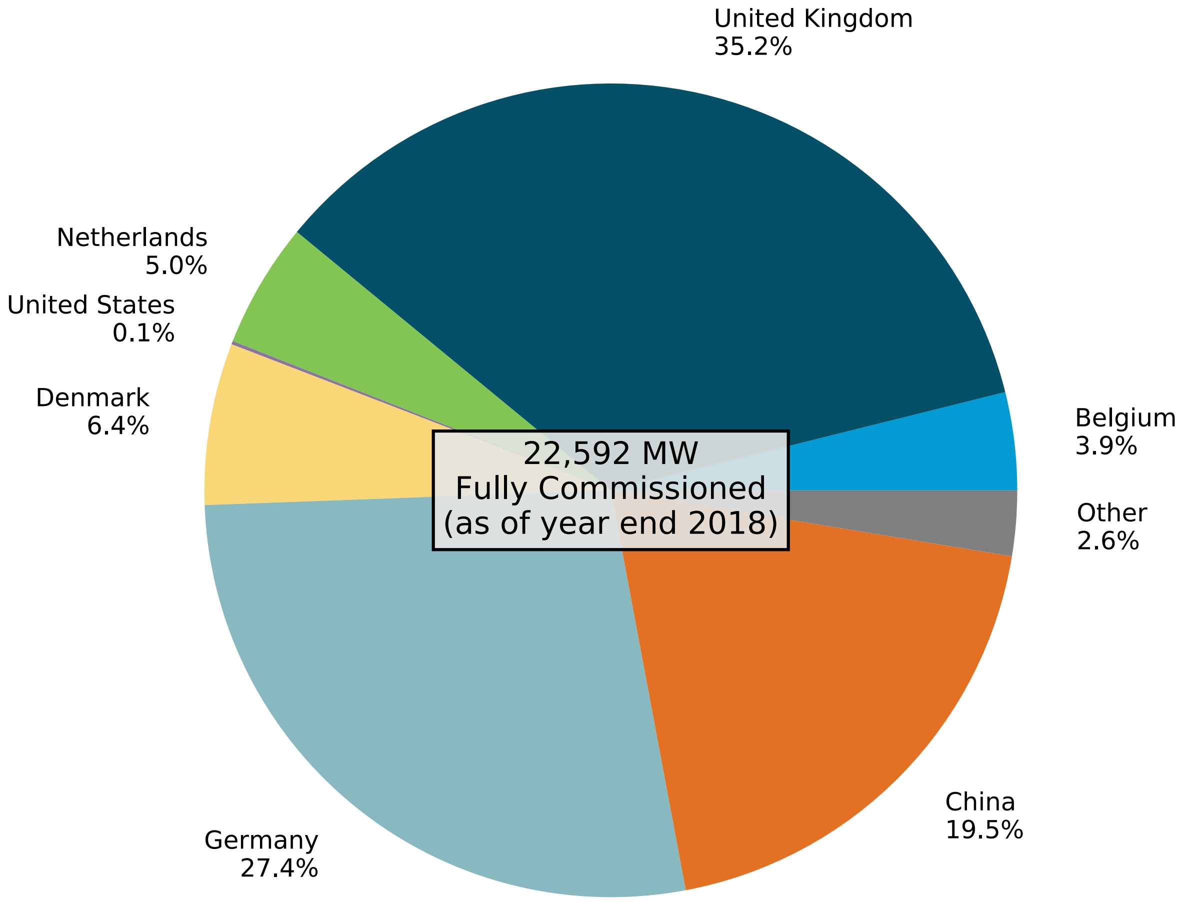
# A Record 5,652 MW of Offshore Wind Capacity Was Installed Globally in 2018

- In 2018, 5,652 MW of new offshore wind capacity was installed–a significant increase over the 3,500 MW installed in 2017.
- China installed 2,652 MW, the United Kingdom installed 2,120 MW, Germany installed 835 MW, Denmark installed 28 MW, and about 17 MW were divided between the rest of Europe and Vietnam.



# The Majority of Cumulative Capacity Is Still in Europe

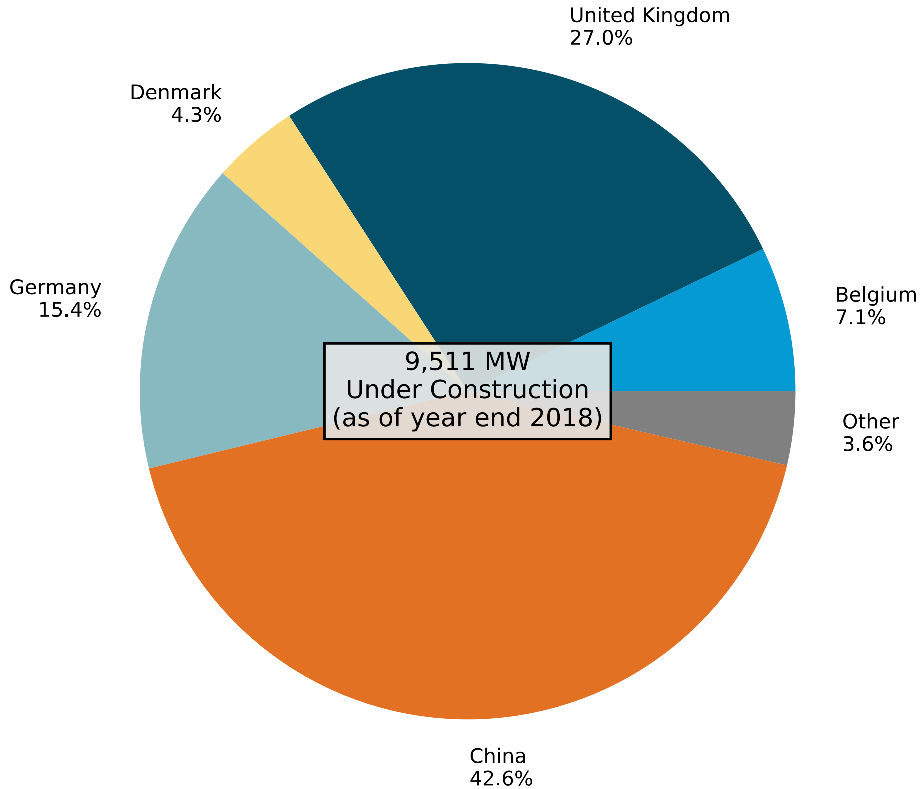
The United Kingdom continues to lead the world in total offshore wind deployment, with 35.2%, followed by Germany (27.4%), China (19.5%), Denmark (6.4%), the Netherlands (5%), and Belgium (3.9%).



# Over 9.5 GW of Offshore Wind Is Under Construction

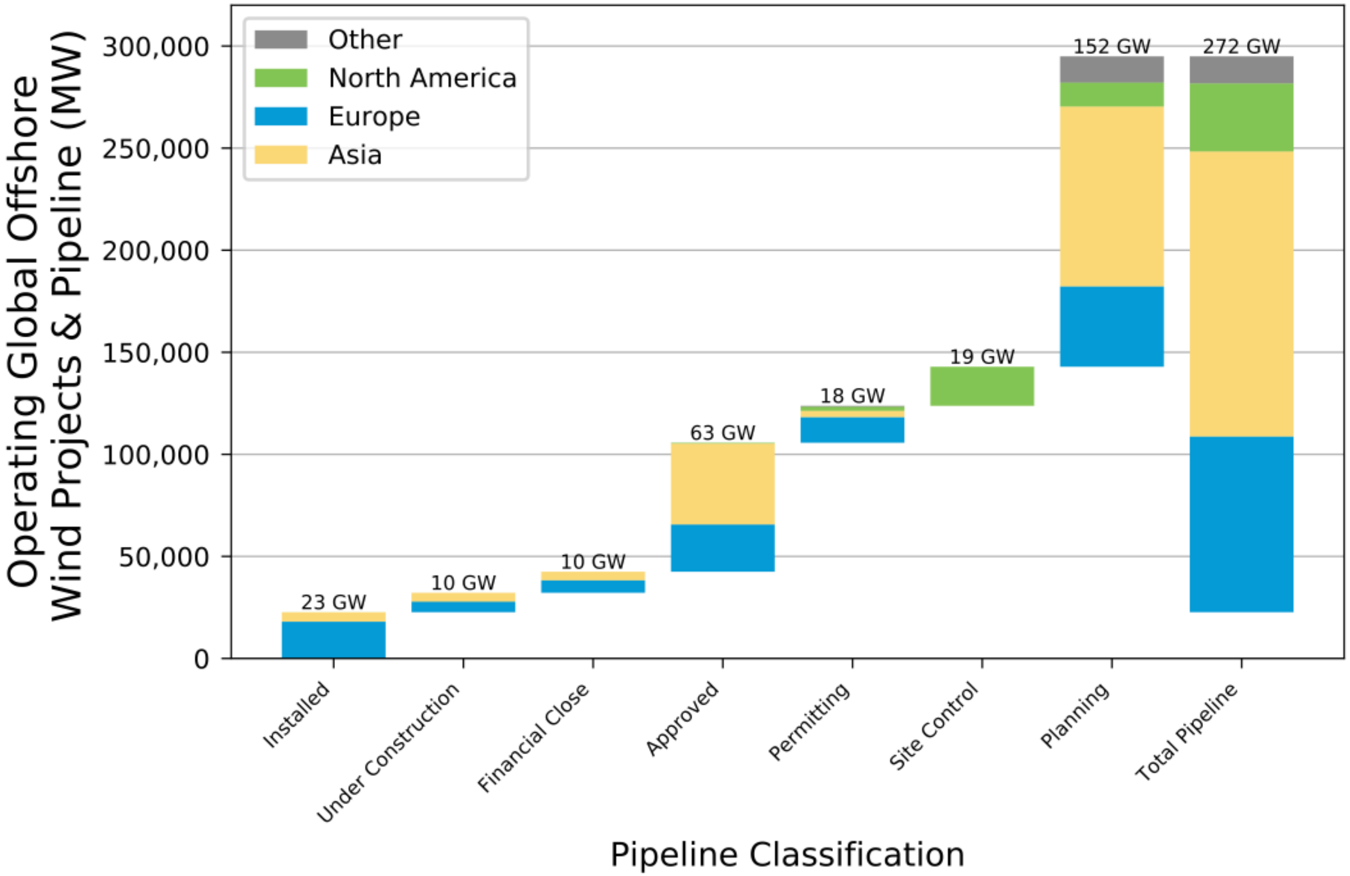
- By the end of 2018, there were 12 European projects under construction representing 5,115 MW of new capacity. Most of the construction in Europe is in the United Kingdom, with 2,520 MW, followed by Germany with1,460 MW, Belgium with 678.6 MW, and Denmark with 406 MW.

- In Asia, there were 17 projects under construction at the end of 2018, with a combined capacity of 3,469 MW; 12 projects in China, 3 in Vietnam, 1 in Japan, and 1 in South Korea.

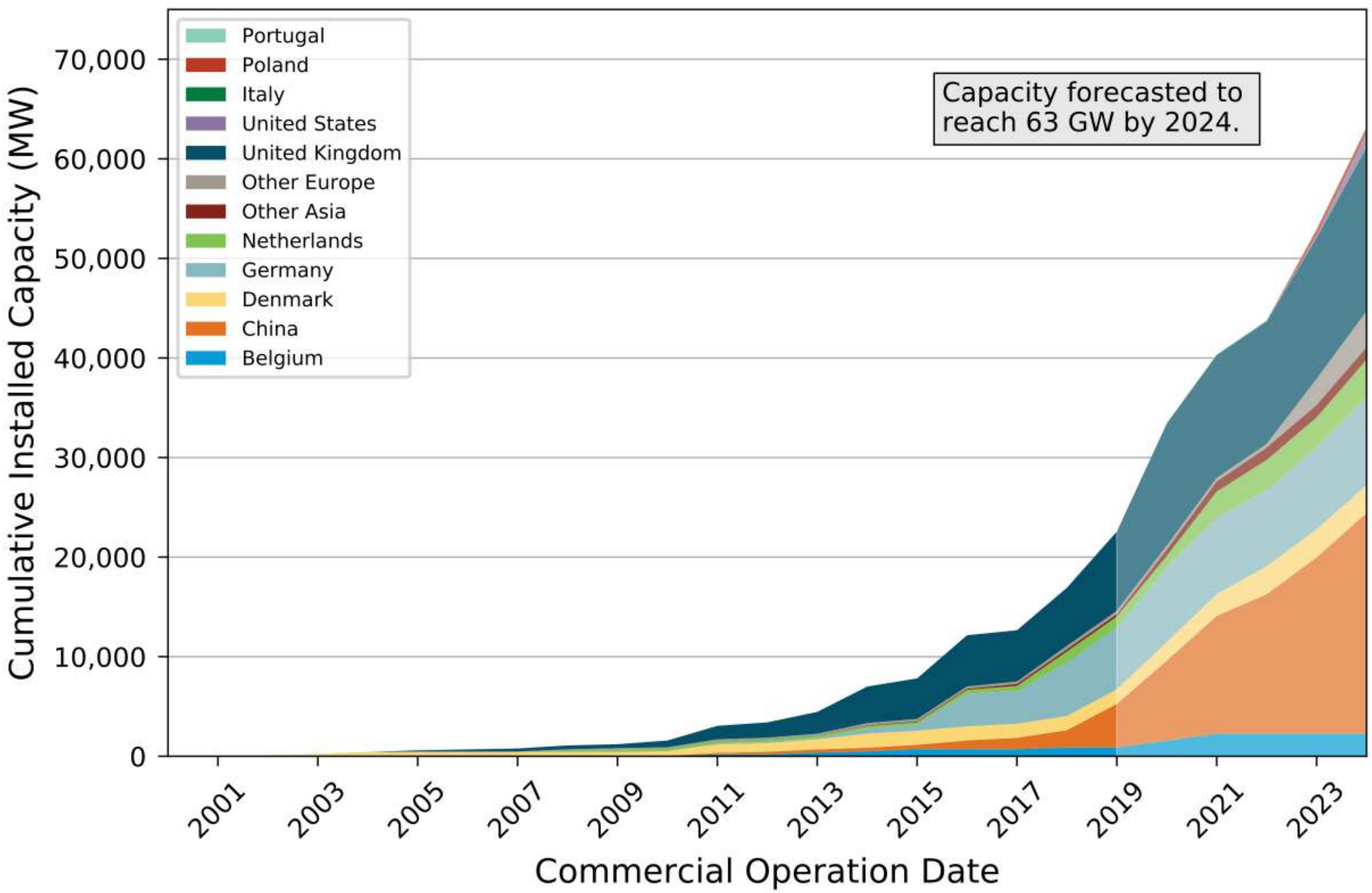


# Global Offshore Wind Project Pipeline Capacity at 272 GW

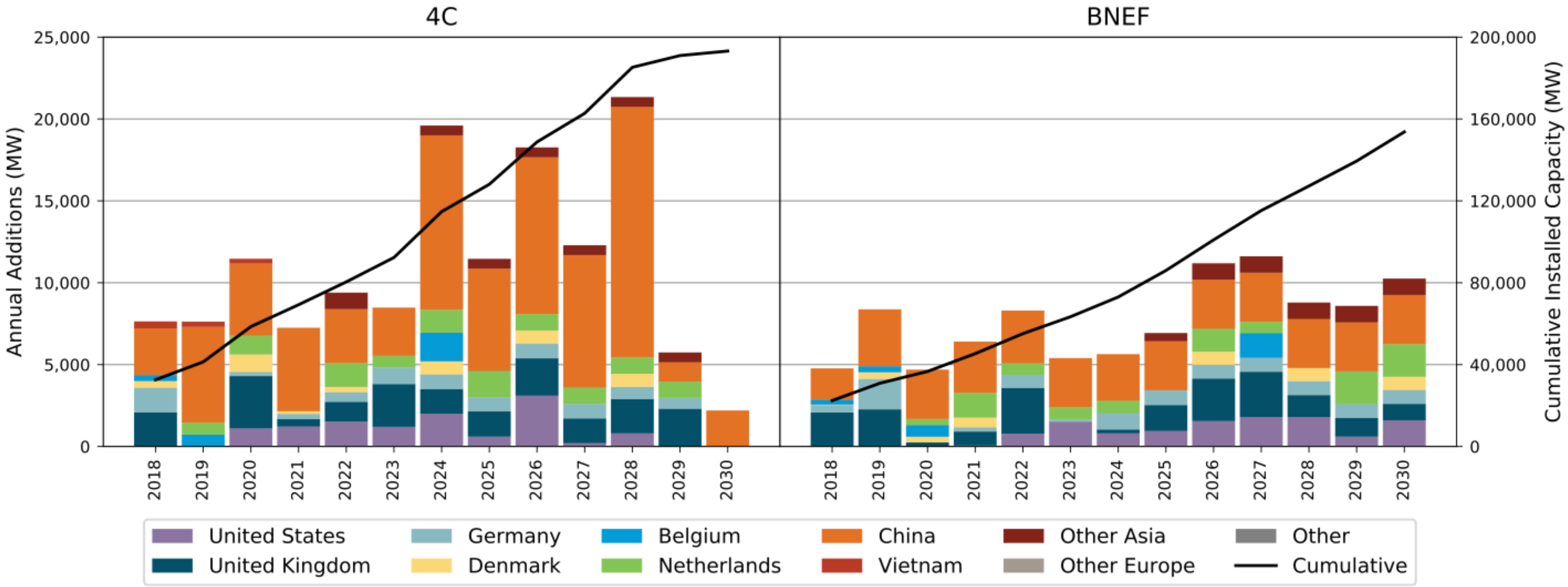
- The global pipeline capacity grew by 42 GW in 2018 to reach 272 GW.
- The increase in pipeline capacity is attributed to many new Asian projects that recently entered the planning phase.



# Global Cumulative Capacity To Reach 63 GW by 2024



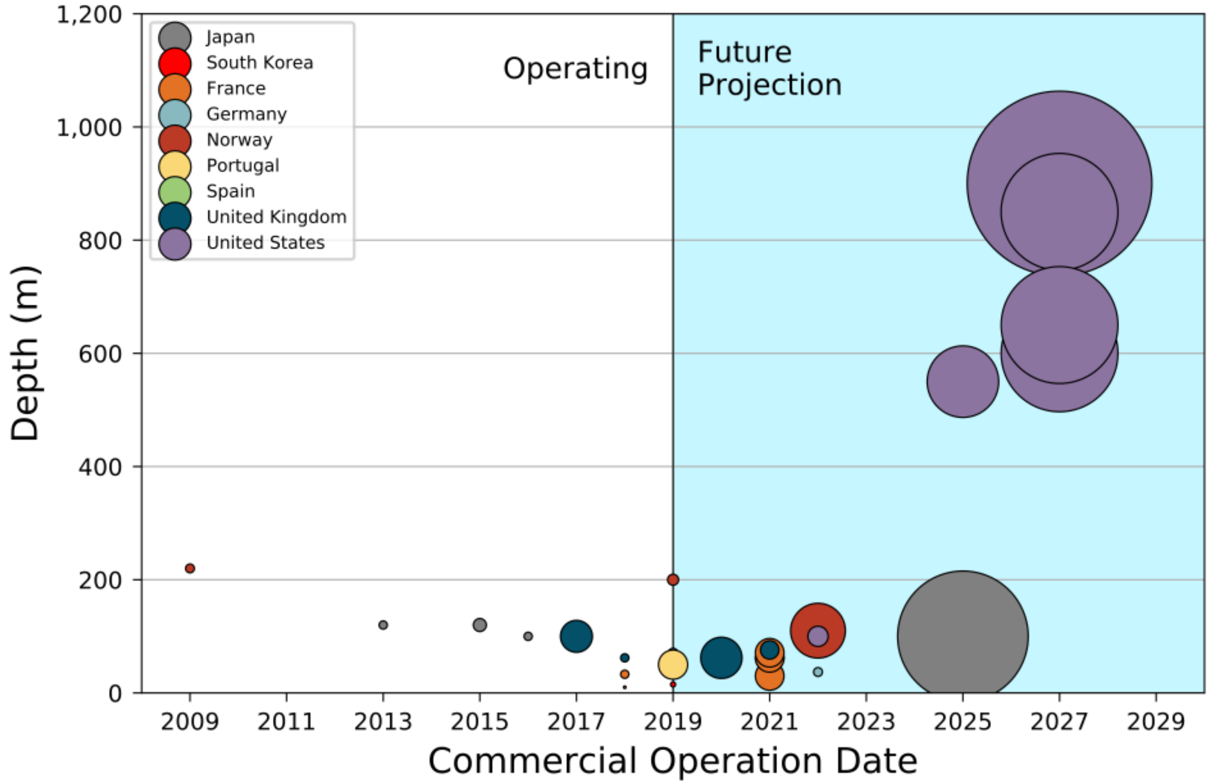
# Global Forecasts Predict 154 to 193 GW of Offshore Wind by 2030




- BNEF and 4C Offshore forecast China will deploy between 41 and 84 GW by 2030 which is likely to shift market dynamics.
- Forecasts predict European developers will build projects at a similar rate relative to today, with Europe holding about 47% of the total installed global offshore wind capacity in 2030.

# Floating Offshore Wind Projects Are Predicted To Increase in Size and Push to Deeper Water

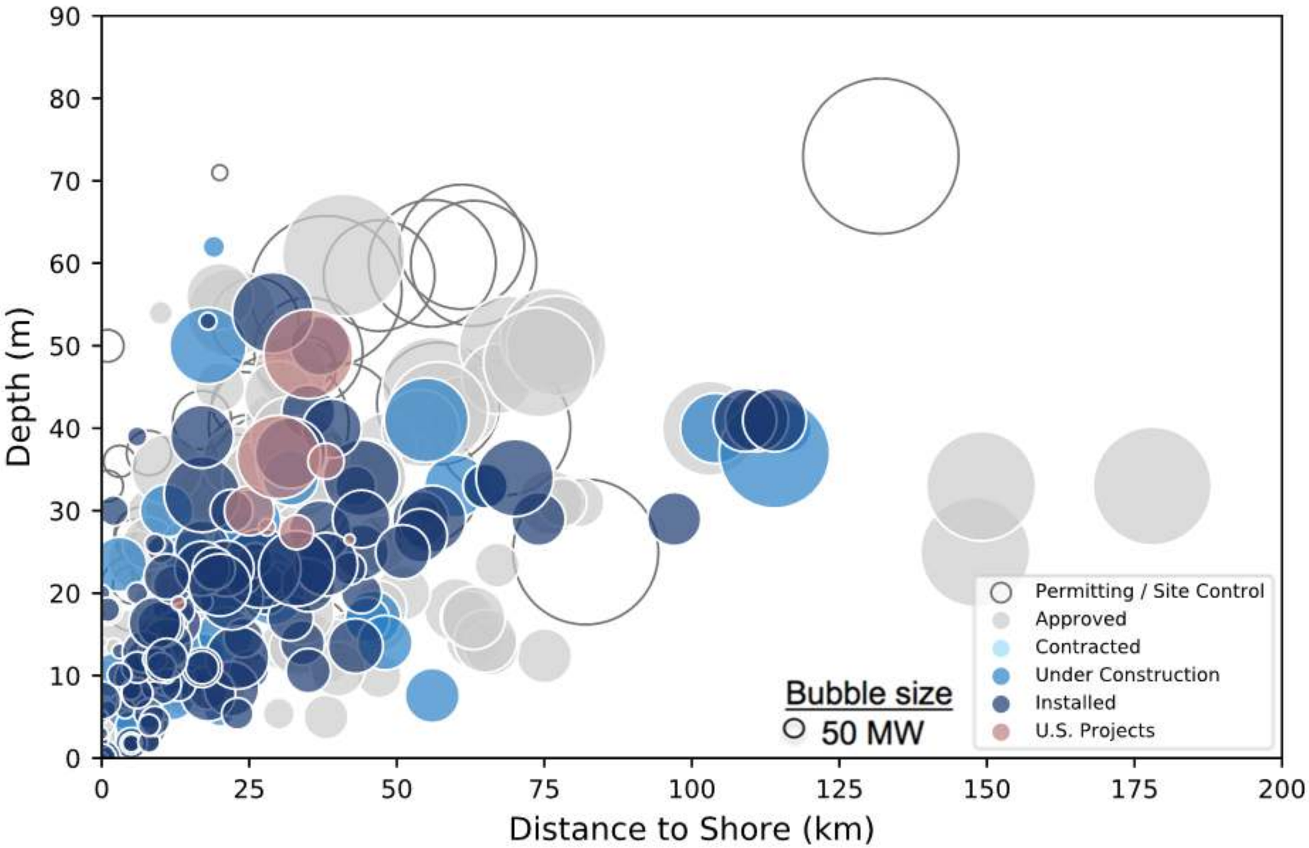
- The 2018 global floating offshore wind pipeline had approximately 4,888 MW of capacity, growing by 2,000 MW relative to the *2017 Offshore Wind Technologies Market Report Update*.
- There are eight floating wind projects installed globally with 46 MW of total capacity; five projects (37 MW) are in Europe and three (9 MW) are in Asia.
- There are 14 floating projects totaling about 200 MW that are under construction or have achieved either financial close or regulatory approval.



# Offshore Wind Technology Trends

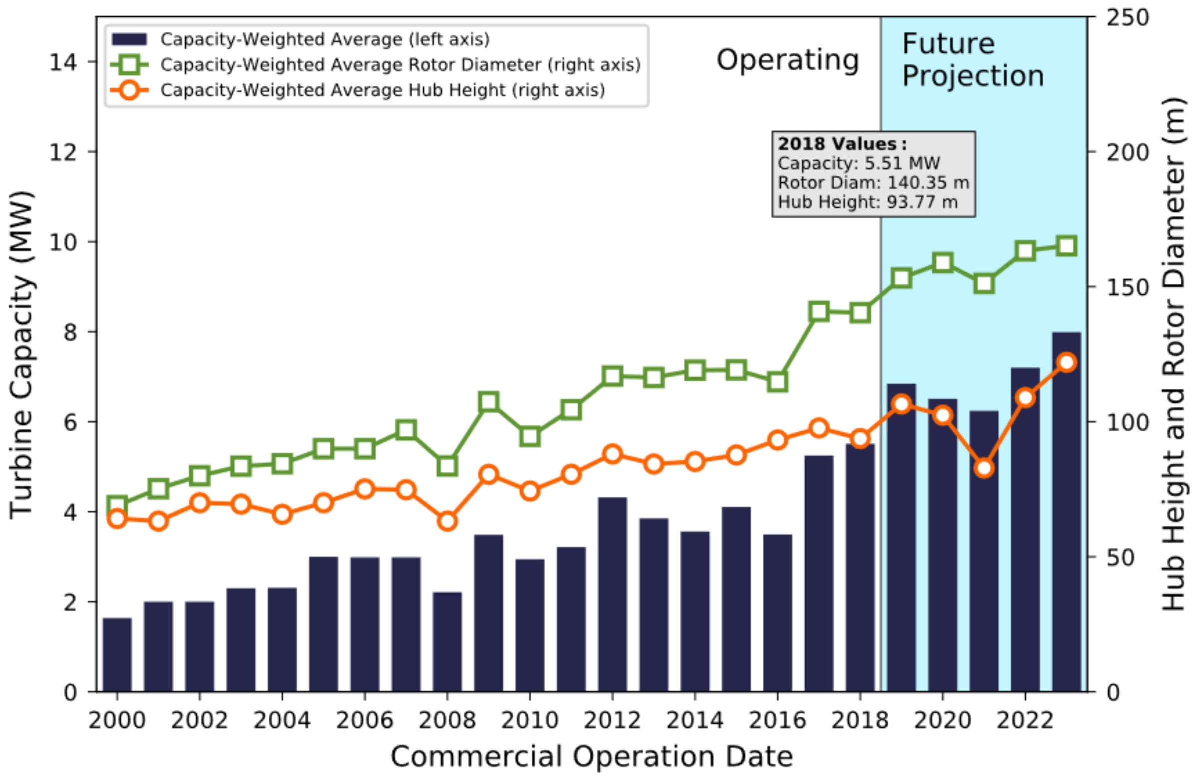
# Fixed–Bottom Projects Continue to be Larger in Size, Farther from Shore, and in Deeper Water

- Fixed-bottom projects are being deployed in deeper waters farther from shore.
- Developers are building larger projects and taking advantage of economies of scale to reduce cost.
- U.S. projects are in a narrower band in their distance to shore, constrained by geography of lease areas.



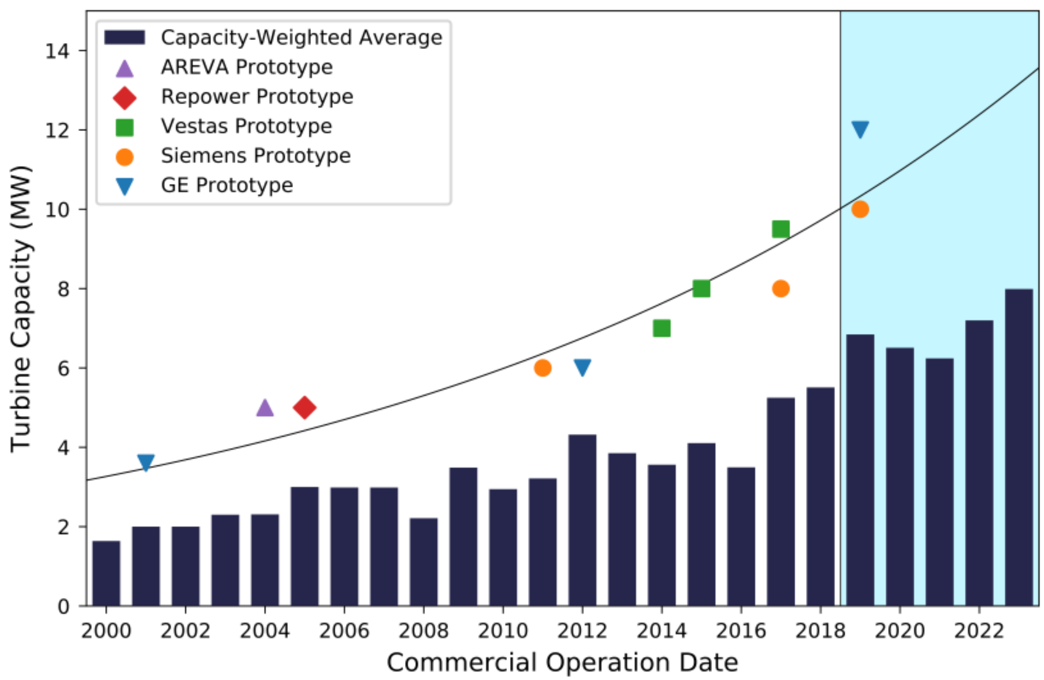
# Offshore Turbines Continue To Increase in Capacity, Height, and Rotor Diameter

- Increasing turbine size is a major factor attributed to cost declines. Larger-capacity turbines yield lower balance-of-plant costs, fewer installations, lower maintenance, and more energy.
- Developers will generally select the largest turbine available.
- At the end of 2018, the largest turbine installed was the MHI-Vestas V164 – 8.8-MW turbine at the Aberdeen Bay (European Offshore Wind Development Centre) project in Scotland.



# New Turbine Prototypes Foretell Continued Turbine Growth to 12 MW and Beyond

- In March 2018, GE announced the new 12-MW Haliade-X turbine prototype, now being installed in Rotterdam (2019), and planned to be on the market in 2021.The turbine is first in class, with a 12-MW direct-drive generator, 220-m rotor, and 140-m hub height.
- In January 2019, Siemens Gamesa announced the development of the SG10.0-193 DD turbine—a 10-MW direct-drive turbine with a 193-m rotor—which is planned to be ready for market in 2022.

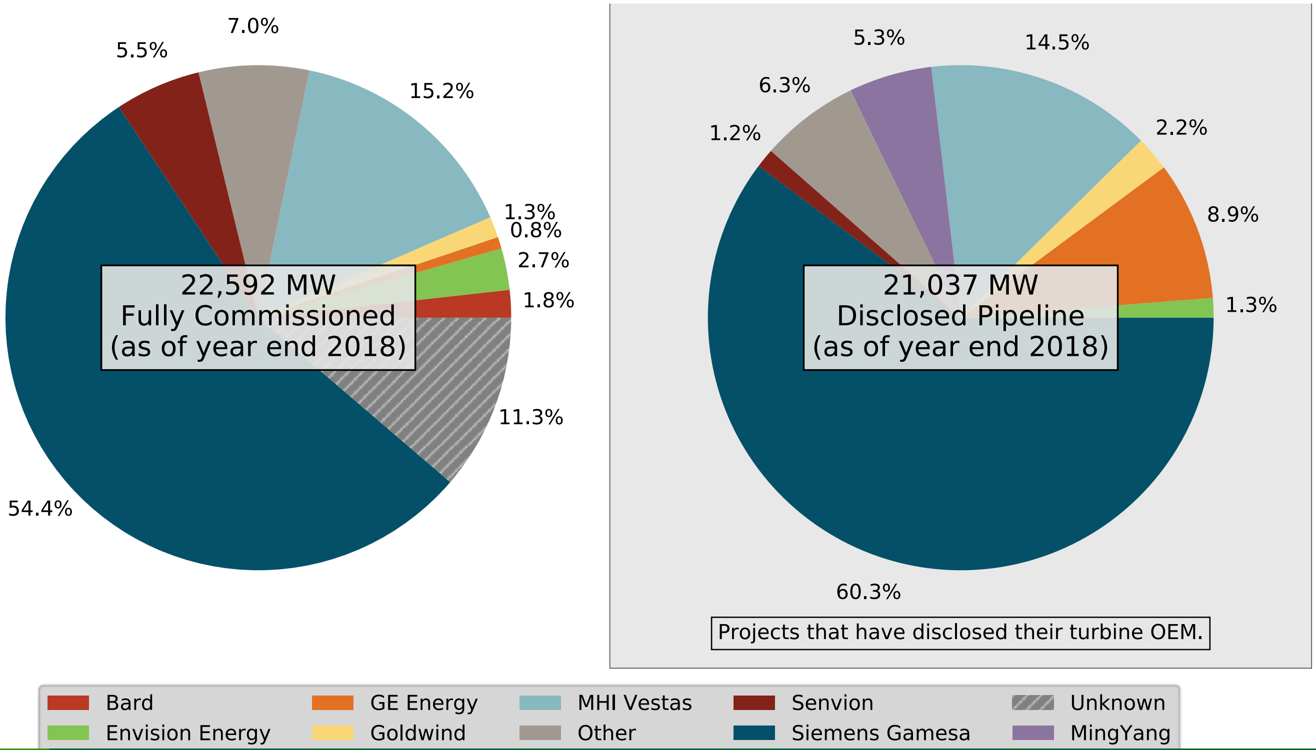



Sources: Ragheb (2019), GE (2018), de Vries (2012), Composites World (2014), Adwen GmbH (2019), Power Engineering (2005), 4C Offshore (2017), Siemens (2013, 2019), Dvorak (2017)

# Siemens Gamesa and MHI-Vestas Dominate Offshore Turbine Market

- Siemens Gamesa continues to be the largest global supplier of offshore wind turbines, with 55% of installed capacity (12.3 GW) operating.
- MHI-Vestas has just over a 15% share of installed offshore wind capacity.
- The Siemens Gamesa share of global capacity is projected to grow to 60.3% for new projects, whereas MHI-Vestas is expected to hold about 14.5%.
- GE's share is projected to grow to 8.9%.
- Goldwind and Ming Yang are building strength in the emerging Chinese market.

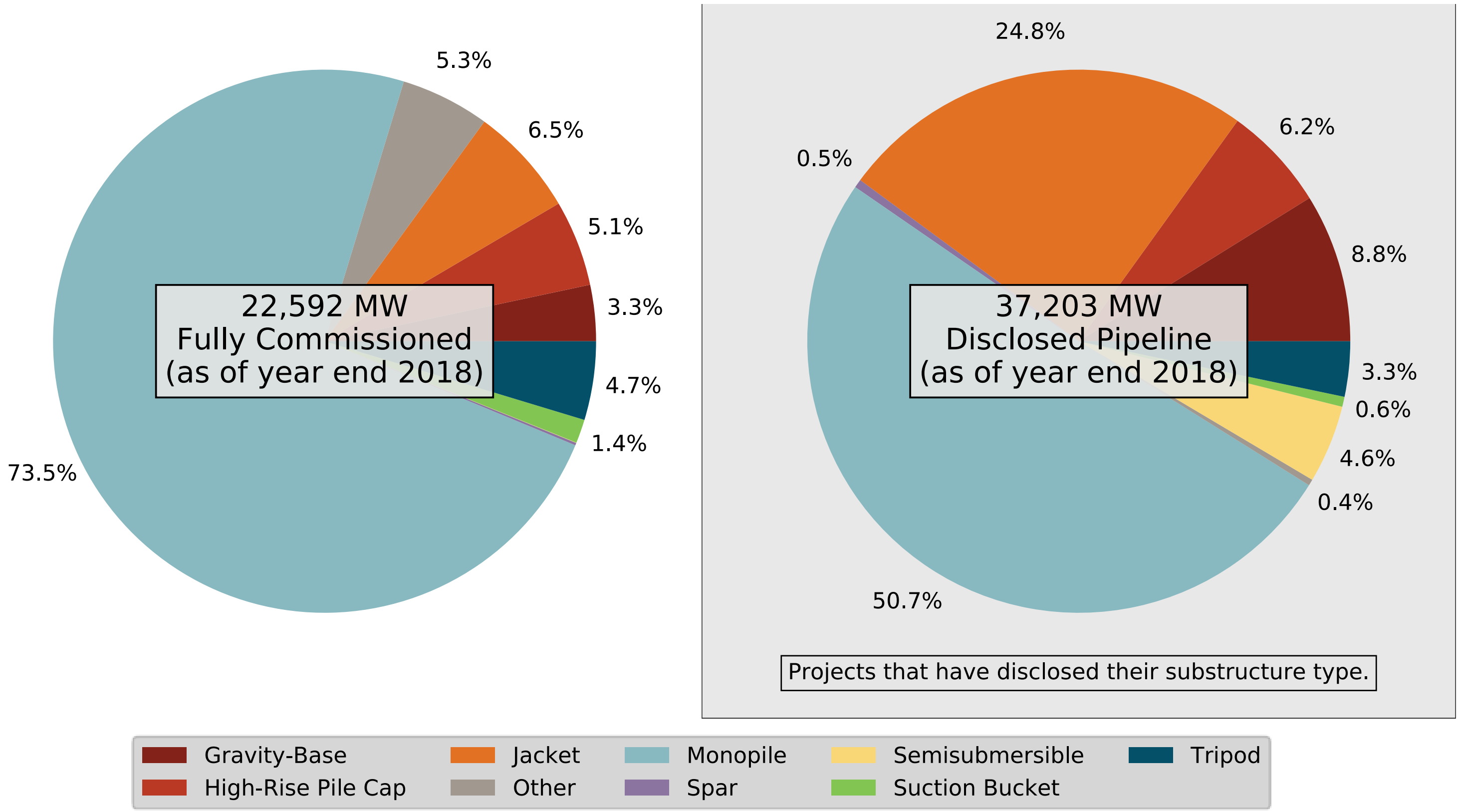
## Offshore Wind Turbines



# Monopiles Are the Preferred Foundation Type; More Substructure Diversity Is Predicted in the Future

- Monopiles represented over 70% of total installed offshore wind capacity globally at the end of 2018.
- Deeper water is pushing the industry toward more diverse foundation types including jackets, gravity bases, and suction buckets.
- For depths greater than 60 m, the industry is developing multiple types of floating substructures.

**Offshore Wind Substructures**



# Array Cable Supply Divided Between Three Major Companies

- Forty-two percent of new intra-array cables energized in 2018 were supplied by Nexans, whereas JDR Cable Systems supplied 32.1% and Prysmian supplied 16.1%.
- Continued development of several offshore projects in Southeast Asia has created new market opportunities for the undersea cable industry, which is expected to grow in the future.
- The offshore wind industry is adopting 66-kilovolt array cables to lower electrical infrastructure costs (3 projects in 2018).

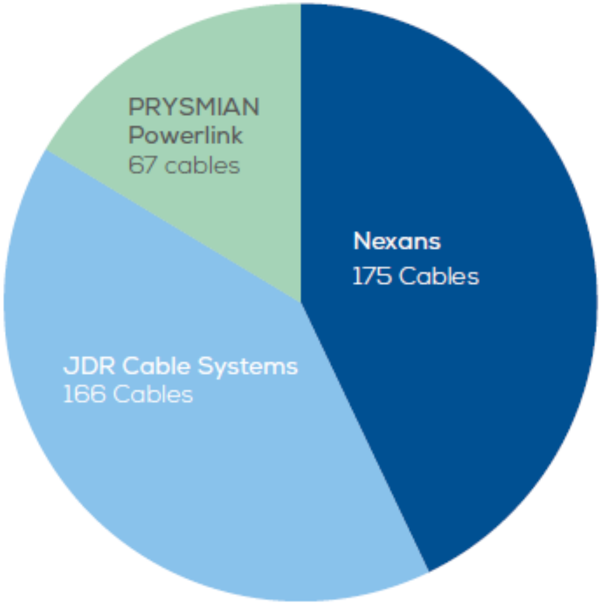



*Chart courtesy of WindEurope 2019*

# NKT Group Leads Export Cable Market in 2018

Eight export cables manufactured by NKT Group were energized in 2018, representing 53.3% of the annual market. Prysmian, Ls Cable & System, and JDR Cable Systems each had about a 13.3% share, and Nexans represented the remaining 6.7%.

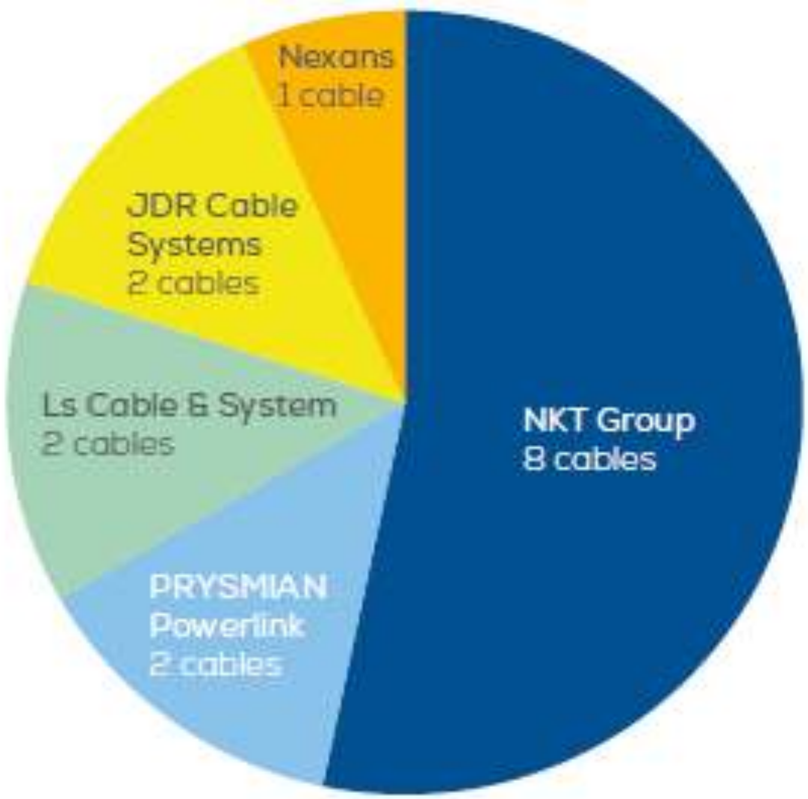
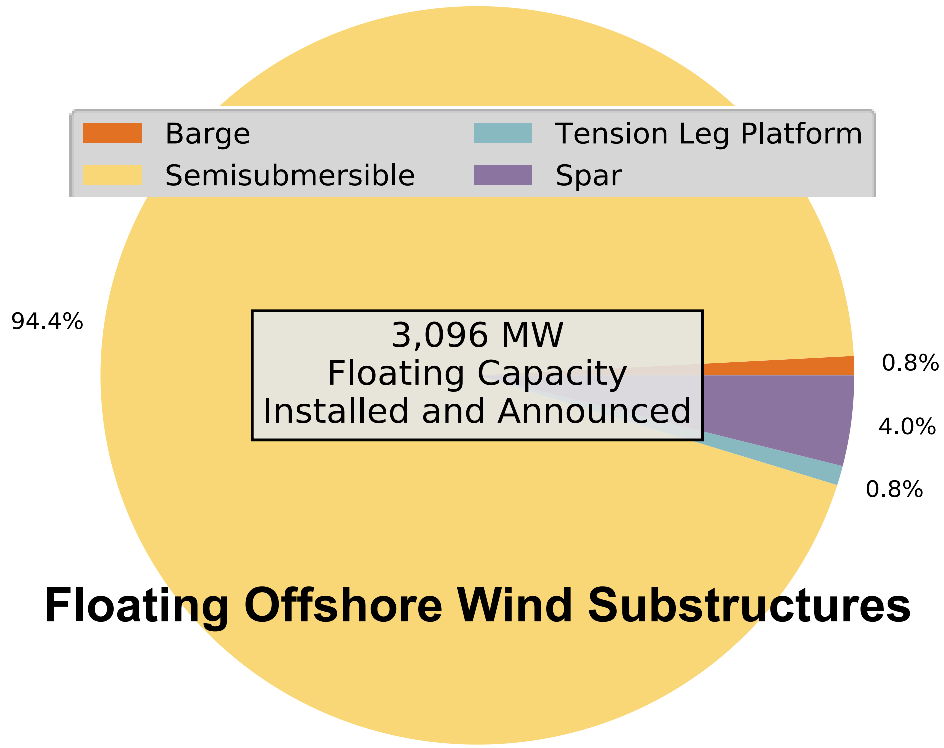



*Chart courtesy of WindEurope 2019*

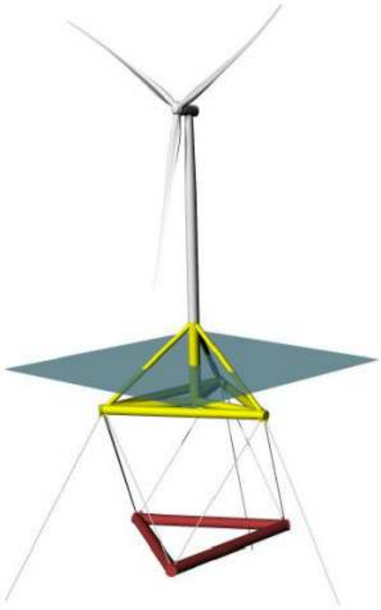
# Semisubmersibles Dominate in Nascent Floating Market

- In 2018, 94% of floating projects reporting plan to use semisubmersible substructures.
- Semisubmersibles allow full assembly and commissioning at quayside, as well as tow-out to an offshore station without the use of heavy-lift installation vessels.
- Approximately 4% use or plan to use spars (e.g., Equinor's 30-MW floating wind plant).
- The remaining substructures are tension leg platforms and barges.
- Hybrid substructures are beginning to emerge.



# Next-Generation Hybrid Floating Substructures May Compete with Semisubmersibles and Lower Costs

- Hybrid platform designs in the next generation of floating substructures have desirable characteristics of the semisubmersible but strive to be lighter
- In 2018, Stiesdal Offshore Technologies introduced the TetraSpar; a stable floating platform with low draft for inshore assembly and a deployable ballast weight.
- SBM has developed a lightweight tension leg platform that is stable during assembly and load-out.



**SOT TetraSpar**

**SBM Tension Leg Platform**

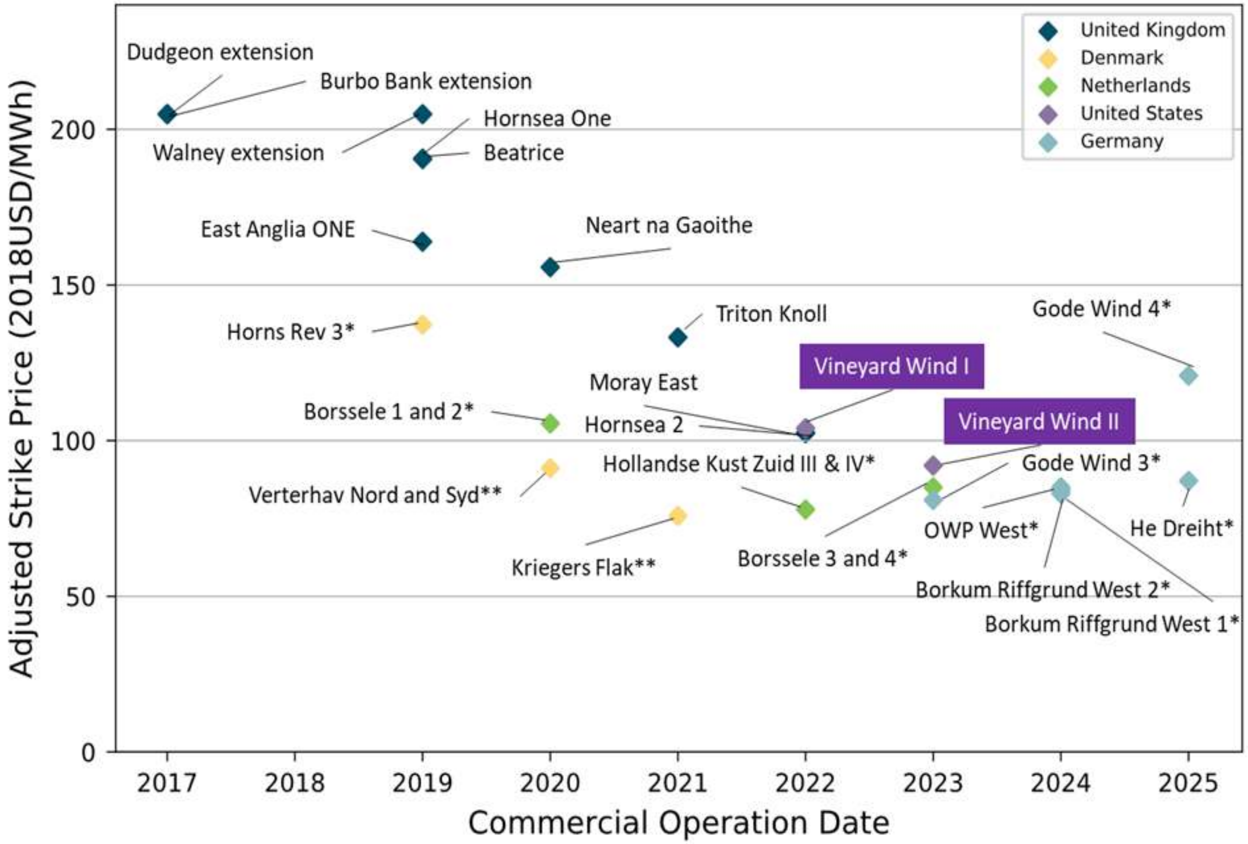
*Images courtesy of Stiesdal Offshore Technologies (left) and SBM Offshore (right)*

# Cost and Pricing Trends

# Vineyard Wind Power Purchase Agreement Terms Match European Fixed-Bottom Auction Prices

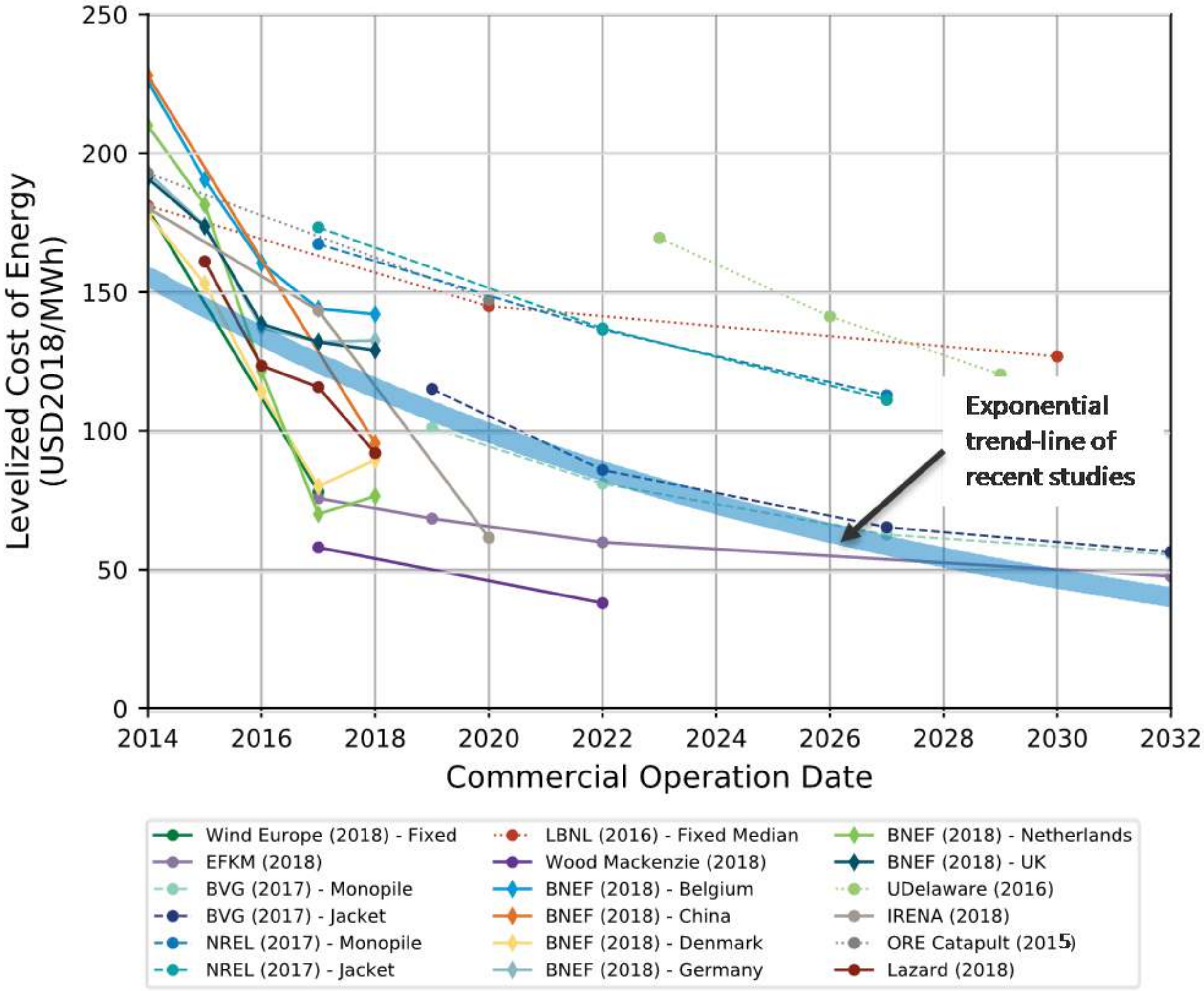
- European strike price data (adjusted for comparisons) show declining prices from about $200/MWh (2017–2019 commercial operation date [COD]) to about $75/MWh for projects with a 2024–2025 COD.

- Vineyard Wind (800 MW), likely the first commercial-scale U.S. offshore wind project (COD in 2022–2023), signed a 20-year PPA at a price that aligns with European projects for the same years.




Notes: *Grid and development costs added; **Grid costs added and contract length adjusted; includes data for commercial-scale projects only

# Fixed-Bottom Levelized Cost of Energy Forecasted To Decline to $50/MWh by 2030

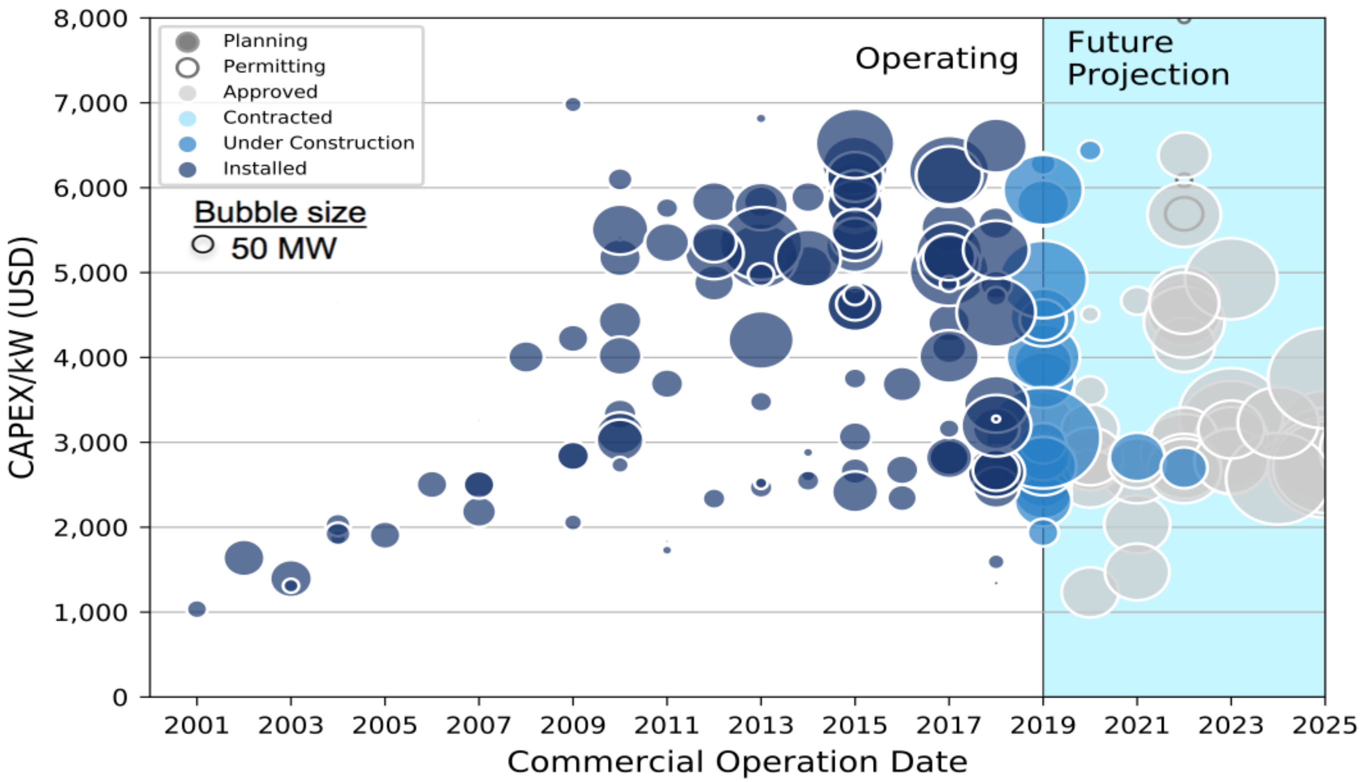



- Analysts agree the cost reduction trend for fixed-bottom projects will continue globally and in the United States.
- Levelized cost of energy projections from the most recent studies suggest a decrease from $120/MWh in 2018 to $50/MWh by 2030.

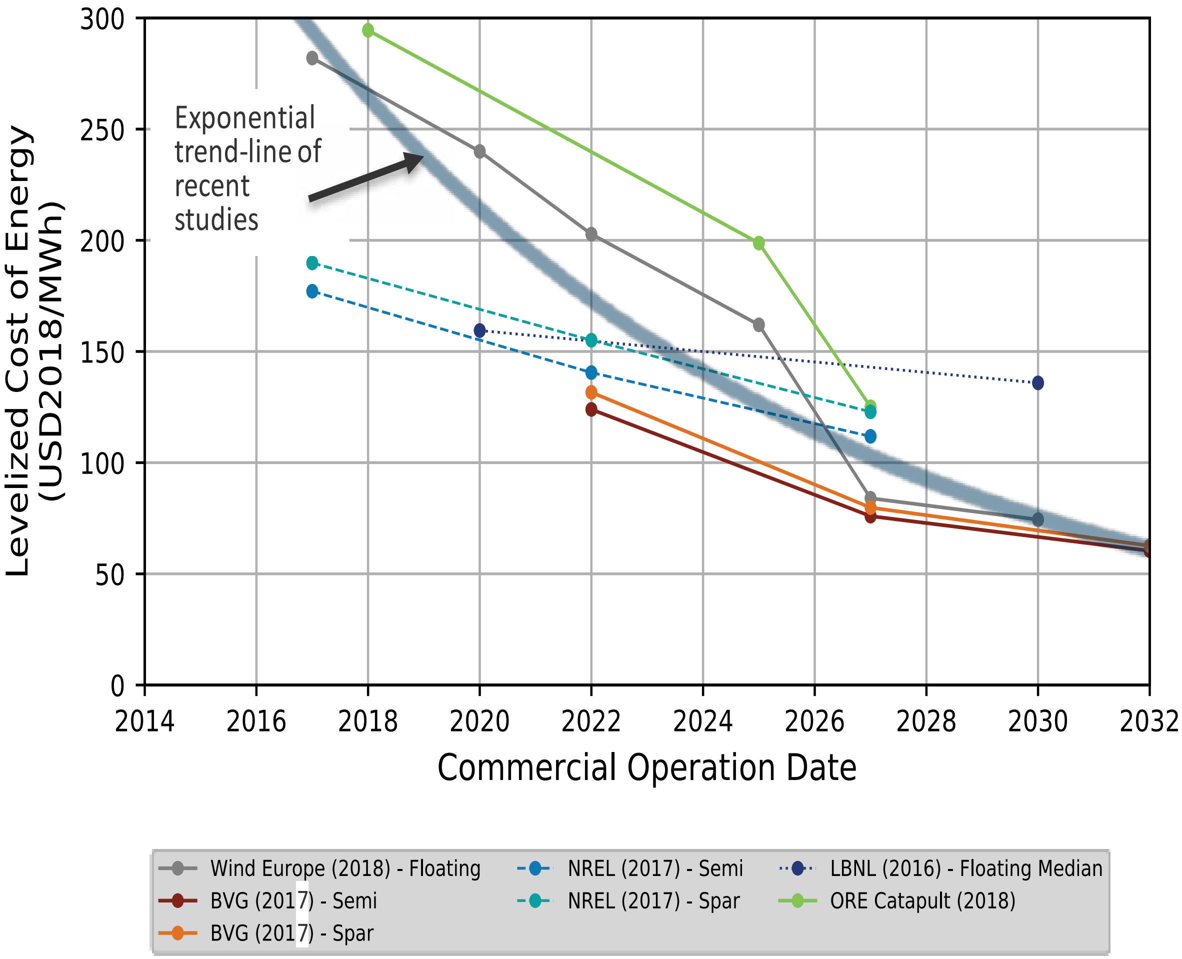
Sources: WindEurope (2018), Danish Ministry of Energy, Utilities and Climate (2018), Valpy et al. (2017), Beiter et al. (2017), Wiser et al. (2016), Barla (2018), BNEF (2018b, 2018c), Kempton et al. (2016), IRENA (2018), ORE Catapult (2015), and Lazard (2018)

# Offshore Wind Capital Costs Continue To Decline Globally

- In 2018, the capacity-weighted average capital expenditure (CapEx) was estimated at **$4,350/kilowatt (kW)** globally.
- For projects with a COD in 2018 and capacities greater than 100 MW, CapEx falls into a range from $2,470/kW (Jiangsu Luneng Dongtai project, China [200 MW]) to $6,500/kW (Galloper project, United Kingdom [353 MW]).
- Data indicate a decline of CapEx to a range of **$2,500–$4,000/kW** between 2020 and 2030.



# Levelized Cost of Energy for Floating Projects Projected to Decline to $75/MWh by 2030




- The most recent levelized cost of energy projections from industry analysts predict floating cost reductions to $75/MWh by 2030.
- Technological innovations and commercial progress benefits from fixed-bottom wind systems could help accelerate floating wind cost declines.

Sources: WindEurope (2018), Hundleby et al. (2017), Beiter et al. (2017), Wiser et al. (2016), ORE Catapult (2018)

# Key Findings

**United States**

- The U.S. offshore wind pipeline stands at 25,824 megawatts (MW) and includes:
  - 30 MW of installed capacity
  - 2,043 MW of capacity with site control and offtake pathways
  - 19,151 MW of potential capacity where developers have exclusive site control over a defined lease area
  - 2,250 MW of potential capacity in unleased wind energy areas (North Carolina)
  - 2,350 MW of potential capacity in unsolicited project applications (Pacific region).
- State-level policies continue to drive the U.S. market. By June 2019, the sum of official state offshore wind targets increased to 11,468 MW to be operating in 2030 and 19,968 MW to be operating by 2035.
- Increased U.S. market interest spurred increased competition at auctions for new lease areas. Three lease areas in Massachusetts were each sold for $135 million—more than tripling the previous highest winning bid.
- Several projects made progress in their permitting and offtake processes. Overall, **four** projects submitted construction and operations plans, **nine** projects received site assessment plan approvals, and **six** signed power offtake agreements.
- Offtake prices for the first commercial-scale offshore wind project (Vineyard Wind) were lower than expected. The project signed two 400-MW power purchase agreements for 20 years at **$74/megawatt-hour (MWh) and $65/MWh**, respectively.
- The Bureau of Ocean Energy Management (BOEM) is examining new Call Areas for offshore wind development. In 2018, the agency assessed commercial interest in multiple Call Areas in the New York Bight and along the central and northern California coast.

# Key Findings (continued)

## Global Offshore Wind Market

- The global offshore wind industry installed 5,652 MW of new capacity in 2018, bringing the cumulative global capacity to 22,592 MW.
- The pace of European offshore wind auctions slowed in the second half of 2018, but forecasts show sustained industry growth through 2030. In the future, annual capacity additions in Asia, especially China, are expected to outpace Europe.

## Offshore Wind Technology Trends

- The offshore wind industry is developing larger turbines (10 MW+) to increase energy output and accelerate cost declines.
- The offshore wind industry is adopting 66-kilovolt array cables to lower electrical infrastructure costs.
- The nascent floating wind energy project pipeline is growing, and floating pilot projects are advancing. The global pipeline for floating offshore wind energy reached 4,888 MW in 2018, with 32 announced projects and 46 MW of operating projects.

## Offshore Wind Pricing Trends

- New offshore wind strike prices from 2018 auctions validated cost reduction trends. Prices dropped from $200/MWh for projects coming online between 2017 and 2019 to roughly $75/MWh for projects in 2025.

## Future Outlook

- Offshore wind market projections show accelerated growth in the next decade, with global cumulative capacity ranging from 154 to 193 gigawatts (GW) by 2030, and long-range predictions of over 500 GW by 2050.
- Industry forecasts indicate U.S. offshore wind capacity will reach a range of 11–16 GW by 2030.

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