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OFFSHORE WIND MARKET REPORT
2024 EDITION

Offshore Wind Market Report: 2024 Edition

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Cover Photo by Joe DelNero: NREL 90979. Wind turbine construction in October 2023 at Vineyard Wind 1 off the coast of Massachusetts.

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The underlying data used for analysis in this report can be accessed at https://www.nrel.gov/docs/fy24osti/90525data.xlsx.

List of Acronyms

BNEF	Bloomberg New Energy Finance
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CAISO	California Independent System Operator
CapEx	capital expenditures
COD	commercial operation date
COP	Construction and Operations Plan
CTV	crew transfer vessel
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
GW	gigawatt
IRA	Inflation Reduction Act
IRS	Internal Revenue Service
ITC	investment tax credit
km	kilometer
kW	kilowatt
LCOE	levelized cost of energy
m	meter
MW	megawatt
MWh	megawatt-hour
NREL	National Renewable Energy Laboratory
NY PSC	New York Public Service Commission
NYISO	New York Independent System Operator
NYSERDA	New York State Energy Research and Development Authority
OCS	Outer Continental Shelf
OEM	original equipment manufacturer
OREC	Offshore Wind Renewable Energy Certificate
OWDB	offshore wind database
SGRE	Siemens Gamesa Renewable Energy
SOFR	Secured Overnight Financing Rate
SOV	service operation vessel
USD	U.S. dollars
WTIV	wind turbine installation vessel

Executive Summary

The *Offshore Wind Market Report: 2024 Edition* provides detailed information on the U.S. and global offshore wind energy industries to inform policymakers, researchers, and analysts about technology, economic, and market trends. The report provides the status of more than 322 operating offshore wind energy projects in the global fleet through Dec. 31, 2023, as well as the broader global pipeline of projects in various development stages. To provide current information and discussion on the emerging offshore wind industry in the United States, this report tracks significant U.S. domestic progress and events from Jan. 1, 2023, to May 31, 2024. Maps of the U.S. pipeline activity and Call Areas are shown in Figure ES-1.

U.S. Offshore Wind Energy Market

The first commercial-scale[1] offshore wind power plant in the United States, the 132-megawatt (MW) South Fork Wind Farm off Rhode Island, began delivering power to New York in November 2023 and was fully commissioned on March 14, 2024. Another commercial-scale offshore wind power plant, the 806-MW Vineyard Wind 1 project, also achieved first power in January 2024 with the installation of several operating turbines and remained under construction through the publication of this report (August 2024).[2] As of May 31, 2024, there were 174 MW of offshore wind power in operation.

The U.S. offshore wind energy pipeline had 4,097 MW under construction as of May 31, 2024. Three projects contribute to this total: Vineyard Wind 1 (806 MW), Revolution Wind (704 MW), and Coastal Virginia Offshore Wind (2,587 MW). This is an increase of more than 300% from the 938 MW under construction reported in the *Offshore Wind Market Report*: *2023 Edition* (Musial et al. 2023).

By May 31, 2024, the U.S. offshore wind energy project development and operational pipeline reached a potential generating capacity of 80,523 MW. The U.S. offshore wind energy pipeline grew 53% (27,836 MW) from the previous edition of this report. Notable additions include the following: Eight proposed lease areas in the Gulf of Maine provided 15,702 MW of pipeline growth, two proposed lease areas in the mid-Atlantic provided 4,499 MW, two proposed lease areas off the coast of Oregon provided 3,156 MW, and four proposed lease areas in the Gulf of Mexico added 6,638 MW. Finally, one research lease area in the Gulf of Maine contributed 144 MW in potential capacity to the U.S. offshore wind industry pipeline.[3]

[1] In this report, projects greater than 100 MW are considered commercial scale.
[2] Projects that have not placed all turbines in service are categorized as under construction for the purposes of this report.
[3] Note that the listed developments add up to more than the total pipeline growth because of recalculations of other project capacities in the pipeline from changes to or the loss of offtake agreements.

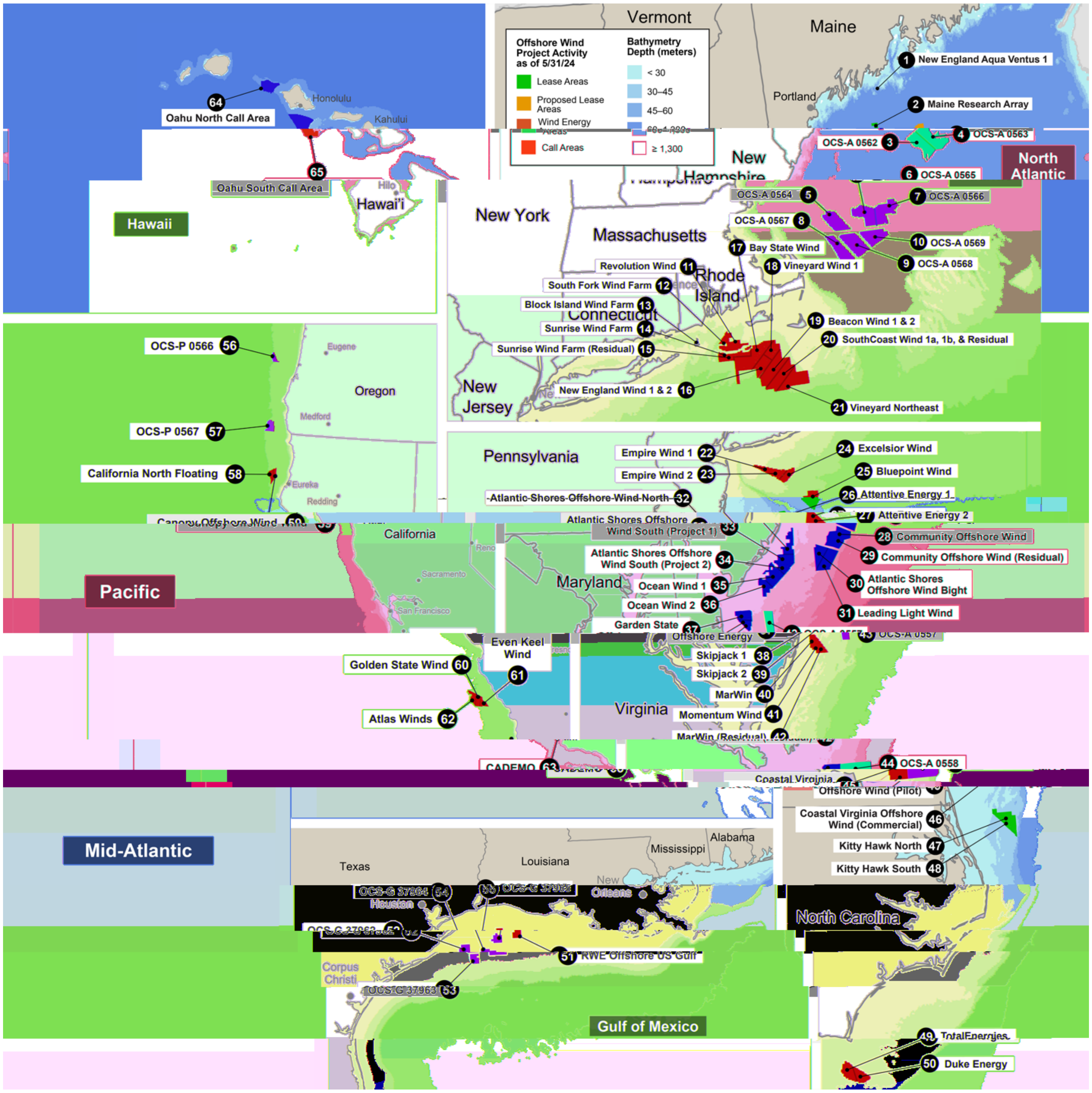

Figure ES-1. Locations of U.S. offshore wind energy pipeline activity and Call Areas as of May 31, 2024.

Maps created by John Frenzl, National Renewable Energy Laboratory

The U.S. floating offshore wind energy market has approximately 25,116 MW in the pipeline as of May 31, 2024, which includes lease areas and proposed lease areas on the west and east coasts. Of the 25,116 MW floating total, 6,042 MW of floating offshore wind potential are in the "site control" phase[4] following the December 2022 auction of five lease areas in California. The remaining 19,074 MW are in the planning phase, including the Gulf of Maine where a May 2024 proposed sale notice published by the Bureau of Ocean Energy Management (BOEM) identified eight floating offshore wind energy lease areas for an auction planned in

[4] See Section 1.2.2 for a discussion of site control.

October 2024. On April 24, 2024, U.S. Secretary of the Interior Deb Haaland announced the new BOEM leasing plan through 2028 (U.S. Department of the Interior 2024), with 7 of the 12 new proposed offshore wind energy auctions in deep water suited for floating offshore wind technology.

On March 22, 2024, the Internal Revenue Service issued guidance that updated the eligibility criteria for offshore wind projects seeking the Energy Communities Bonus Credit[5] passed under the Inflation Reduction Act. Offshore wind projects with multiple points of interconnection may benefit from bonus credits if they locate any power conditioning and transfer equipment at one of their points of interconnection within an energy community. Also, projects may now qualify for bonus credit benefits if their supervisory control and data acquisition system is situated at an "eligible project port" within an energy community.

The U.S. Department of Energy (DOE) estimates that $10 billion has been announced or invested in the U.S. offshore wind supply chain since the beginning of 2021. This $10 billion figure includes $2.1 billion in 2023 alone for port development, vessel orders, workforce development, research, and other supply chain investments in the U.S. offshore wind energy market (DOE 2024). The National Renewable Energy Laboratory estimates that an investment of at least $22 billion in ports, large installation vessels, and major manufacturing facilities will be needed to establish the U.S. offshore wind supply chain (Shields et al. 2023).

The Bureau of Ocean Energy Management advances leasing in 2024. BOEM held a competitive lease auction in August 2023 for the Gulf of Mexico and awarded one lease area. New lease activity has advanced in four regions where proposed sale notices have been issued, and lease areas are being prepared for auction in 2024. The proposed wind energy lease sales in 2024 are the Central Atlantic (Aug. 14, 2024), the coast of Oregon (October 2024), and the Gulf of Maine (October 2024) (BOEM 2024a).

Eight states have set procurement mandates that total 45,730 MW of offshore wind capacity by 2040. The U.S. offshore wind energy market continues to be driven by state-level offshore wind procurement, planning activities, and energy policies. As of May 31, 2024, state mandates totaled 45,730 MW from eight states. Five other states have set formal planning targets that, when combined with the state mandates, total 115,130 MW by 2050. While planning goals do not require agencies to take direct action for offshore wind, procurement mandates are statutory requirements for the state to achieve a predetermined quantity of offshore wind generation on a scheduled timeline.

As of May 31, 2024, 15 contracts to purchase 12,378 MW of electricity from offshore wind power plants have been signed. Multiple state procurements were open as of May 31, 2024. This total does not include projects for which offtake agreements have been canceled.

In 2023, increased costs driven by macroeconomic pressures, market volatility, and limited hedging made many projects with existing fixed-price power offtake contracts financially

[5] Energy communities are located at sites that are historically affected by industrial pollution, communities affected by closed coal mines or coal-fired power plants, or communities that had a dependence on fossil fuel industries (through jobs or tax revenues) that are now facing higher than average unemployment. For more information, refer to https://energycommunities.gov/energy-community-tax-credit-bonus/.

nonviable. Eight projects canceled their offtake contracts: SouthCoast Wind 1, New England Wind 1 and 2, Empire Wind 2, Beacon Wind 1, Ocean Wind 1 and 2, and Skipjack Wind. Challenges such as cost increases driven by inflation and rising interest rates impacted developers with signed offtake agreements who were attempting to bring projects online before 2030. Figure ES-2 summarizes state planning goals, procurement mandates, and offtake contracts awarded in the U.S. offshore wind energy market.

States have quickly responded to economic headwinds and power contract cancellations. Most states have reaffirmed their original offshore wind commitments and timelines. Multiple states have restructured their procurement strategies and opened new solicitation rounds to enable canceled projects to re-bid with updated offtake prices, such as by introducing inflation indexing. Most projects with canceled offtake agreements are still in active development and are seeking new offtake opportunities.

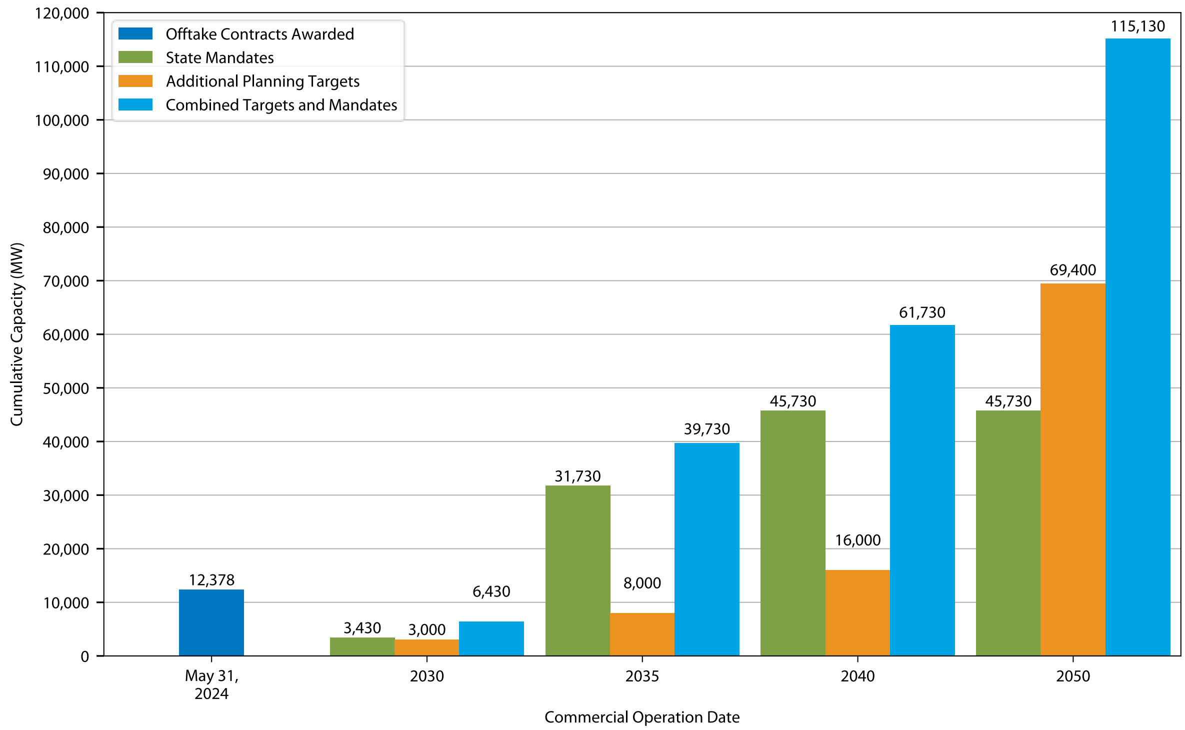

Figure ES-2. Cumulative capacity of U.S. offshore wind energy state planning goals, procurement mandates, and offtake agreements awarded

Global Offshore Wind Energy Market

In 2023, 6,326 MW of offshore wind energy were deployed globally, bringing total installed capacity to 68,258 MW as of Dec. 31, 2023. More than 13,096 operating offshore wind turbines in 319 operating projects contributed to this total installed capacity. The capacity installed in 2023 represents the fourth largest capacity installed in a single year.

The global generating capacity potential in the pipeline for all offshore wind energy projects reached 453.6 gigawatts (GW) by the end of 2023 for both installed and planned projects. European projects dominate the future project pipeline. Most projects in advanced development stages are in Europe and China, but a significant portion of projects in the development pipeline are also moving forward in the United States and Oceania.

The global pipeline for floating offshore wind energy increased 1.8% to 104,399 MW. This increase is one of the lowest percentage changes observed since the annual report started tracking global pipeline growth in floating offshore wind. Since the publication of the *Offshore Wind Market Report: 2023 Edition* (Musial et al. 2023), 10% of the capacity was delayed and recharacterized in the planning stage. The growth is attributed in part to the Gulf of Maine lease area announcements.

New capacity for global floating offshore wind energy projects nearly doubled in 2023, bringing the total global capacity to 231.4 MW. The 88-MW Hywind Tampen floating offshore wind plant in Norway was fully commissioned in 2023 and is the largest operational floating offshore wind plant in the world (Equinor 2023). Other floating offshore wind energy projects came online near Marseille, France (25 MW) (SBM Offshore 2023); Bilbao, Spain (2 MW) (RWE 2023); Longyuan Nanri Island, China (3.6 MW) (Shanghai Electric 2023; M. Lewis 2023); and on the Wenchang oilfield off the coast of China (7.25 MW) (Buljan 2023a; China National Offshore Oil Corporation 2023).

Offshore Wind Energy Technology Trends

Larger offshore wind turbines are advancing toward commercial production. Offshore wind turbines have grown substantially over the past decade. The average installed turbine rating grew from 7.7 MW in 2022 to 9.7 MW in 2023 as developers began shifting to the new 15-MW turbine technology platform. Some original equipment manufacturers (OEMs), such as Vestas, and other industry experts have expressed a hesitation to continue increasing turbine size to allow supply chain and R&D investments to be paid off and to allow the benefits of industrialization, standardization, and industry learning to lower costs. This hesitation became apparent when General Electric dropped plans for an 18-MW turbine and announced a shift to its new 15.5-MW turbine. Vestas secured the first orders of its 15-MW turbine model and plans to make the first deliveries in 2025 (Vestas 2024) but has been steadfast in its position to remain at this scale. Siemens Gamesa has secured grants to develop and deploy what was announced as the "world's most powerful" offshore wind prototype and plans to start operations in early 2025 (European Commission 2023). Chinese OEMs have also announced plans to develop 18-MW to 22-MW turbines.

Offshore Wind Energy Cost and Price Trends

Rising interest rates, supply chain constraints, and higher commodity prices during 2021–2023 have led to higher offshore wind energy costs globally and in the United States. Rising costs affect projects planned for commercial operation between 2023 and 2026 the most because of a lag of at least 1–3 years between the placement of supply chain orders and the start of commercial operations. Projects planned for later commercial operation might be less affected because of the actions taken at the state and federal levels and may have time to wait for macroeconomic conditions to return to prior levels.

Reporting by a set of consultancies and research entities[6] suggests an unsubsidized levelized cost of energy for a hypothetical, commercial-scale offshore wind project in the United States of $125 per megawatt-hour (MWh) in 2023 (on average and using mid-case estimates).[7] The same sources report a wide range of $75/MWh to $149/MWh across scenarios (due to, for example, favorable siting conditions, closer proximity to port and grid infrastructure, varying financing assumptions, and other factors). These costs represent an average increase of more than 45% when compared to the 2023 edition of this report (Musial et al. 2023).

Future Outlook

The U.S. offshore wind energy pipeline grew to almost 81 GW. Forecasts from 4C Offshore (2024) and Bloomberg New Energy Finance (BNEF) (2023) estimate that U.S. offshore wind energy deployment could reach 40 GW and 42 GW, respectively, by the end of 2035.

Forecasted global projections for offshore wind energy indicate strong market growth with more than a fivefold increase in offshore wind energy projected over the next decade. Forecasts from BNEF (2023) indicate that global offshore wind energy will reach 492 GW by 2035, and 4C Offshore (2024) forecasts 422 GW by 2035. The most prominent trend in the 2035 forecast is the estimated growth of China's market (from 52.2 GW to 188.9 GW by 2035). U.S. installed capacity is forecast to be 9% (4C Offshore 2024; BNEF 2023) of the global total by 2035.

In the United States, key offshore wind energy market indicators, such as permitting, interconnection, commercial leasing, state energy planning targets, procurement policies, offtake agreements, and federal support for U.S. jobs and supply chain development, point toward sustained, long-term market growth when viewed together. But the macroeconomic hurdles facing the first generation of commercial offshore wind energy projects continue to linger, and ongoing challenges with the deployment of those first projects make the prospects for long-term growth of offshore wind in the United States more uncertain.

[6] The consultancies and research entities referenced include those cited with Figure 28 in Section 5.2.1: Bloomberg New Energy Finance (2024b), the U.S. Energy Information Administration (2023), DNV (2023), the International Energy Agency (2023), Lazard (Bilicic and Scroggins 2023), and the National Renewable Energy Laboratory (2024).
[7] Mid-case estimates refer to a baseline, business-as-usual or "most likely" scenario.

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1 Introduction

Offshore wind is a growing sector of the wind energy market that enables large-scale utility generation near populated areas where there is insufficient area on land for wind farms. Locating offshore wind farms several miles from shore can reduce conflicts with nearshore wildlife, such as birds and bats, and human use activities while accessing significantly more energy than land-based renewable sources. In addition to offshore wind's clean energy contributions, the infrastructure upgrades needed to deploy offshore wind energy are revitalizing marine waterfronts in the United States, creating thousands of good-paying jobs in coastal regions around the country (American Clean Power 2023a). In addition to the 42 megawatts (MW) generated by the two flagship offshore wind projects at Block Island (30 MW) and Coastal Virginia (12 MW), two commercial offshore wind energy projects began construction in 2023: the 806-MW Vineyard Wind 1 project south of Massachusetts and the 132-MW South Fork Wind project off Rhode Island. South Fork began delivering power to eastern Long Island, New York, in November 2023 and was fully commissioned in March 2024. Vineyard Wind 1 delivered power for the first time (termed "first power") in January 2024 with several operating turbines and remained under construction through the publication of this report (August 2024).

Since May 31, 2023, the cutoff date for the *Offshore Wind Market Report: 2023 Edition* (Musial et al. 2023), offshore wind has experienced significant market restructuring at a state level, driven by rising costs from inflation, higher interest rates, and supply chain bottlenecks. Macroeconomic impacts have been felt by the industry globally. More positively, new lease activity by the Bureau of Ocean Energy Management (BOEM) has advanced in three regions where proposed sale notices have been issued, and lease areas are being prepared for auction in 2024. Market restructuring, manifested in multiple project cancellations, redesign of state auctions, rebidding of projects, and higher offtake prices—combined with new leasing—has resulted in substantial changes to the offshore wind pipeline and to key market indicators in this report.

At a state level, the 2023 market disruptions tested policy commitments and state resolve. Although changes to the states' approaches to offshore wind energy procurement are still underway, states have not terminated their original offshore wind procurement targets, commitments, and timelines. The near-term market turmoil and project cancellations did not reduce the pipeline size, but project delays will likely result. However, in the long term, the restructuring could increase market stability and economic viability.

At the federal level, the Inflation Reduction Act (IRA)—passed in 2022 at the height of inflation—provides an important means of softening the macroeconomic impacts affecting offshore wind project costs. The IRA extends and expands the tax credits available to offshore wind energy. In particular, offshore wind projects are eligible for a 30% investment tax credit or an inflation-adjusted production tax credit at $27.50 per megawatt-hour (MWh) (in 2023) if they meet prevailing wage and apprenticeship requirements. The IRA also established bonus credits of 10% each for meeting domestic content requirements or building key project facilities in energy communities that have had recent coal closures, that have brownfields, or that have a high local economic dependence on fossil fuel jobs and high unemployment. The IRA is intended to offset the hurdles that threaten to prevent this nascent industry from achieving commercial success. In addition to the economic benefits, the IRA also put U.S. territories under BOEM jurisdiction, allowing offshore wind to move forward in these regions.

The long-term market outlook is positive, contingent on sustained state and federal policies combined with strong federal regulatory support. Overall, the key market drivers are still in place despite the recent macroeconomic and supply chain disruptions. Although developers have reported that there will be delays in many offshore wind energy project schedules, projections of long-term U.S. deployment capacities appear to be consistent with past projections.

1.1 About This Report

This report includes detailed information on the domestic offshore wind energy industry, providing context to help industry stakeholders navigate technical and market barriers and opportunities. The reporting period for this report covers the U.S. offshore wind industry from June 1, 2023, to May 31, 2024 (unless otherwise noted) and the global offshore wind industry from Jan. 1, 2023, through Dec. 31, 2023 (in the global section of this report, the U.S. offshore wind industry only goes through Dec. 31, 2023, as well). The report provides details and analysis on a broader global pipeline of projects at varying stages of development.

This report is also a companion to the *Land-Based Wind Market Report: 2024 Edition* (Wiser et al. 2024) and the *Distributed Wind Market Report: 2024 Edition* (Sheridan et al. 2024), which are also funded by the U.S. Department of Energy's Wind Energy Technologies Office and are authored by Lawrence Berkeley National Laboratory and Pacific Northwest National Laboratory, respectively. These companion reports review the status of utility-scale and distributed land-based wind energy in the United States, providing quantitative data and context for the wind energy industry and its stakeholders.

1.2 Approach and Method

1.2.1 National Renewable Energy Laboratory Offshore Database

The *Offshore Wind Market Report: 2024 Edition* uses the National Renewable Energy Laboratory's (NREL's) internal offshore wind database (OWDB), which contains information on more than 3,279 offshore wind energy projects located in 61 countries (NREL 2023). The database includes fully operational projects dating back to 1990, dormant projects, decommissioned and canceled projects, and anticipated future deployment that may or may not have announced commercial operation dates (CODs).

The database is built from internal NREL research using a wide variety of data sources, including press releases, industry news reports, manufacturer specification sheets, subscription-based industry databases, global offshore wind energy project announcements, and peer-reviewed literature. Unless stated otherwise, the data analysis in this report—both global and domestic—is derived by NREL from the OWDB and reflects the best judgment of the authors and industry subject matter experts that were consulted. To ensure accuracy, NREL verified the OWDB against the following sources:

- 4C Offshore Wind Database (4C Offshore 2024)
- BOEM online published data and direct consultations

- Bloomberg New Energy Finance's (BNEF's) Renewable Energy Project Database (BNEF 2023).

Although we validated and harmonized the data with these other sources, minor differences in their definitions and methodology[8] may cause the data in this report to vary from other published reports. Despite annual variability and potential future project-level uncertainty, trends reported elsewhere are consistent with long-term market trends in the OWDB.

Cost and pricing data gathered for the OWDB span many years and are reported in different currencies. To analyze and compare these data, we normalized all information in this report into 2023 U.S. dollars (USD) by:

- Converting costs and prices to USD, using the exchange rate for the year in which the latest data were reported (FiscalData n.d.)
- Inflating the values, which are in nominal USD after the exchange rate conversion, to 2023 USD using the U.S. Consumer Price Index (U.S. Bureau of Labor Statistics n.d.).

1.2.2 Classification of Project Status

The "pipeline" in this report is an offshore wind energy development and operating project tracking process that provides the status of a project from early-stage planning through decommissioning. We aligned the primary tracking method with the U.S. offshore wind regulatory process, but the methodology generally applies to tracking global projects as well. All offshore wind projects in federal waters must navigate the regulatory process that formally begins when state and federal officials initiate the leasing process to designate a wind energy area, which may lead to a lease being competitively awarded. This classification system is also used in nonfederal waters of the United States where the regulatory process is overseen by state governments (e.g., the Great Lakes).

The "pipeline" is defined as the set of all offshore wind energy areas and projects, including potential generating capacity of designated lease areas that are being prepared for auction, potential generating capacity of sites where developers hold offshore wind leases, nameplate capacity of projects under development, operational project capacity, and capacity of decommissioned projects. If known, we provide information on a project's power offtake agreements and financial contracts as well (Mulas Hernando et al. 2023).

Table 1 describes the classification criteria used in this report for tracking the development of offshore wind energy projects in the United States, but these criteria are also applied to the global project classification. However, some differences between the domestic and global regulatory processes may not allow for direct comparisons, especially during the earlier stages of planning, because some countries have other methods of establishing "site control." Generally, the site control step is applied to U.S. projects because they are clearly defined based on the BOEM auction process, but in other countries, site control is more ambiguous. Therefore, we assign global early-stage projects to "planning" unless more information is available.

[8] For details on year-over-year global pipeline accounting updates, see Appendix B.

Table 1. Offshore Wind Energy Project Pipeline Classification Criteria

Step	Phase Name	Start Criteria	End Criteria
1	Planning	Starts when a developer or regulatory agency initiates the formal site control process (e.g., designation of a lease area under a proposed sale notice)	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])
2	Site Control	Starts 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 [COP] or is selected for offtake agreement negotiations for electricity sales)
3	Permitting = COP or Offtake Pathway	Starts when the developer files major permit applications (e.g., a COP) or is selected for offtake agreement negotiations for electricity sales	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	Ends when the sponsor announces a "financial investment decision" and has signed contracts for construction work packages
5	Financial Close	Starts when the sponsor announces a financial investment decision and has signed contracts for major construction work packages	Ends when the project begins major construction work
6	Under Construction	Starts when major construction work is initiated	Ends when all wind turbines have been installed and the project is connected and generating power to an electrical grid
7	Operating	Starts when all wind turbines are installed and transmitting power to the grid; commercial operation date 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

1.3 Report Structure

The remainder of this report is structured as follows:

- Section 2 summarizes the status of the offshore wind energy industry in the United States, providing in-depth coverage of the project development pipeline, regulatory activity, offtake mechanisms, infrastructure and vessel trends, and regional developments.

- Section 3 provides an overview of the global offshore wind energy market. Operational and proposed future projects are tracked by country, status, COD, and capacity. Developments on international floating offshore wind energy projects are also covered in detail, and national targets are summarized by country and year.
- Section 4 describes offshore wind energy siting and technology trends focusing on wind turbine technologies, turbine manufacturers, fixed-bottom and floating substructures, and electrical power systems.
- Section 5 provides insight into global and domestic offshore wind capital and operating costs, procurement prices, and financing trends for both fixed-bottom and floating technologies.
- Section 6 provides a general outlook and insights for long-term offshore wind development and trends based on global forecasts.

2 U.S. Offshore Wind Market Assessment

2.1 Offshore Wind Industry Overview

In 2023, increased costs driven by macroeconomic pressures, market volatility, and shifting market conditions made many projects with existing fixed-price power offtake contracts financially nonviable. In total, eight projects canceled their offtake contracts and are searching for alternative pathways to secure offtake contracts (SouthCoast Wind 1, New England Wind 1 and 2, Empire Wind 2, Beacon Wind 1, Ocean Wind 1 and 2, and Skipjack Wind).

The *Offshore Wind Market Report: 2023 Edition* (Musial et al. 2023) updated capacity density assumptions to 4 megawatts per square kilometer (MW/km^2) for lease areas where project capacities have not been announced. As of May 31, 2024, the U.S. wind energy pipeline grew more than 53% (27,836 MW) to a total of 80,523 MW, from the 2023 edition of this report.

- The 27,836 MW of total pipeline growth came from the following developments[9]:
    - 15,702 MW came from the eight proposed lease areas in the Gulf of Maine.
    - 4,499 MW came from the two proposed lease areas in the Central Atlantic.[10]
    - 3,156 MW came from the two proposed lease areas off the coast of Oregon.
    - 6,638 MW came from the four proposed lease areas in the Gulf of Mexico.[11]
    - 144 MW came from one research lease area in the Gulf of Maine.
- Ongoing challenges that began in late 2022 continued to impact developers who had previously signed offtake agreements and were attempting to bring projects online before 2030. Developers reported significant cost increases driven by inflation and rising interest rates that potentially rendered their projects financially nonviable (Lloyd-Williams 2023; American Clean Power 2023b).[12]
- In April 2024 the New York State Energy Research and Development Authority (NYSERDA) announced that no final awards would be made for the 2022 third Offshore Wind Solicitation. On Oct. 24, 2023, NYSERDA had provisionally awarded three offshore wind projects to Attentive Energy One (1,404 MW), Community Offshore Wind (1,314 MW), and Excelsior Wind (1,314 MW), as well as a New York State grant to GE Vernova and LM Wind Power for nacelle and blade manufacturing in New York's Capital Region, which were associated with the provisionally awarded projects. Material modifications to the three projects that had bid into New York's offshore wind

[9] Note that the listed developments add up to more than the total pipeline growth because of recalculations of other project capacities in the pipeline from changes or loss of offtake agreements.
[10] BOEM held the Central Atlantic offshore wind energy lease sale on Aug. 14, 2024. The two proposed lease areas were provisionally awarded to two developers.
[11] BOEM canceled the 2024 Gulf of Mexico lease sale due to a lack of competitive interest in response to the March 2024 proposed sale notice. BOEM may decide to move forward with a lease sale at a future time, based on industry interest.
[12] In this case, financial nonviability could be driven by a project with a preexisting offtake contract that is expected to yield lower revenues than updated project costs, or a project that still has a positive revenue expectation but with a lower return margin that does not satisfy external financial backers relative to other investment opportunities.

solicitation caused complexities between provisional awardees and their partners, resulting in the provisionally awarded parties' inability to come to terms (NYSERDA 2024a).

Despite near-term financial setbacks, the U.S. offshore wind energy market experienced multiple developments that put it on a trajectory for potential long-term growth, as discussed in the following subsections.

2.2 U.S. Offshore Wind Energy Market Potential and Project Pipeline Assessment

As of May 31, 2024, NREL estimates the U.S. offshore wind energy pipeline to have 80,523 MW of capacity, which is the sum of installed projects, projects under construction, projects approved for construction, projects undergoing various state and federal permitting processes, existing lease areas, and the potential capacity of yet-to-be-leased wind energy areas. Table 2 breaks down the U.S. offshore wind energy pipeline by project status.

Table 2. U.S. Offshore Wind Energy Pipeline by Classification Status[13]

Status	2023 Total (As of May 31)	Change From Last Year	2024 Total	Notes
Operating	42 MW	132 MW	174 MW	South Fork Wind Farm became operational.
Under Construction	932 MW	3,165 MW	4,097 MW	Revolution Wind (704 MW), and Coastal Virginia Offshore Wind (2,587 MW) began construction.
Financial Close	0 MW	No Change	0 MW	
Approved	1,100 MW	2,278 MW	3,378 MW	Empire Wind 1, Sunrise Wind,[14] and New England Wind 1 and 2 all had Records of Decision and were approved by BOEM.
Permitting	20,978 MW	−1,184 MW	19,793 MW	New Jersey Board of Public Utilities awarded two new offtakes to Attentive Offshore Wind Energy 2 and Leading Light Wind. Several projects that lost offtake were moved back to site control.
Site Control	24,596 MW	−1,725 MW	22,870 MW	Ocean Wind 1's New Jersey Offshore Wind Renewable Energy Certificate (OREC) award and Record of

[13] The report uses developer-specified capacity values for operating projects, projects under construction, and projects advancing through the permitting and offtake processes. These projects have announced project plans, a specified site boundary, and definitive design details related to wind turbine size, array density, and nameplate capacity, among others. For projects in more nascent stages of development (e.g., site control and planning), we use developer-specified capacity where available, or we estimate the potential capacity using a capacity density factor of 4 MW/km^2.

[14] Sunrise Wind and Empire Wind 1 have both entered construction since the report cutoff date of May 31, 2024. There are approximately 6 GW of capacity currently under construction. For the purpose of this report, their capacity is attributed to the "approved" stage of the pipeline.

Status	2023 Total (As of May 31)	Change From Last Year	2024 Total	Notes
				Decision were suspended; now in site control category. Skipjack 1 and 2 canceled their Maryland OREC agreement and did not submit a COP. RWE Offshore US Gulf won the Gulf of Mexico Auction 1 lease.
Planning	5,039 MW	25,172 MW	30,211 MW	New lease area designations occurred in the Gulf of Maine, Central Atlantic,[15] and Oregon.
Total	**52,687 MW**		**80,523 MW**	

Figure 1 shows the U.S. wind energy pipeline as of May 31, 2024, for all categories in Table 2 by project status and state. The U.S. pipeline by project status includes:

- Three operating projects (Block Island Wind Farm [30 MW], Coastal Virginia Offshore Wind Pilot [12 MW], and South Fork Wind Farm [132 MW]).
- Three projects under construction (Vineyard Wind 1 [806 MW],[16] Revolution Wind [704 MW], and Coastal Virginia Offshore Wind [2,587 MW]).
- Four approved projects: two projects that have their permits approved and an offtake agreement and plan to start construction in late 2024 (Empire Wind 1 [810 MW] and Sunrise Wind [which broke ground in July 2024 but not with at-sea construction]),[17] and two projects that have their permits approved and are attempting to secure offtakes (New England Wind 1 and New England Wind 2 [1,664 MW combined]).
- Eighteen projects (19,793 MW) that have submitted a Construction and Operations Plan (COP) with BOEM or secured a power offtake contract.
- Twenty projects in lease areas where the developers have site control with rights to pursue development (a technical potential of at least 22,871 MW).
- Sixteen proposed lease areas (29,995 MW) and three proposed state projects (1,281 MW), one of which is a floating demonstration project in California, in the planning stages of development. Vestas' Steelhead Americas and Mitsubishi-owned Diamond Offshore Wind also signed agreements with the state of Louisiana to explore development in state waters but are not included in the U.S. project pipeline due to uncertainty and the lack of information available to inform their viability.

Note that in Figure 1 we enlarged the vertical scale for operating projects to show them at a higher resolution.

[15] The Central Atlantic lease areas have been provisionally awarded to two developers since the report cutoff date of May 31, 2024. In this report, their capacity continues to be attributed to the "planning" stage of the pipeline.
[16] Vineyard Wind 1 has achieved first power with several operating turbines but has not completed installation of all turbines and is categorized as under construction.
[17] Sunrise Wind and Empire Wind 1 have both entered construction since the report cutoff date of May 31, 2024. There are approximately 6 GW of capacity currently under construction. For the purpose of this report, their capacity is attributed to the "approved" stage of the pipeline.

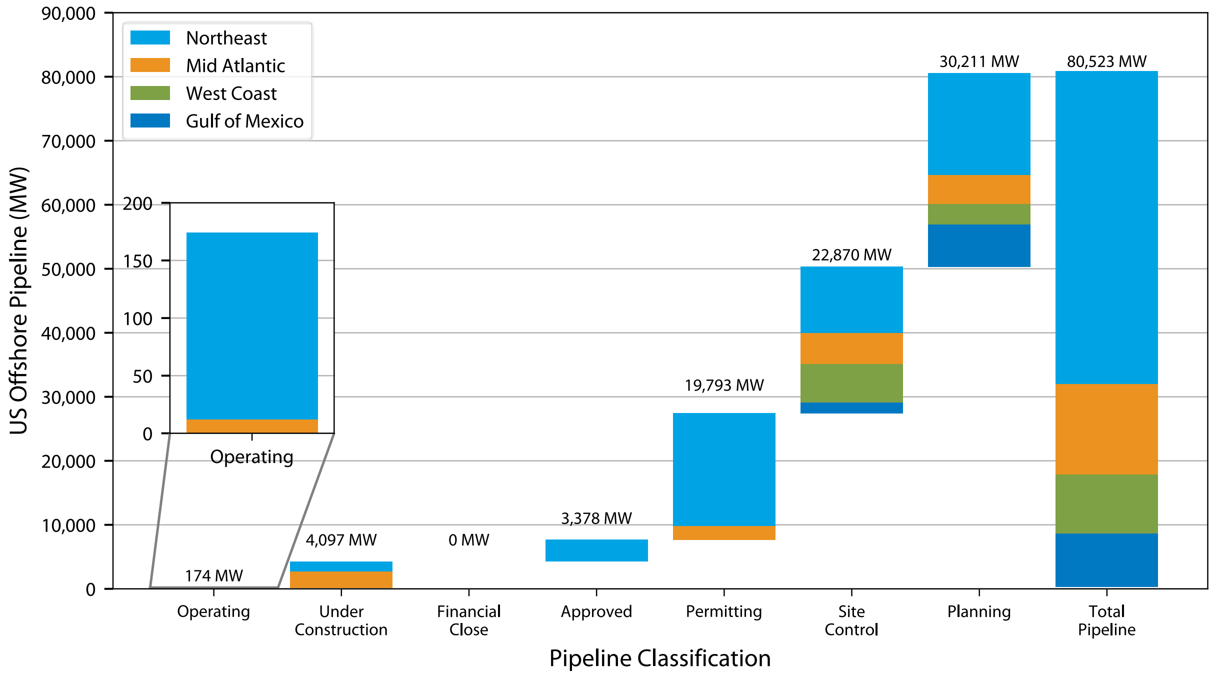

Figure 1. U.S. project pipeline classification by status

Figure 2 shows the same pipeline data but sorted by state. This figure allocates generating capacities to states based on existing power offtake contracts, which may differ from the geographic location of the closest coastline to a project's lease area. With the six new lease areas in the New York Bight, New York and New Jersey now have a combined estimated pipeline potential of more than 15,050 MW. Massachusetts has an estimated pipeline capacity of 9,456 MW. Note that projects in planning and site control could ultimately sell their power to multiple adjacent states.

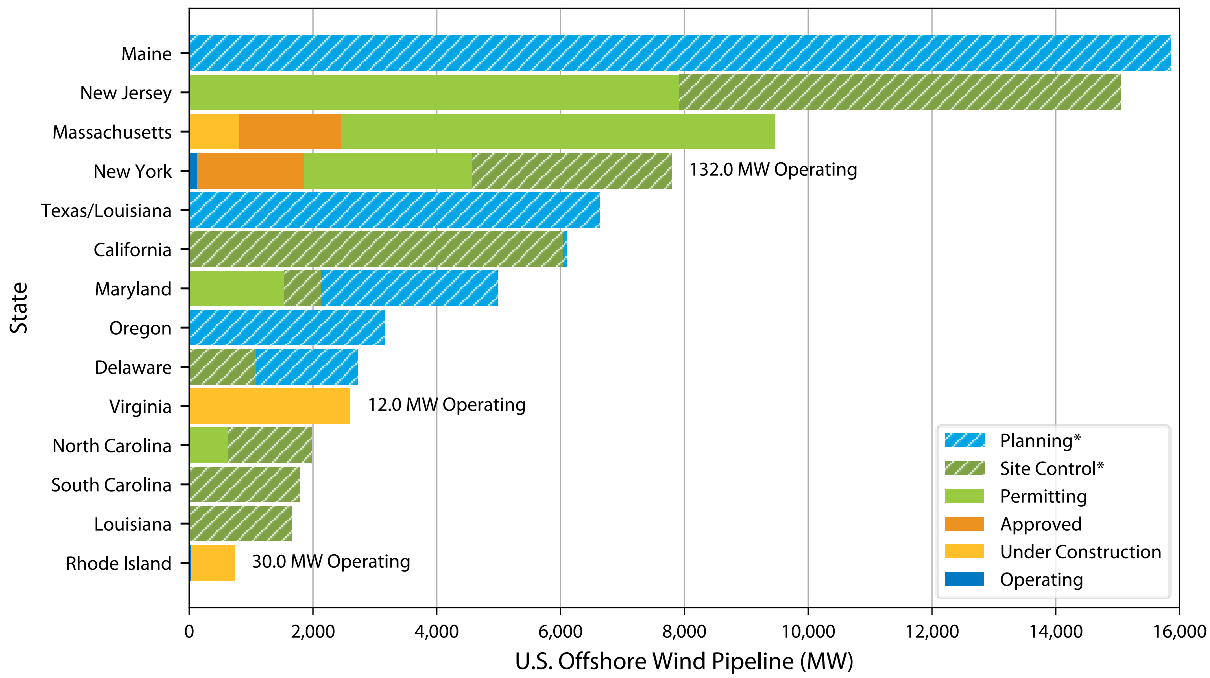

Figure 2. U.S. project pipeline by state.

The asterisks (*) indicate that planning and site control pipeline capacity is subject to reallocating pipeline capacity to a different state after offtake agreements are negotiated.

2.2.1 U.S. Offshore Wind Energy Pipeline

All 80,523 MW that make up the U.S. offshore wind energy pipeline are listed as individual projects or project opportunities in Tables 3–6 with corresponding maps shown in Figures 3–7. These maps show U.S. leasing activity for the Gulf of Maine and North Atlantic, Mid-Atlantic and South Atlantic, Gulf of Mexico, Pacific Coast, and Hawaii, respectively. The tables and maps also include Call Areas, but because those areas are subject to change, the capacities are not included in the pipeline.

In total, there are 65 sites in these tables for U.S. offshore wind energy development activity (as shown on the five maps, compared to 59 sites in the *Offshore Wind Market Report: 2023 Edition*). Included in this activity are three projects in state waters: the operating Block Island Wind Farm in Rhode Island, New England Aqua Ventus I in Maine, and the CADEMO project off Vandenberg Space Force Base in California.

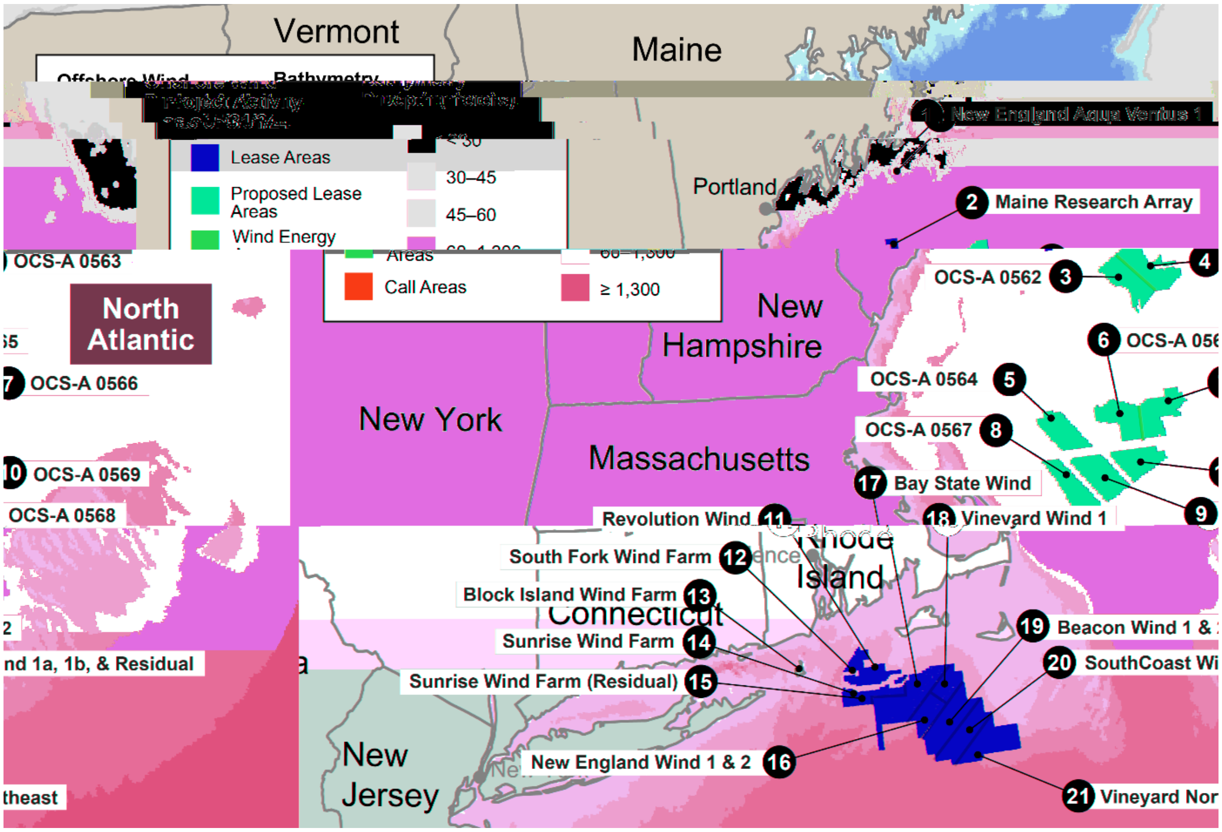

Figure 3. U.S. offshore wind energy pipeline in the North Atlantic, including the Gulf of Maine.

Image by John Frenzl, National Renewable Energy Laboratory (NREL)

Table 3. Offshore Wind Energy Project Pipeline (North Atlantic)

No.	Location[a]	Name	Developer	Lease Area[b]	Offtake Agreement	Status	Capacity
1	ME	New England Aqua Ventus 1	University of Maine, Diamond Offshore	State Lease	Power Purchase Agreement (PPA) – ME	Permitting	12 MW
2	ME	Maine Research Array	State of Maine	TBD	TBD	Planning	144 MW
3	ME	Proposed Lease Area	TBD	OCS-A 0562	TBD	Planning	1,964 MW
4	ME	Proposed Lease Area	TBD	OCS-A 0563	TBD	Planning	2,143 MW
5	ME	Proposed Lease Area	TBD	OCS-A 0564	TBD	Planning	1,786 MW
6	ME	Proposed Lease Area	TBD	OCS-A 0565	TBD	Planning	1,866 MW
7	ME	Proposed Lease Area	TBD	OCS-A 0566	TBD	Planning	2,062 MW
8	ME	Proposed Lease Area	TBD	OCS-A 0567	TBD	Planning	1,993 MW
9	ME	Proposed Lease Area	TBD	OCS-A 0568	TBD	Planning	2,172 MW
10	ME	Proposed Lease Area	TBD	OCS-A 0569	TBD	Planning	1,716 MW
11	RI/MA/CT	Revolution Wind	Ørsted/GIP	OCS-A 0486	PPA – RI (400 MW) PPA – CT (304 MW)	Under Construction	704 MW
12	RI/MA/CT	South Fork Wind	Ørsted/GIP	OCS-A 0517	OREC – NY	Operational	132 MW
13	RI	Block Island Wind	Ørsted	State Lease	PPA – RI	Operational	30 MW
14	RI/MA/CT	Sunrise Wind[18]	Ørsted	OCS-A 0487	OREC – NY	Approved	924 MW
15	RI	Sunrise Wind (Residual)	Ørsted	OCS-A 0487	TBD	Planning	TBD
16	RI/MA/CT	New England Wind 1 and 2	Avangrid	OCS-A 0534	TBD	Approved	1,644 MW
17	RI/MA/CT	Bay State Wind	Ørsted	OCS-A 0500	TBD	Site Control	2,334 MW

[18] Sunrise Wind has entered the construction phase since the May 31, 2024, report cutoff.

No.	Location[a]	Name	Developer	Lease Area[b]	Offtake Agreement	Status	Capacity
18	RI/MA/CT	Vineyard Wind 1	Vineyard Offshore	OCS-A 501	PPA – MA	Under Construction	806 MW
19	RI/MA/CT	Beacon Wind 1 and 2	BP	OCS-A 0520	TBD	Permitting	2,085 MW
20	RI/MA/CT	SouthCoast Wind 1a,1b, and Residual	Ocean Winds	OCS-A 0521	TBD	Permitting	2,062 MW
21	RI/MA/CT	Vineyard Northeast	Vineyard Offshore	OCS-A 0522	TBD	Site Control	2,600 MW

[a] CT = Connecticut; MA = Massachusetts; ME = Maine; RI = Rhode Island

[b] OCS = Outer Continental Shelf

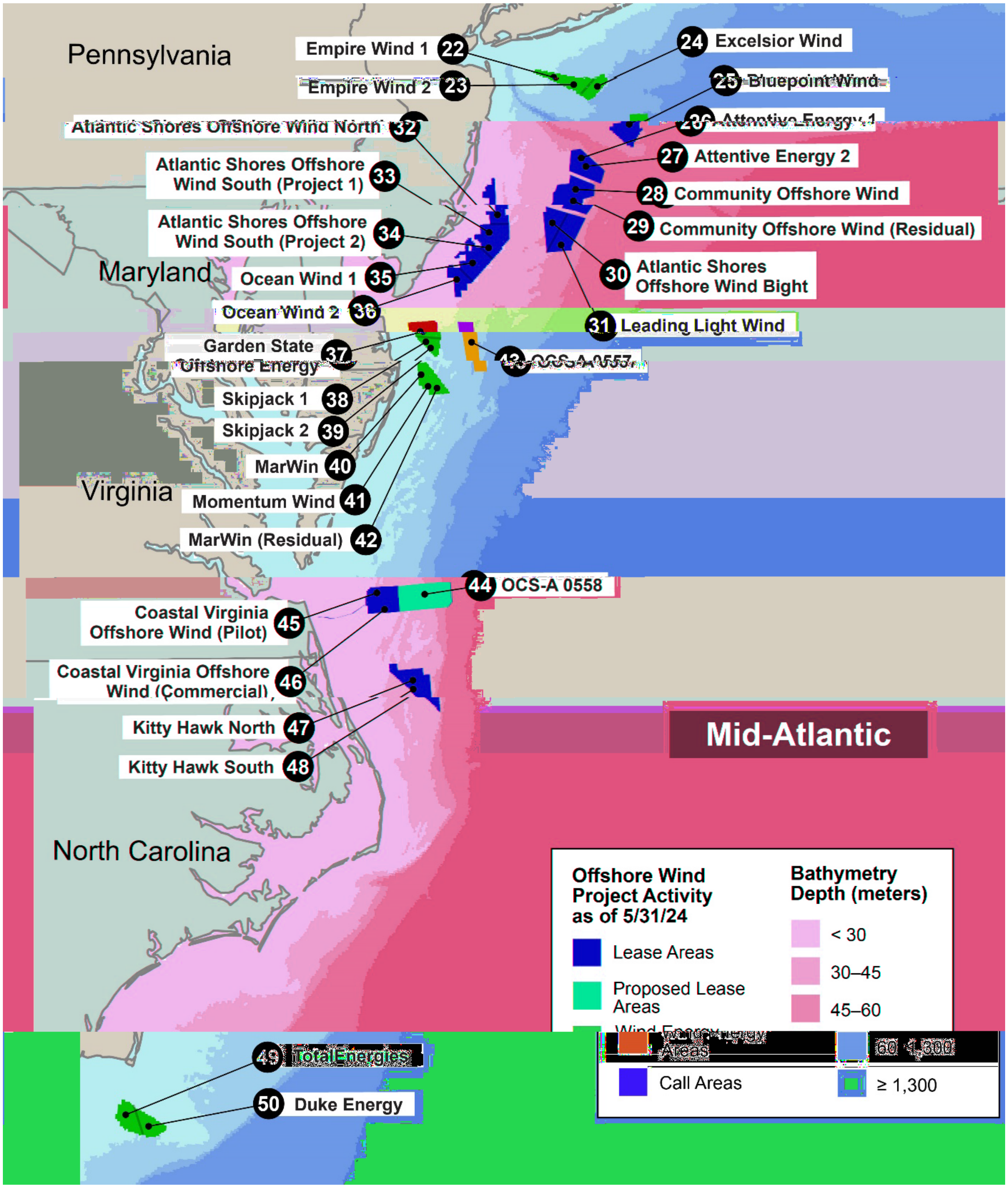

Figure 4. U.S. offshore wind energy pipeline (mid-Atlantic and South Atlantic).

Image by John Frenzl, NREL

Table 4. Offshore Wind Energy Project Pipeline (Middle and South Atlantic)

No.	Location[a]	Name	Developer	Lease Area	Offtake Agreement	Status	Capacity
22	NY	Empire Wind 1[19]	Equinor	OCS-A 0512	OREC– NY	Approved	810 MW
23	NY	Empire Wind 2	Equinor	OCS-A 0512	TBD	Site Control	621 MW
24	NY	Excelsior Wind	Vineyard Offshore	OCS-A 0544	TBD	Site Control	697 MW
25	NY	Bluepoint Wind	OW Ocean Winds East, LLC	OCS-A 0537	TBD	Site Control	1,158 MW
26	NJ	Attentive Energy One	TotalEnergies, Rise Light & Power, and Corio Generation	OCS-A 0538	TBD	Site Control	1,365 MW
27	NJ	Attentive Energy Two	Total Energies, Rise Light & Power, and Corio Generation	OCS-A 0538	OREC – NJ	Site Control	1,342 MW
28	NJ	Community Offshore Wind	RWE Offshore, National Grid	OCS-A 0539	TBD NY	Site Control	1,314 MW
29	NJ	Community Offshore Wind (Residual)	RWE Offshore, National Grid	OCS-A 0539	TBD	Site Control	725 MW
30	NJ	Atlantic Shores Offshore Wind Bight	EDF/Shell	OCS-A 0541	TBD	Site Control	2,500 MW
31	NJ	Leading Light Wind	Invenergy	OCS-A 0542	OREC – NJ	Permitting	2,400 MW
32	NJ	Atlantic Shores Offshore Wind North	EDF/Shell	OCS-A 0549	TBD	Site Control	1,313 MW
33	NJ	Atlantic Shores Offshore Wind South 1	EDF/Shell	OCS-A 0499	OREC – NJ	Permitting	1,510 MW
34	NJ	Atlantic Shores Offshore Wind South 2	EDF/Shell	OCS-A 0499	TBD	Permitting	1,350 MW
35	NJ	Ocean Wind 1	Ørsted	OCS-A 0498	TBD	Site Control	1,223 MW

[19] Empire Wind 1 has entered the construction phase since the May 31, 2024, report cutoff.

No.	Location[a]	Name	Developer	Lease Area	Offtake Agreement	Status	Capacity
36	NJ	Ocean Wind 2	Ørsted	OCS-A 0532	TBD	Site Control	1,375 MW
37	DE	Garden State Offshore Energy	Ørsted	OCS-A 0482	TBD	Site Control	1,080 MW
38	DE	Skipjack 1	Ørsted	OCS-A 0519	TBD	Site Control	426 MW
39	DE	Skipjack 2	Ørsted	OCS-A 0519	TBD	Site Control	
40	MD	MarWin	US Wind	OCS-A 0490	OREC – MD	Permitting	300 MW
41	MD	Momentum Wind	US Wind	OCS-A 0490	OREC – MD	Permitting	809 MW
42	MD	MarWin Residual	US Wind	OCS-A 0490	OREC – MD	Site Control	600 MW
43	DE	Proposed Lease Area	TBD	OCS-A 0557	TBD	Planning	1,642 MW
44	VA	Proposed Lease Area	TBD	OCS-A 0558	TBD	Planning	2,857 MW
45	VA	Coastal Virginia Offshore Wind Pilot	Dominion Energy	OCS-A 0497	Utility Owned	Operational	12 MW
46	VA	Coastal Virginia Offshore Wind Commercial	Dominion Energy	OCS-A 0483	Utility Owned	Under Construction	2,587 MW
47	NC	Kitty Hawk North	Avangrid	OCS-A 0559	TBD	Permitting	631 MW
48	NC	Kitty Hawk South	Avangrid	OCS-A 0508	TBD	Site Control	1,351 MW
49	NC/SC	TotalEnergies	TotalEnergies	OCS-A 0545	TBD	Site Control	889 MW
50	NC/SC	Duke Energy	Duke	OCS-A 0546	TBD	Site Control	893 MW

[a] DE = Delaware; MD = Maryland; NC = North Carolina; NJ = New Jersey; NY = New York; SC = South Carolina; VA = Virginia

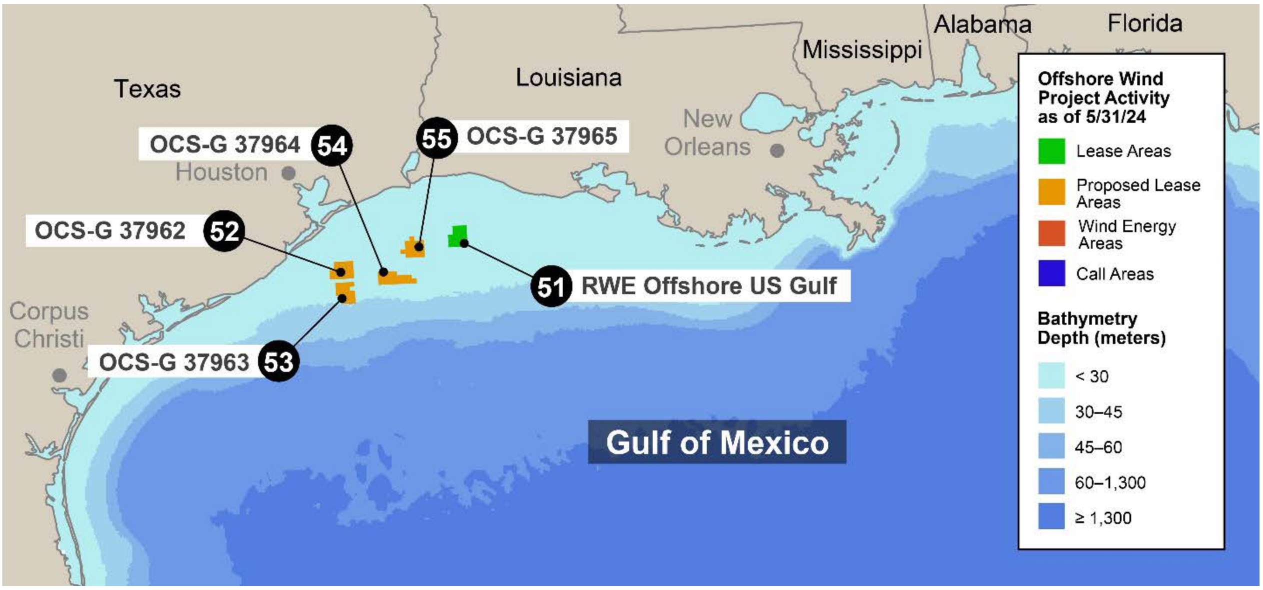

Figure 5. U.S. offshore wind energy pipeline (Gulf of Mexico).

Image by John Frenzl, NREL

Table 5. U.S. Offshore Wind Energy Project Pipeline for the Gulf of Mexico

No.	Location[a]	Name	Developer	Lease Area	Offtake Agreement	Status	Capacity
51	LA	RWE Offshore US Gulf LLC	RWE	OCS-G 37334	TBD	Site Control	1,659 MW
52	TX	Proposed Lease Area	TBD	OCS-G 37962	TBD	Planning	1,659 MW
53	TX	Proposed Lease Area	TBD	OCS-G 37963	TBD	Planning	1,567MW
54	TX	Proposed Lease Area	TBD	OCS-G 37964	TBD	Planning	1,752 MW
55	LA/TX	Proposed Lease Area	TBD	OCS-G 37965	TBD	Planning	1,660 MW

[a] LA = Louisiana; TX = Texas

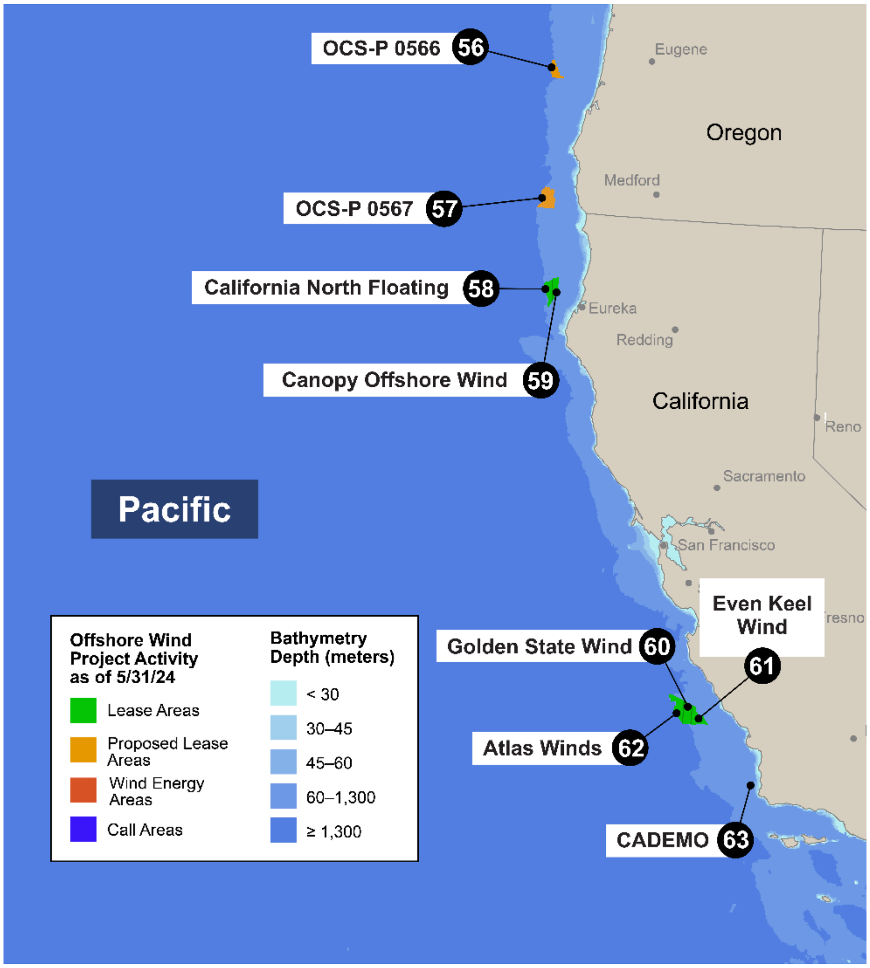

Figure 6. U.S. offshore wind energy pipeline (Pacific).

Image by John Frenzl, NREL

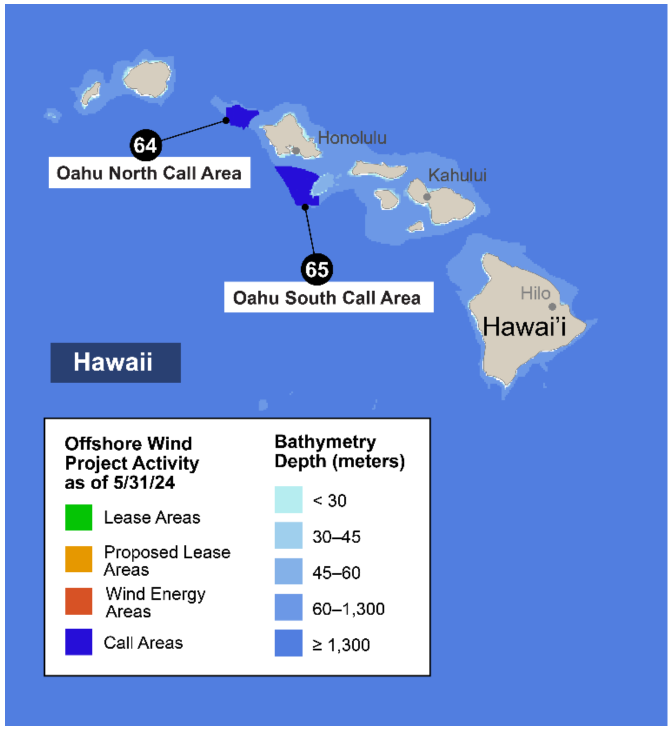

Figure 7. U.S. offshore wind energy pipeline (Hawaii).

Image by John Frenzl, NREL

Table 6. U.S. Offshore Wind Energy Project Pipeline for the West Coast and Hawaii

No.	Location[a]	Name	Developer	Lease Area	Offtake Agreement	Status	Capacity
56	OR	Proposed Lease Area	TBD	OCS-P 0566	TBD	Planning	991 MW
57	OR	Proposed Lease Area	TBD	OCS-P 0567	TBD	Planning	2,166 MW
58	CA	California North Floating	CIP	OCS-P 0562	TBD	Site Control	1,117 MW
59	CA	Canopy Offshore Wind	RWE	OCS-A 0561	TBD	Site Control	1,025 MW
60	CA	Golden State Wind	EDPR/ENGIE	OCS-P 0564	TBD	Site Control	1,302 MW
61	CA	Even Keel Wind	Invenergy	OCS-P 0565	TBD	Site Control	1,302 MW
62	CA	Atlas Winds	Equinor	OCS-P 0563	TBD	Site Control	1,296 MW
63	CA	CADEMO	Floventis, Cierco, SBM	State Lease	TBD	Permitting	60 MW
64	HI	Oahu North Call Area	N/A	N/A	N/A	N/A	N/A
65	HI	Oahu South Call Area	N/A	N/A	N/A	N/A	N/A

[a] CA = California; HI = Hawaii; OR = Oregon

2.3 Federal and State Policy Activities

2.3.1 Federal Activity

In April 2024, the U.S. Department of Energy (DOE) released its *Pathways to Commercial Liftoff: Offshore Wind* report (DOE 2024). The report describes how the U.S. offshore wind sector is adapting to market challenges and is poised for progress in job creation and expanded access to clean energy. The report finds that "liftoff" of the U.S. offshore wind industry is achievable and lays out a pathway to more than 100 gigawatts (GW) of offshore wind capacity by 2050. The report also identifies several key gaps and challenges that must be addressed in the near and long term. Key takeaways include:

- The 10–15 GW of U.S. offshore wind projects in advanced stages of the pipeline will lay the foundation for long-term deployment, carbon reductions, and economic benefits.
- Current market structures expose the sector and developers to exogenous risks and require early-mover projects to bear the costs of long-term industry build-out needs. Improved sequencing of offtakes with the permitting process and incorporating risk mitigation strategies can help overcome this challenge.
- Recent offtake cancellations caused by macroeconomic conditions created funding gaps and timing uncertainty for near-term sector build-out. States are responding with additional competitive procurements for affected projects, and improved risk mitigation is being built into industry planning through state and federal leadership and policy as well as the resources made available through the Bipartisan Infrastructure Law and the IRA.
- While costs increased due to inflation, rising interest rates, supply chain constraints, and schedule delays, new offtake agreements de-risk the advancement of offshore wind. Governments at the federal and state levels are working together with industry to improve procurement processes, supply chain, and transmission planning to make infrastructure investments.
- Offshore wind offers unique value in its ability to decarbonize coastal population centers and revitalize maritime infrastructure and U.S.-based manufacturing. It complements other clean energy resources to support grid reliability and resource diversification.

The Bipartisan Infrastructure Law and IRA support the advancement of offshore wind by providing significant incentives to increase the economic attractiveness of offshore wind energy projects, catalyze domestic manufacturing and supply chain investments, accelerate permitting and project interconnection, and develop a highly skilled and diversified workforce.

To overcome market volatility, these new federal laws extended long-term tax credits that increase cost certainty and make project financing more likely. The tax credits provide additional bonuses for developers that use domestically produced iron and steel products and manufactured products and/or ensure the project's economic benefits accrue to communities who have historically been negatively impacted by energy production or have had a historical reliance on fossil fuel employment. The IRA also creates a manufacturing tax credit to spur equipment manufacturers to make new investments in manufacturing capacity for wind turbine blades, nacelles, towers, floating foundations, fixed-bottom foundations, and related offshore wind vessels. Funds have also been made available to enhance transmission planning, especially focused on offshore wind, to ensure projects maintain high system reliability when they are interconnected to the grid. BOEM and the National Oceanic and Atmospheric Administration received additional federal support to bolster their permitting staff to ensure timely and robust project reviews and safe project implementation.[20]

2.3.2 State Offshore Wind Procurement Policy and Status

The U.S. offshore wind energy market continues to be driven by an increasing amount of state-level offshore wind procurement activities and policies. In this year's report, we differentiate between state planning goals and state procurement mandates. Planning goals are aspirational and do not require agencies to take any direct action. On the other hand, procurement mandates are statutory requirements for the state to achieve a predetermined quantity of offshore wind generation on a scheduled timeline. There are various pathways to securing offshore wind energy generation, including power purchase agreements, ORECs, or direct utility ownership of projects.

As of May 31, 2024, 12 states have set planning targets or procurement mandates:

- The planning targets total 115,130 MW of offshore wind capacity by 2050. The mandated procurement totals 45,730 MW of offshore wind capacity by 2040 (Table 7).
- As of May 31, 2024, 15 offtake agreements have been signed, which are associated with 12,378 MW of contracted capacity.
- Figure 8 illustrates that substantial additional deployment and projects advancing through the pipeline stages are needed to achieve 2040 state mandate requirements and the 2050 planning goal targets.

[20] For more information, see (DOE and BOEM 2024).

Table 7. State Planning Goals, Mandated State Procurements, and Offtake Contracts Awarded by Year

State	Planning Targets		Mandated Procurement		Offtake Contracts Awarded (MW)	Awarded Projects (MW)	Supporting Policies and Documents
	Capacity (MW)	Year	Capacity (MW)	Year			
ME	3,000	2040	3,000	2040	12	Aqua Ventus (12)	An Act Regarding the Procurement of Energy From Offshore Wind Resources (2023)
MA	23,000	2050	5,600	2035	806	Vineyard Wind 1 (806)	An Act Driving Clean Energy and Offshore Wind (2022)
RI	1,430	2030	1,430	2030	430	Block Island Wind Farm (30) Revolution Wind (400)	Request for Proposals for Long-Term Contracts for Offshore Wind Energy (2022)
CT	2,000	2030	2,000	2030	304	Revolution Wind (304)	An Act Concerning the Procurement of Energy Derived From Offshore Wind (2019)
NY	20,000	2050	9,000	2035	1,866	South Fork Wind (132) Empire Wind 1 (810) Sunrise Wind (924)	Climate Leadership and Community Protection Act (2019)
NJ	11,000	2040	11,000	2040	5,252	Atlantic Shores Offshore Wind South (Project 1) (1,510) Attentive Energy Two (1,342) Leading Light Wind (2,400)	New Jersey Executive Order 307 (2022)
MD	8,500	2031	8,500	2031	1,109	MarWin (300) Momentum Wind (809)	Promoting Offshore Wind Energy Resource Act (2023)
VA	5,200	2034	5,200	2034	2,599	Coastal Virginia Offshore Wind (Pilot) (12) Coastal Virginia Offshore Wind (Commercial) (2,587)	Virginia Clean Economy Act (2021)
NC	8,000	2040	-	-	-		North Carolina Executive Order 218 (2021)

State	Planning Targets		Mandated Procurement		Offtake Contracts Awarded (MW)	Awarded Projects (MW)	Supporting Policies and Documents
CA	25,000	2045	-	-	-		Offshore Wind Energy Development off the California Coast: Maximum Feasible Capacity and Megawatt Planning Goals for 2030 and 2045 (2022)
LA	5,000	2035	-	-	-		Louisiana Climate Action Plan (2022)
OR	3,000	2030	-	-	-		Relating to Floating Offshore Wind Energy; and Prescribing an Effective Date (2021)
Total	**115,130**	**2050**	**45,730**	**2040**	**12,378**		

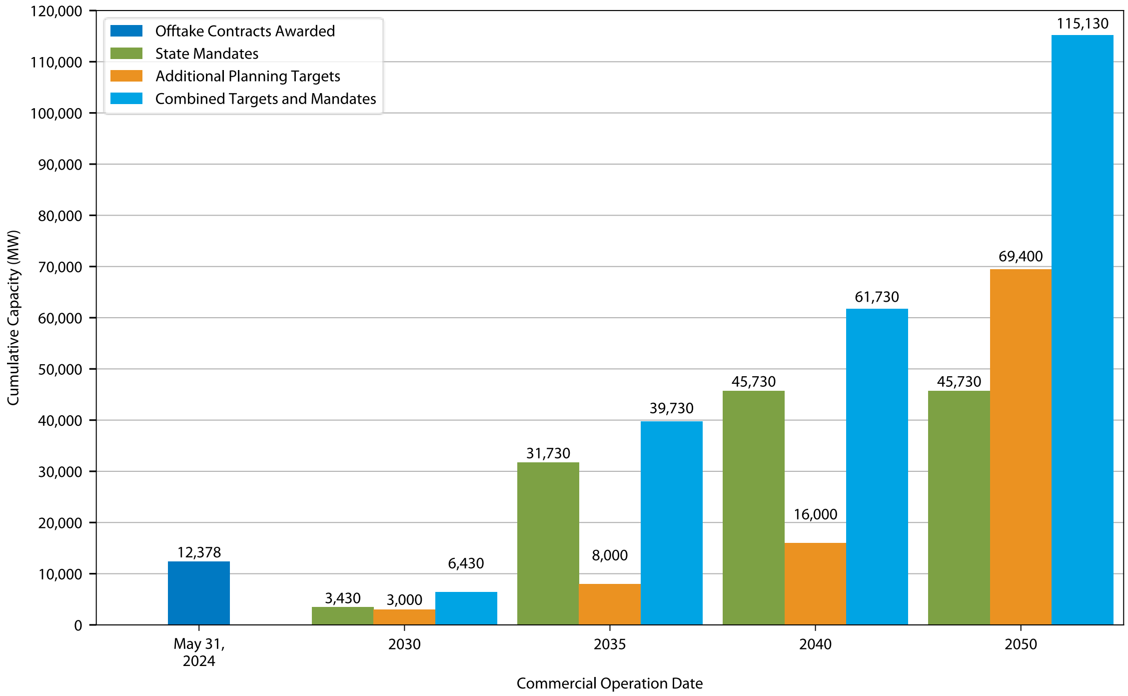

Figure 8. U.S. offshore wind energy state planning goals, procurement mandates, and offtake agreements awarded

2.4 Regulatory Activity

BOEM and the Bureau of Safety and Environmental Enforcement (BSEE) oversee the responsible development of offshore renewable energy resources on the U.S. Outer Continental Shelf (OCS). BOEM transferred the inspection and enforcement functions pertaining to safety, environmental oversight, and compliance to BSEE in January 2023. Since then, BSEE's involvement in post-COP activities has increased significantly. BSEE now has authority to review and object or not object to facility design reports and fabrication and installation reports along with BOEM. Both reports are submitted following a COP approval. BOEM continues to lead wind energy area identification, leasing, permitting, and project approvals.

To accompany the reorganization of BOEM and BSEE roles in offshore wind regulatory authority, the U.S. Department of the Interior proposed the Renewable Energy Modernization Rule in January 2023. The rule modifies Title 30 of the Code of Federal Regulations Part 585 (30 CFR 585) in accordance with the Outer Continental Shelf Lands Act, Title 43 of the United States Code 1337 (43 U.S.C. 1337), as amended by the Energy Policy Act of 2005. The rule also modified 30 CFR 285 and created a new 30 CFR 586. The rule was finalized May 15, 2024 (Renewable Energy Modernization Rule 2024). The final rule clarifies BOEM's renewable energy regulations facilitating offshore renewable energy development in a manner that is safe, is environmentally sound, and provides fair return to U.S. taxpayers. The final rule also helps meet commitments of Executive Order 14008, Tackling the Climate Crisis at Home and Abroad, by supporting renewable energy production in offshore waters.

2.4.1 Federal Permitting Status of U.S. Lease Areas

BOEM issues a Record of Decision following the completion of an environmental impact statement analyzing the potential impacts of a proposed offshore wind energy project in accordance with the National Environmental Policy Act. The Record of Decision is the document setting the basis for the agency's permit approval. Following the issuance of a Record of Decision, BOEM would then issue its approval of a COP, approval with modifications, or disapproval of a COP for developers to build an offshore wind energy project in the United States. Since the start of 2021, the Biden-Harris administration has approved eight commercial-scale offshore wind projects totaling more than 10 GW of power capacity.[21]

2.4.2 Lease Activity and New Site Identification

The IRA limits the issuance of future offshore wind energy leases by requiring that BOEM hold an offshore oil and gas lease sale in which at least 60 million acres are offered for development within the year preceding the issuance of offshore wind energy leases. On Dec. 14, 2023, the U.S. Department of the Interior approved the 2024–2029 National OCS Oil and Gas Leasing Program, which includes three potential oil and gas lease sales, fulfilling the IRA requirements and allowing BOEM to issue offshore wind energy leases (BOEM 2023).

BOEM held its first competitive auction for offshore wind in the Gulf of Mexico on Aug. 29, 2023. There were three lease areas available for auction, but only one received bids. RWE Offshore US Gulf LLC was the winner of the Lake Charles Lease Area for $5.6 million, which has the potential to provide approximately 1.24 GW of offshore wind capacity. Lease prices from 2013 through 2023 are shown in Figure 9.

[21] For more information on the status of project permits, visit the Permitting Dashboard for Federal Infrastructure at permits.performance.gov and filter by "Lead Agency Bureau" Bureau of Ocean Energy Management (Permitting Dashboard n.d.).

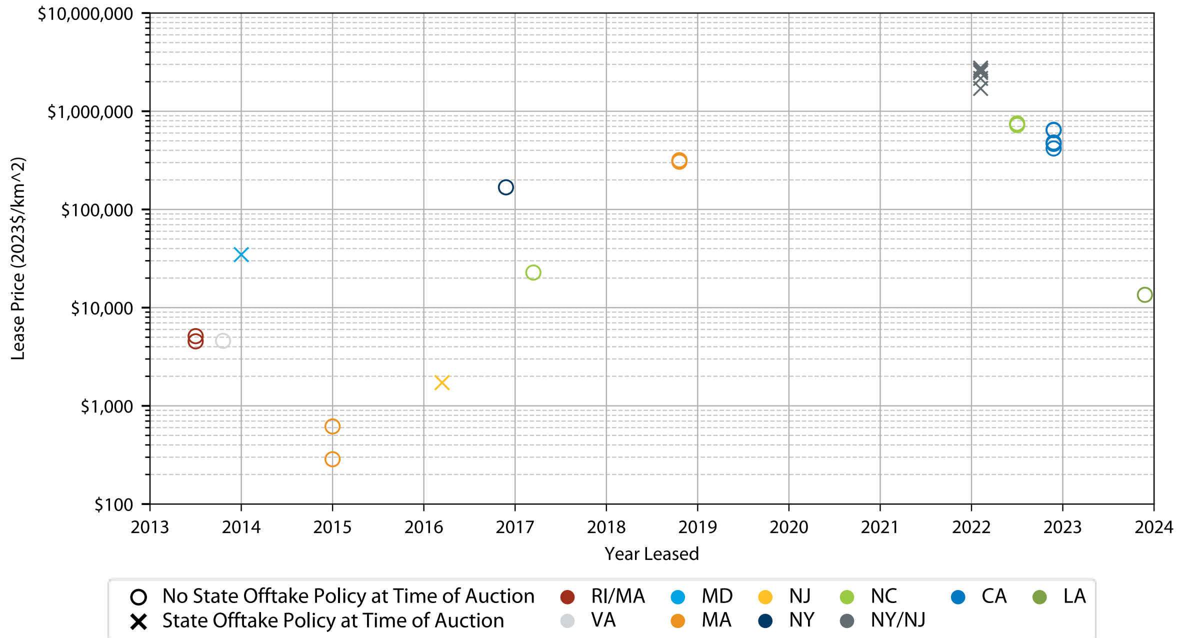

Figure 9. U.S. offshore wind energy lease prices

BOEM publishes Calls for Information and Nominations (calls) to initiate the commercial competitive leasing process and assess commercial competitive interest for offshore wind energy development on specific parcels of ocean acreage in federal waters. Since 2021, BOEM has identified new areas, refined existing areas, and/or developed previously identified Call Areas. Since the previous edition of this report, BOEM has not initiated any new area identification. Table 8 lists the active offshore wind Call Areas on the OCS. BOEM is likely to initiate new calls for sales in 2025 and after.

Table 8. BOEM Call Areas on U.S. Outer Continental Shelf

State	Name	Year Designated	Area (km^2)	Likely Substructure Type
HI	Oahu North Call Area	2016	1,331	Floating
HI	Oahu South Call Area	2016	626	Floating

On April 24, 2024, the U.S. Department of the Interior announced a new 5-year offshore wind leasing schedule that includes up to 11 competitive offshore wind lease sales across the Atlantic, Gulf of Mexico, Pacific, and the U.S. territories (BOEM 2024a). Lease sales are planned for the Central Atlantic, Gulf of Maine, and offshore Oregon in 2024 with a total of 12 proposed lease areas. BOEM anticipates holding a lease auction in October for eight proposed lease areas in the Gulf of Maine, and another auction in October for two proposed lease areas offshore Oregon (Figure 10).[22,23]

[22] BOEM canceled the 2024 Gulf of Mexico lease sale due to a lack of competitive interest in response to the March 2024 proposed sale notice. BOEM may decide to move forward with a lease sale at a future time, based on industry interest.

[23] The Central Atlantic lease areas have been provisionally awarded to two developers since the report cutoff date of May 31, 2024.

Figure 10. Offshore wind leasing schedule.

Figure from BOEM

2.5 U.S. Offshore Wind Energy Infrastructure Trends

Progress to build the enabling infrastructure needed for offshore wind energy—including ports, vessels, manufacturing, and the electric grid—continued in the United States. Figure 11 shows announced domestic supply chain and infrastructure projects up to May 31, 2024. DOE estimates that about $10 billion in investments have been announced in the U.S. offshore wind supply chain since the beginning of 2021, including $2.1 billion just in 2023 for port development, vessel orders, workforce development, research, and other supply chain investments (DOE 2024).

Despite this momentum, substantially more investment will be required to develop a robust domestic supply chain; for example, NREL reported in 2023 that at least $22 billion in ports, large installation vessels, and manufacturing facilities will be needed to achieve the 30-GW-by-2030 target (Shields et al. 2023). DOE also reports that more vessels are needed to meet state construction goals, highlighting that many announced supply chain facilities face obstacles because of uncertain demand, especially for projects with planned completion between 2025 and 2030 due to uncertain project timelines (DOE 2024).

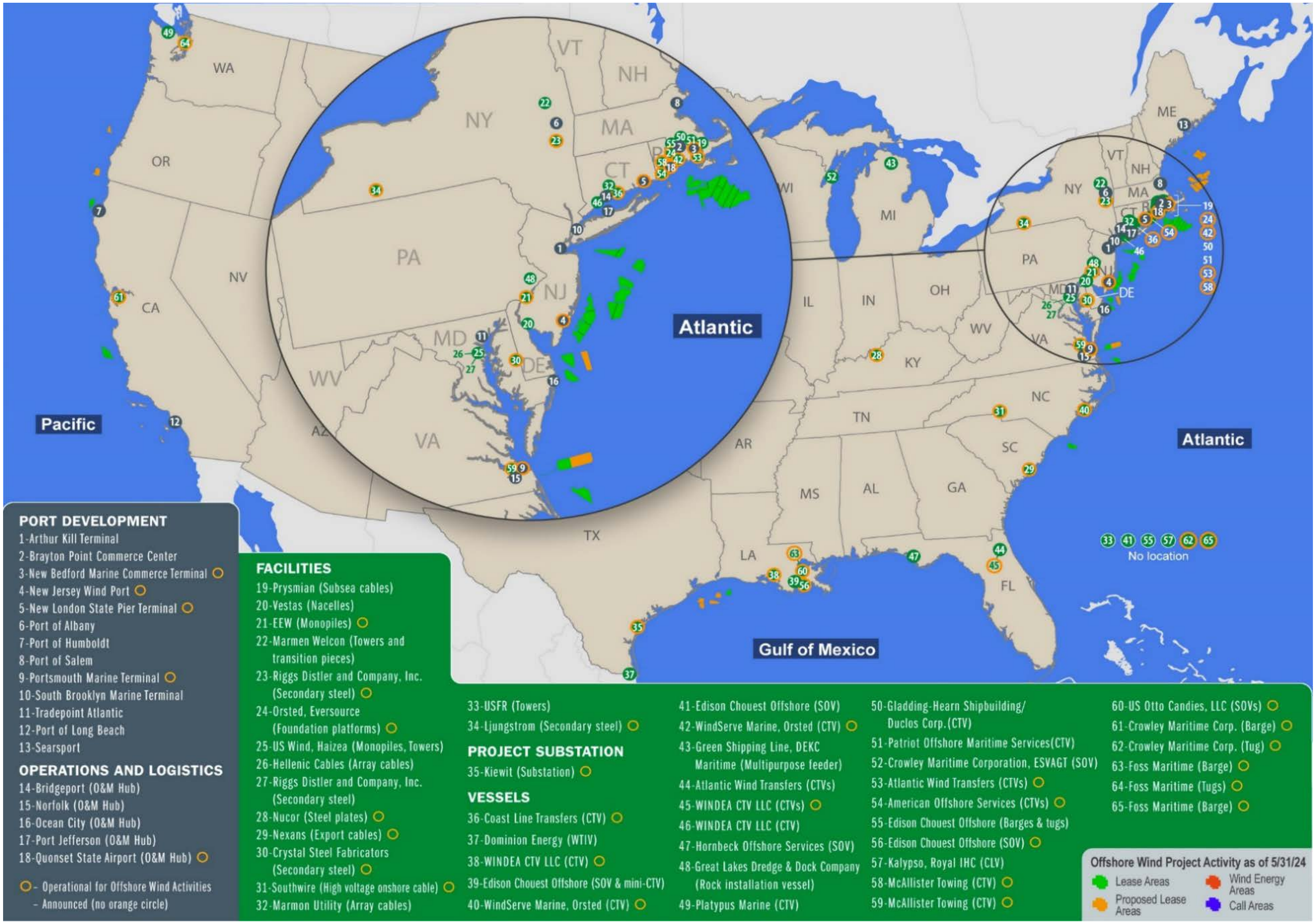

Figure 11. Announced and active port, vessel, and supply chain activity in the United States.

Image by Al Hicks and John Frenzl, NREL

2.5.1 Vessels and Logistics

The U.S. offshore wind vessel fleet has 22 vessels in operation and 30 vessels announced as of May 31, 2024. The greatest share of these vessels are crew transfer vessels (CTVs) and service operation vessels (SOVs), essential for both the construction and the operation and maintenance stages of an offshore wind farm. CTVs are designated for fast transport of personnel and light equipment in day trips, whereas SOVs are dynamically positioned vessels from which technicians “walk to work” directly from vessel to turbine. SOVs have onboard living quarters and recreation facilities designed for 2-week deployments.

Other key specialized vessels like wind turbine installation vessels (WTIVs), feeders, heavy-lift vessels and cable-lay vessels are also essential for the construction stages of an offshore wind farm. WTIVs are self-propelled heavy-lift jack-up vessels designed for the installation of offshore wind turbines. Feeders can support turbine or monopile installation by transporting components from a U.S. staging port. Heavy-lift vessels are heavy-load carriers with high-capacity crane and dynamic positioning, designed for installing fixed-bottom foundations and substations. Cable-lay vessels are equipped with one or two high carousels capable of spooling long lengths of array and/or export cables and typically have a redundant dynamic positioning system.

This year, there have been major development updates on the offshore wind vessel fleet. The most important announcements are listed below:

- In April 2024, the only Jones Act compliant WTIV, *Charybdis*, was successfully launched to water in Brownsville, Texas; its estimated time of arrival after sea trials is expected to be late 2024 or early 2025 (Dominion Energy n.d., 2024).
- Two barges and two tugs will be built by Maersk Supply Service and Edison Chouest Offshore for delivery in 2026. These vessels are expected to support Maersk Supply Service’s foreign-flagged WTIV, which is expected to come to U.S. waters in 2026 to support Equinor’s Empire Wind project[24] (Maersk Supply Service 2022, 2024).
- An SOV constructed in Edison Chouest shipyard in Louisiana was delivered in May 2024 and is expected to be in operation in the same year for the operations and maintenance support of the Ørsted Northeast portfolio (Ferry 2023a; Ørsted 2024). Another Edison Chouest SOV is under construction in Louisiana to support Equinor’s Empire Wind project (Empire Wind 2022; American Clean Power 2024).
- Crowley and Danish offshore maritime leader ESVAGT will build and operate an SOV under a long-term charter with Siemens Gamesa Renewable Energy for Dominion Energy’s Coastal Virginia Offshore Wind project. The vessel is under construction in the Fincantieri shipyard in Sturgeon Bay, Wisconsin, and is expected to be operational in 2026 (American Clean Power 2024; Crowley 2023).
- In May 2024, the keel for *Acadia*, which will become the first U.S.-built subsea rock installation vessel for the offshore wind industry, was laid at the Philly Shipyard in Philadelphia, Pennsylvania (Buljan 2024).

[24] The announcement stated that the contract was awarded by the joint venture between Equinor and bp for the support of U.S. offshore wind farms Empire 1 and 2. Since Equinor took ownership of bp’s 50% stake in the Empire Wind 1 and 2 projects, we took bp’s name out of the award.

Table 9 shows the number of operational Jones Act-compliant offshore wind vessels by vessel type as of May 31, 2024, according to DOE's Clean Energy tracking efforts (DOE n.d.), as well as additional announced vessels of the same type. There is also one announced rock installation vessel, one announced WTIV, one announced multipurpose feeder, and one announced cable-lay vessel. The complete list of commissioned U.S.-flagged vessels to date can be found in Table C-1 (Appendix C).

Table 9. Operational and Announced U.S.-Flagged Vessels To Serve the Offshore Wind Energy Industry

Vessel Category	Operational	Announced	Total
Crew transfer vessel	13	18	31
Service operation vessel	3	4	7
Barge	3	2	5
Tug	3	2	5

Even though there has been progress in the commissioning of vessels for offshore wind purposes, the insufficient availability of WTIVs and other key vessels may pose considerable challenges and risks to the U.S. offshore wind energy sector. American Clean Power's estimation of 2 to 3 years for offshore installation per project and the requirement of at least 25 vessel types per project across all stages underscores the critical role of vessel availability (American Clean Power 2021). Shields et al. (2023) reported that without substantial investment in large installation vessels like WTIVs, heavy-lift vessels, and feeder barges, there is a risk of delays for up to half of the 30-GW pipeline targeted for installation by 2030. Ocean Wind 1 and 2 cancellations serve as recent examples of setbacks to project timing due to major vessel delays, among other issues such as increased inflation and interest rates and other supply chain hurdles (Ørsted 2023). The capital-intensive nature of WTIVs, which cost more than $600 million each in the United States (compared to more than $325–$400 million for an Asian-built WTIV), further exacerbates the challenge, as the U.S. market will likely need 4–6 dedicated WTIVs to meet the national 30-GW-by-2030 offshore wind energy target (Dominion Energy 2023; Shields et al. 2023; Foxwell 2023a; Sakurai 2019; P. Lewis 2023; Lepic 2024). Efforts are underway to increase the availability of WTIVs with the expected arrival of *Charybdis* in 2025 and Maersk's foreign-flagged option in 2026. Despite these measures, sourcing additional WTIVs from foreign markets remains necessary to prevent potential project delays in the short to medium term. In 2023–2024, the U.S. market managed to attract two foreign WTIVs at the same time (DEME's *Sea Installer* for Vineyard Wind 1 and Van Oord's *Aeolus* for South Fork Wind). However, Spinergie projects a peak in the global deficit of heavy-lift vessel and WTIV supply by 2029, indicating that relying on foreign large installation vessels may not be sustainable in the future (Spinergie 2024).

In the financing landscape, vessels present significant hurdles, particularly in raising capital for specialized vessels without long-term contracts (Brady 2024). Despite the promising prospects that offshore wind vessels offer in a global growing renewable energy market, many lenders perceive the sector as inherently risky. However, despite these challenges, developers have begun proactively securing long-term agreements on installation vessels to support a pipeline of offshore wind projects. An example of this approach occurred in April 2024 when Ørsted announced a landmark long-term global lease agreement for a WTIV in partnership with Cadeler, spanning from the first quarter of 2027 to the end of 2030 (Cadeler 2024). This partnership exemplifies how a developer can provide suppliers with the clarity and scale needed to invest in new technology and capabilities, ultimately increasing the supply of installation vessels for current and future offshore wind projects (Cadeler 2024).

Acknowledging the imperative to attract investment in offshore wind vessels, the U.S. Department of Transportation's (DOT's) Maritime Administration has designated them as Vessels of National Interest. This designation opens doors to financial support through initiatives like the Title XI Federal Ship Financing Program, advertising credit loans with extended terms and reduced interest rates (DOT 2022). As of April 2024, the Title XI program is actively processing four Vessels of National Interest loan applications totaling more than $415 million in requested loans (DOE and BOEM 2024). Funding initiatives of this type may push sponsors closer to agreement for shipbuilding contracts.

2.5.2 Ports and Supply Chain

From January 2023 to May 31, 2024, the offshore wind industry in the United States has made significant port and supply chain developments and investments. Several key announcements are listed below:

- In January 2023, Nucor unveiled Elcyon, a new sustainable heavy-gauge steel plate product tailored for America's offshore wind sector. The steel plates will be produced at the $1.7 billion Nucor Bradenburg mill in Kentucky, which started operations in December 2022 (Memija 2023d).
- In April 2023 Ørsted announced the investment of $14 million in the co-development of a steel fabrication facility in Maryland with American contractor Riggs Distler,[25] highlighting the commitment to supply chain development and workforce enhancement (Ferry 2023b).
- NYSERDA provisionally awarded $300 million in October 2023 for GE Vernova and LM Wind Power to establish nacelle and blade manufacturing facilities in New York's Capital Region, associated with three provisionally awarded offshore wind projects. However, technical and commercial complexities, including GE Vernova's pivot from the 18-MW platform to a 15.5/16.5-MW platform, prevented final offtake agreements for the offshore wind projects and resulted in the cancellation of the award to GE Vernova. The $300 million grant will be reallocated in future solicitations to support the offshore wind supply chain in New York (GE Vernova 2023; Gerke 2024).
- The Humboldt Bay Harbor District received $8.6 million in November 2023 to support the development of an offshore wind terminal, funded through the Port Infrastructure Development Program disbursed by DOT's Maritime Administration (Huffman 2023).
- In January 2024, the Humboldt Bay Harbor District secured a $426.7 million grant from DOT's Nationally Significant Multimodal Freight & Highway Projects (INFRA) grant program. This funding will support the construction and maintenance of offshore wind infrastructure (Huffman 2024).

[25] The investment was intended to support the Skipjack projects; however, the offtake agreements for these projects were canceled. There has been no public announcement regarding cancellation of this investment; we therefore maintain the facility in the "announced" category.

- Also in January 2024, Attentive Energy committed $58.85 million, and Invenergy committed $105.25 million toward the completion of Phase 3 of the EEW Foundation Manufacturing Facility in New Jersey, as part of the third New Jersey solicitation awards (State of New Jersey 2024a, 2024b).
- In February 2024, US Forged Rings Inc. announced a $700 million investment in a tower and rolled ring fabrication facility, aiming to address critical supply chain gaps in the domestic offshore wind market, with strategic partnerships with Nucor and Ellwood Quality Steels (US Forged Rings Inc. 2024).
- In April 2024, Skanska announced an $861 million contract award to transform the 73-acre South Brooklyn Marine Terminal into one of the nation's largest dedicated offshore wind ports, supporting installation and operation and maintenance of Equinor's Empire Wind project (Skanska 2024).

Figure 12 illustrates the number of operational and announced manufacturing facilities, ports, and vessels as of May 31, 2024, according to DOE's Clean Energy tracking efforts (DOE n.d.). Nine manufacturing facilities are operational (four of them manufacturing steel plates and secondary steel) and 10 have been announced as of May 31, 2024. In terms of port development, five ports have been developed to support offshore wind activity in the United States while 13 remain "announced" for future development and cannot yet support offshore wind activity.

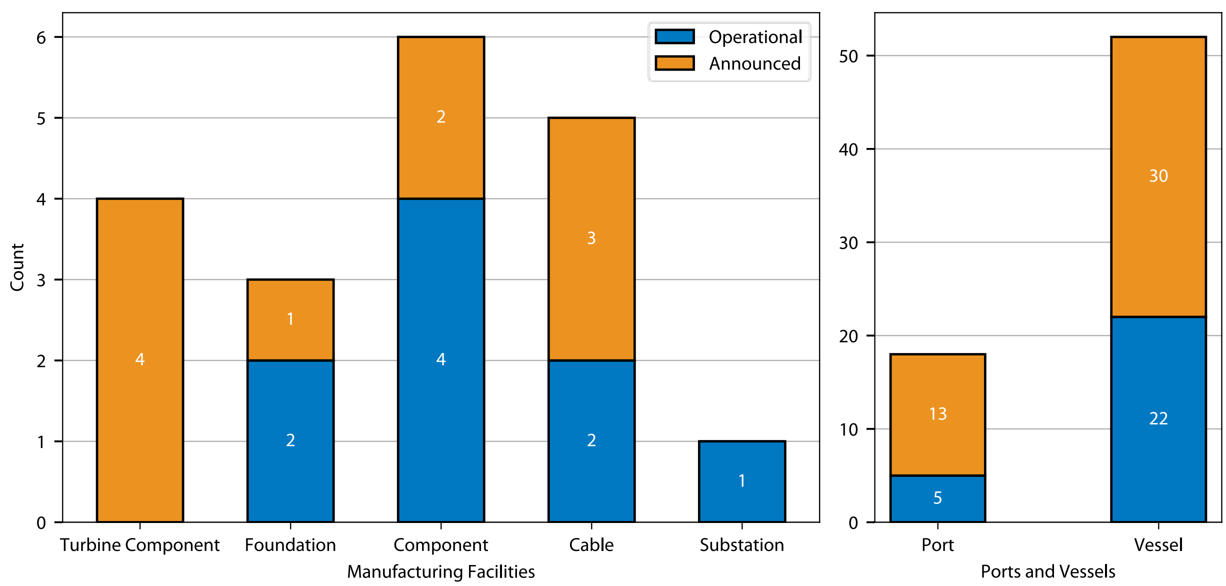

Figure 12. Announced and operational manufacturing facilities, ports, and vessels as of May 31, 2024.

Some facilities may be double-counted if they produce various component types from different categories, e.g., a facility that produces turbine components and monopiles.

A summary of more than $2 billion in announced port and supply chain investments from the beginning of 2023 is provided in Table 10. The data are sourced from DOE's Clean Energy tracking efforts; summary data can be viewed at energy.gov/invest (DOE n.d.).

Table 10. Investments in Offshore Wind Ports and Manufacturing Facilities From Jan. 1, 2023, to May 31, 2024

Type of Investment	State	Port (If Applicable)	Announced Investment ($ million)	Funding Source
Secondary steel manufacturing	MD	Tradepoint Atlantic	14	Ørsted, Riggs Distler
Tower manufacturing	-	-	700	US Forged Rings
Port development	CA	Port of Humboldt	8.67	DOT Maritime Administration – Port Infrastructure Development Program
Port development	CA	Port of Humboldt	426.7	DOT INFRA program
Monopile manufacturing	NJ	Paulsboro Marine Terminal	58.85	Attentive Wind/TotalEnergies
Monopile manufacturing	NJ	Paulsboro Marine Terminal	105.25	Leading Light Wind/Invenergy
Port development	NY	South Brooklyn Marine Terminal	861	Skanska
Total announced investment (Jan. 1, 2023–May 31, 2024):			**2,174.47**	**-**

2.5.3 Electric Grid

Stakeholders have made significant progress in investing in grid upgrades to support offshore wind development. Key examples of grid development announcements and published studies from 2023 to May 31, 2024, are summarized below:

- In February 2023, the New York Public Service Commission (NY PSC) approved 62 Phase 2 transmission projects in New York, representing a $4.4 billion investment aimed at integrating clean energy into upstate renewable generation areas (NY PSC 2023a). In June 2023, the New York Independent System Operator (NYISO) selected the $3.26 billion T051 Alternate Solution 5 project to meet Long Island's Offshore Wind Export Public Policy Transmission Need (NYISO 2023). Development agreements are in progress for that project (NYISO 2024). The NY PSC also declared a Public Policy Transmission Need for offshore wind integration into New York City, prompting Con Edison to facilitate interconnection information for developers. The New York City Public Policy Transmission Need project solicitation window opened April 4, 2024, and was extended to June 17, 2024 (NYISO 2024).
- In November 2023, the New Jersey Board of Public Utilities issued a Prebuild Infrastructure Solicitation and the Offshore Wind Prebuild Solicitation Guidance Document. This document outlines plans for a construction effort aimed at facilitating the connection of up to four offshore wind farms to the Larrabee-Tricollector substation under the State Agreement Approach. The deadline for Prebuild Solicitation applications was April 3, 2024, with an award anticipated in August 2024 (New Jersey Board of Public Utilities 2024a). One example of a proposal submitted under this solicitation is the

Garden State Energy Path, proposed by National Grid Ventures and Con Edison Transmission (Con Edison 2024).

- In April 2024, the California Independent System Operator (CAISO) released their draft 2023–2024 Transmission Plan, recommending 26 projects at an estimated cost of $6.1 billion. The largest tranche of funding, $4.59 billion, would be devoted to infrastructure that would carry offshore wind power from the state's isolated northern coast toward hubs of demand like San Francisco. The start of offshore wind generation is anticipated around 2034 (CAISO 2024a). While CAISO's plan aligns with the recommendations from the Assembly Bill 525 Offshore Wind Technologies Assessment published in June 2023—which highlighted the importance of state-led transmission planning—certain critical aspects remain unaddressed, such as the challenges for efficient power transmission at deep-water offshore wind farms (Huang, Busse, and Baker 2023). On May 15, 2024, CAISO published a revised version of the 2023–2024 Transmission Plan draft (CAISO 2024b). The plan received approval from CAISO's Board on May 23 (CAISO 2024c).
- The *Northern California and Southern Oregon Offshore Wind Transmission Study*, published in October 2023, estimates that developing offshore wind resources on the northern California and southern Oregon coasts requires $35–$40 billion in new transmission infrastructure, highlighting the need for proactive, long-term regional planning to optimize costs, reduce environmental impacts, and ensure grid reliability (Zoellick et al. 2023).
- The *Atlantic Offshore Wind Transmission Study*, published by DOE and NREL in March 2024, addresses gaps in offshore transmission planning along the Atlantic seaboard. It emphasizes the benefits of networking offshore transmission, underscores the importance of early high-voltage direct current technology standards implementation, and advocates for proactive, coordinated approaches to offshore wind transmission planning (Brinkman et al. 2024).

These initiatives underline the commitment of stakeholders to facilitate the integration of offshore wind energy into the U.S. grid, highlighting the importance of efficient planning, cost-effectiveness, and collaboration across regions.

3 Global Offshore Wind Energy Development

This section explores offshore wind energy development for both fixed-bottom and floating technologies in key markets around the world. A summary of global offshore wind activity as of Dec. 31, 2023, is presented first, followed by forecasts for growth and country-specific offshore wind deployment goals.

3.1 Global Offshore Wind Energy Industry Current Status

3.1.1 Aggregate Global Deployment Summary

In 2023, 6,326 MW of offshore wind energy were deployed globally, bringing total installed capacity to 68,258 MW across 319 operating projects and more than 13,096 operating offshore wind turbines (Figure 13). This growth in cumulative operating capacity represents an increase of 10.2% compared to the end of 2022.[26]

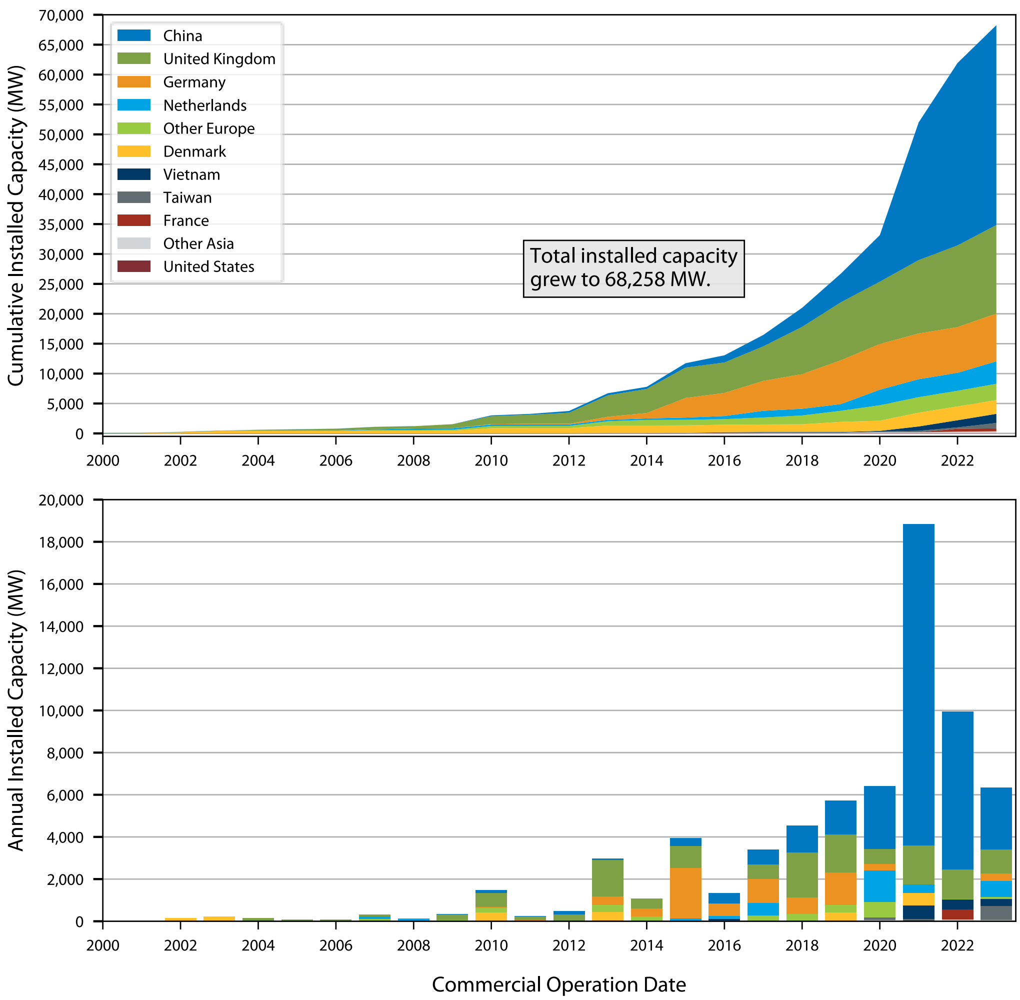

Figure 13. Global cumulative offshore wind energy deployment (top) and annual capacity additions (bottom) through Dec. 31, 2023

[26] For details on year-over-year global pipeline accounting updates, see Appendix B.

The amount of capacity installed in 2023 represents the fourth largest annual installed capacity ever (with only the prior three years higher). The year 2021 was exceptional because many projects in China sought to qualify for government-sponsored feed-in tariff incentives that expired at the end of 2021 (Barla 2023). Figure 14 shows the 2023 additions of offshore wind energy by country.

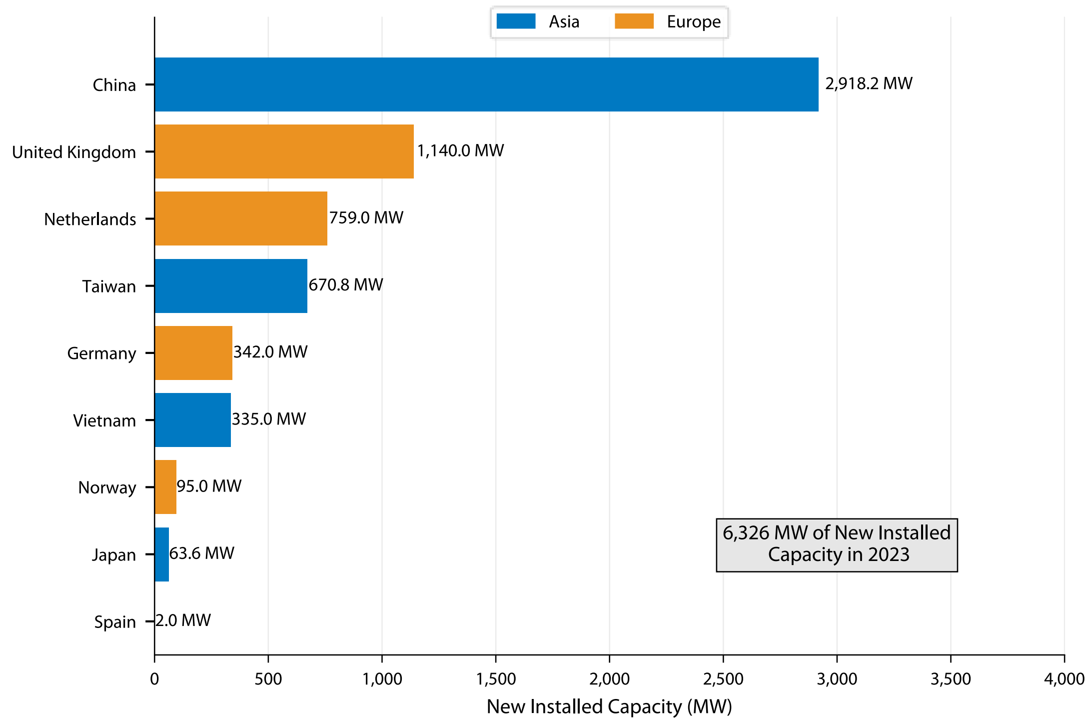

Figure 14. Global offshore wind energy installations in 2023

Of the 6,326 MW new installed capacity in 2023, nearly half (46.1%) was commissioned in China, totaling 2,918.2 MW. The United Kingdom was the next largest contributor, with 1,140 MW of new installations, followed by the Netherlands (759 MW), Taiwan (670.8 MW), Germany (342 MW), and Vietnam (335 MW). Norway, Japan, and Spain installed 160.6 MW combined in 2023.

3.1.2 Floating Offshore Wind Technology Deployment Summary

Operating floating offshore wind capacity reached 234 MW (91% increase in 2023) due to the successful commissioning of pilot projects. The following floating[27] offshore wind energy projects larger than 1 MW achieved notable installation milestones in 2023:

- The 88-MW Hywind Tampen project in Norway was fully commissioned in August 2023, making it the largest operational floating offshore wind plant in the world (Equinor

[27] Floating offshore wind technology allows wind turbines to be deployed in areas with higher-quality wind resources, in deeper waters (approximately 60 meters [m] or greater), which expands development opportunities, particularly in areas located farther from shore. More than 65% of the total offshore wind resource in the United States occurs over deeper waters; in Europe, that number is 80% (Lopez et al. 2022; Komusanac, Fraile, and Brindley 2019).

2023). There are 11 SG 8.0-167 direct-drive turbines operating at the project (Siemens Gamesa Renewable Energy [SGRE] 2019).

- The 25-MW Provence Grand Large pilot project installed three turbines (8.4-MW Siemens Gamesa turbines) on tension-leg floating platforms near Marseille, France (SBM Offshore 2023).
- The 3.6-MW Guoneng Sharing pilot project installed a single turbine on a semisubmersible platform near Longyuan Nanri Island in China (Shanghai Electric 2023; M. Lewis 2023).
- The 2-MW DemoSATH demonstration project in Spain achieved first power in September 2023 (RWE 2023).
- The China National Offshore Oil Corporation Limited connected a Mingyang Smart Energy MySE 7.25-MW wind turbine on a semisubmersible platform to the grid of the Wenchang oilfield in May 2023 (Buljan 2023a; China National Offshore Oil Corporation 2023).

3.1.3 Total Global Offshore Wind Energy Pipeline

Figure 15 shows the capacity of the global offshore wind energy pipeline for all operating projects and projects under development by region through Dec. 31, 2023. The total capacity was assessed to be more than 453 GW, an increase of 27 GW (6.3%) compared to the approximately 426 GW reported in the in the *Offshore Wind Market Report: 2023 Edition* (Musial et al. 2023).

Figure 15 gives overall announced capacity for all active projects recorded in the NREL OWDB, but it does not provide information about the likely timing or probability of developments within the long-term pipeline. Generally, projects that are further along in the pipeline are more likely to reach their announced COD and maintain their announced capacity than those at an earlier stage; however, differences in international regulatory structures can result in a wide range of development timelines.

The global project pipeline data indicate that most installed projects and those under advanced development are in Europe and China; however, a significant portion of potential future capacity is moving forward in the United States and Oceania. Overall, European projects still dominate the future project pipeline.

By project status, the global pipeline includes 23.5 GW of projects in site control, more than 82 GW of projects in the permitting stage, and more than 35 GW of projects under construction. Globally, there are 68.3 GW of operational offshore wind energy projects.

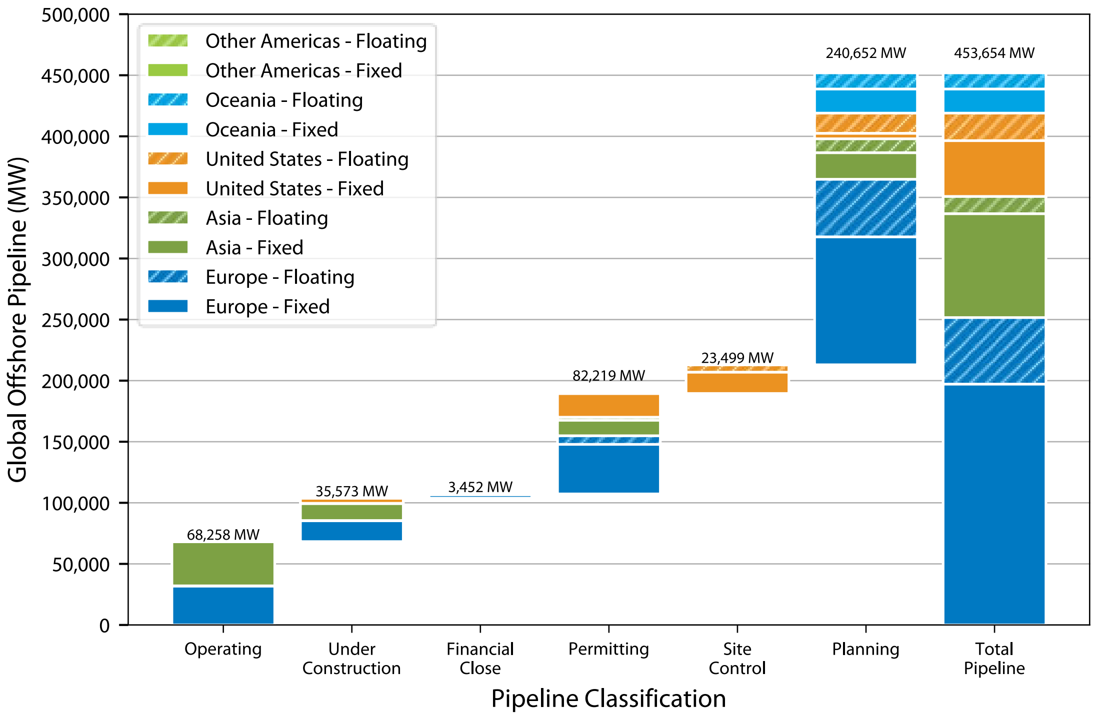

Figure 15. Total global offshore wind energy pipeline by regulatory status

3.1.4 Floating Offshore Wind Energy Pipeline

Figure 15 also includes the floating offshore wind energy pipeline. Compared with what was reported in the *Offshore Wind Market Report: 2023 Edition* (Musial et al. 2023), the global floating offshore wind energy pipeline grew 1.8% to 104,399 MW because of the Gulf of Maine lease area announcements; otherwise, 10% of the capacity had been delayed and was recharacterized in the planning stage.

In the near-term floating offshore wind pipeline (through 2029), there are approximately 323 MW of projects under construction, a 27.5% drop compared to 2022 that can be explained by capacity coming online without more projects reaching the construction phase in 2023. The capacity in the permitting phase increased from 218 MW in 2022 to 9,507 MW in 2023—a more than fortyfold increase driven by projects advancing in Sweden and the United Kingdom. Most of the global floating offshore wind energy pipeline remains in the planning stage, reflecting the nascent stage of floating offshore wind technology. Considering projects with CODs after 2029, the total capacity of floating projects in the planning stage is 88,296 MW. Note that more than 6,000 MW of projects in the United States are in the site control phase because of the December 2022 lease auction in California. Appendix B includes a table showing the breakdown of floating offshore wind energy projects by project phase for 18 countries.

3.2 Announced Deployment Through 2029

To help identify trends in offshore wind energy markets by country or region, we compiled offshore wind deployment projections based on announced project CODs through 2029 using NREL's OWDB.

3.2.1 Announced Projects

Data for projects under construction provide a reasonable basis for understanding near-term deployment because confidence that a project will achieve its announced COD is significantly higher once it reaches financial close and is engaged in construction. Figure 16 shows the distribution of 35,573 MW of projects by country that were under construction as of Dec. 31, 2023.

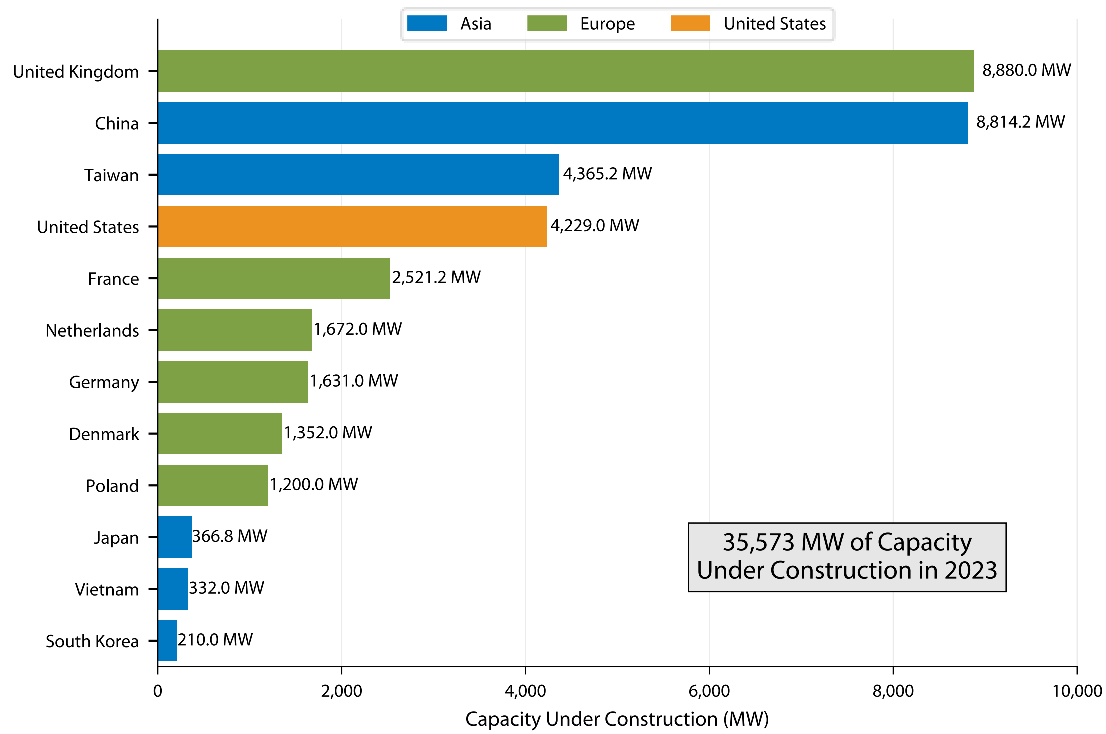

Figure 16. Offshore wind energy capacity under construction by country as of Dec. 31, 2023

The data indicate that there was approximately 64% more capacity under construction in 2023 compared with what we reported for 2022 (21,717 MW) in the *Offshore Wind Market Report: 2023 Edition* (Musial et al. 2023). This growth between 2022 and 2023 is attributable to:

- 5,745 MW of capacity that was supposed to have been completed in 2023 but is now estimated for completion in 2024
- An additional 1,875 MW that have been pushed out beyond 2024
- 19,889 MW of projects that have entered the construction phase.

Regionally, Europe had the greatest share of capacity under construction (48.5%), totaling nearly 17,256 MW across 25 projects. Of these, eight projects were in the United Kingdom (totaling 8,880 MW), eight projects were in France (2,521 MW), three projects were in the Netherlands (1,672 MW), three projects were in Germany (1,631 MW), two projects were in Denmark (1,352 MW), and one project was in Poland (1,200 MW).

The North American region was the third largest market for offshore wind energy projects under construction. Although this market significantly lags Europe and Asia with only 4,229 MW (four projects) under construction, the large pipeline of more than 80,000 MW in the United States signals rapid growth later this decade and beyond.

At the end of 2023, 45 projects were under construction in Asia, totaling 14,088 MW. China had the most capacity under construction, with 8,814 MW (22 projects), which is 92% more capacity than a year earlier. Taiwan had 4,365 MW (12 projects), Japan had 367 MW (three projects), Vietnam had 332 MW (five projects), and South Korea had 210 MW (three projects).

Figure 17 shows cumulative offshore wind installations for all projects based on developer-announced CODs. The chart shows that offshore wind energy deployment could reach more than 193 GW by 2029, an increase of more than 11 GW compared to what we reported through 2022 in the *Offshore Wind Market Report: 2023 Edition* (Musial et al. 2023).

Developer expectations in the figure suggest that the industry is likely to install more capacity in 2024 than in 2023.

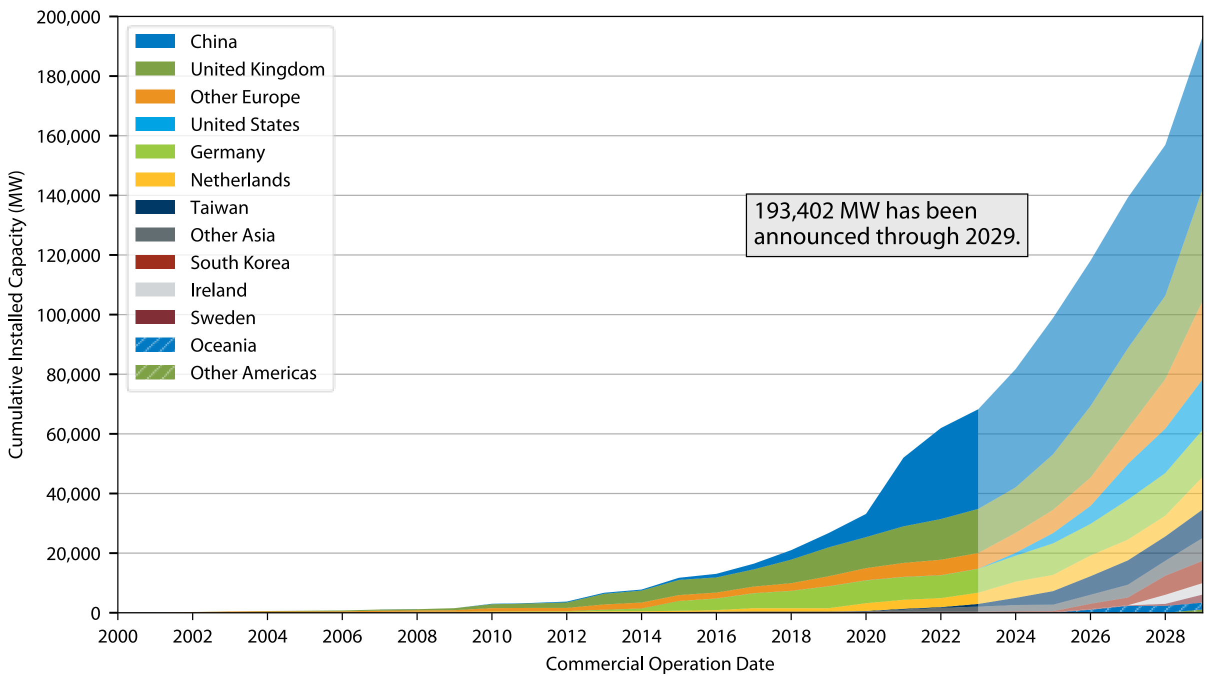

Figure 17. Estimated cumulative fixed-bottom and floating offshore wind capacity by country based on developer-announced CODs.

Note: the darker areas represent existing deployed capacity, and the lighter areas represent projected deployments based on developer-announced CODs.

3.2.2 Announced Floating Projects

Figure 18 shows the estimated cumulative deployment of floating offshore wind energy by country through 2029 for all projects with an announced COD in NREL's OWDB. The data indicate that as much as 14,186 MW may be installed by 2029 based on developer-announced CODs. Most of these projects are still in the planning phase; therefore, there is a high degree of uncertainty about their timing and likelihood of completion. The potential surge after 2028 indicates the transition from pilot-scale to commercial-scale projects. Most of the developer-announced deployment through 2029 is in the United Kingdom (4,242 MW), Italy (4,160 MW), Taiwan (1,530 MW), China (1,052 MW), and Spain (995 MW). Most other near-term floating offshore wind deployment estimates are evenly spread throughout multiple countries in Europe.

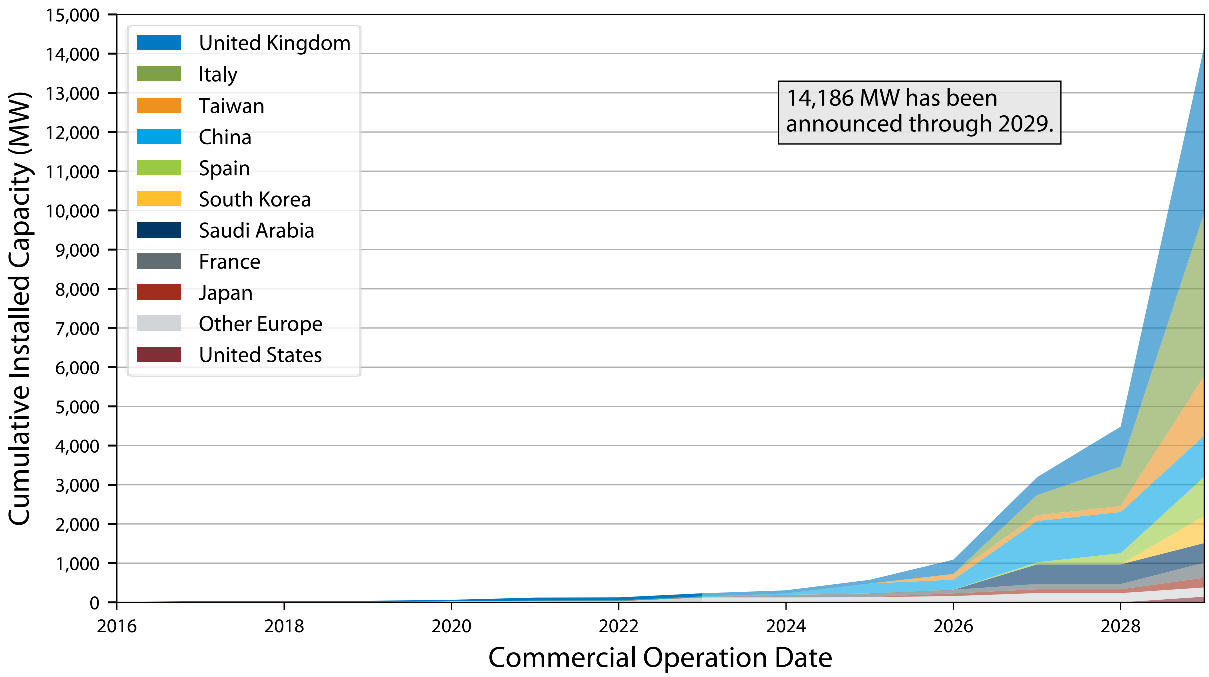

Figure 18. Estimated cumulative floating offshore wind capacity by country based on announced CODs through 2029

3.3 Country-Specific Offshore Wind Energy Markets

Government renewable energy objectives play a key role in driving the expansion of offshore wind energy. Despite encountering challenges such as permitting delays, transmission constraints, supply chain logistics, and cost increases, pursuing these objectives not only enhances public awareness and support but also fosters improved planning and collaboration among diverse stakeholders (Richard 2024). Furthermore, targets have the potential to catalyze investment, reduce costs, and provide guidance, thereby aiming to ensure lasting stability. In this section, we have compiled a broad spectrum of offshore wind energy targets from various countries, illustrated in Figure 19. Some targets are legally binding like those in Greece, and others are not presently legally binding, such as the U.S. target. Additionally, Tables A-1, A-2, and A-3 (Appendix A) present national deployment objectives and procurement targets for the United States, and countries in North and South America, Oceania, Europe, and Asia.

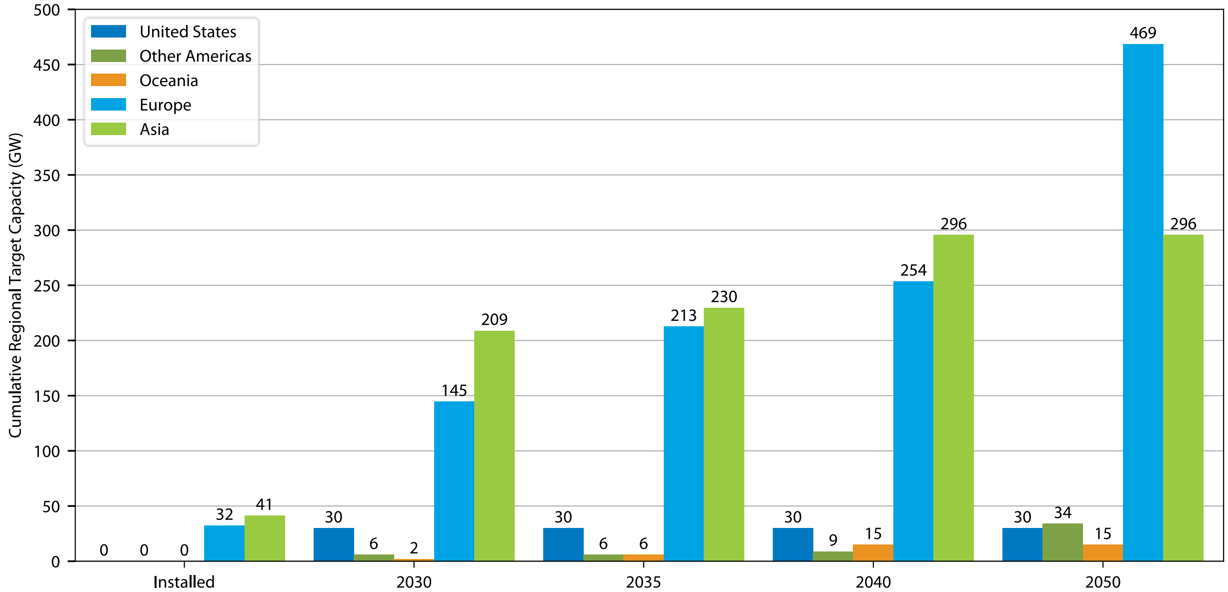

Figure 19. Total regional offshore wind energy targets

4 Offshore Wind Energy Technology Trends

Globally, projects continue to be built in deeper waters farther from shore. This indicates technology is improving to overcome siting challenges. Monopiles remain the dominant choice for fixed-bottom offshore wind projects, but other options like jacket and gravity-base substructures are being used by projects in areas with different soil conditions. Novel floating offshore wind technologies are also enabling new regional markets to evolve and other markets to expand into deep-water regions with strong wind resources.

Offshore wind turbines have grown substantially over the last decade as intense competition pushed developers to reduce project costs and original equipment manufacturers (OEMs) sought a form of product distinction. In 2023, industry debate over the merits and pace of this turbine "upsizing" grew more public and presented new challenges to the financial sustainability of the sector (see Section 5). Despite this, the pipeline of offshore wind projects is larger than ever as countries around the world increasingly turn to offshore wind energy technology to help meet their climate goals.

4.1 Global Offshore Wind Energy Siting Trends

Figure 20 and Figure 21 summarize global offshore wind energy project siting trends over time and by region in terms of project distance to shore and water depth.

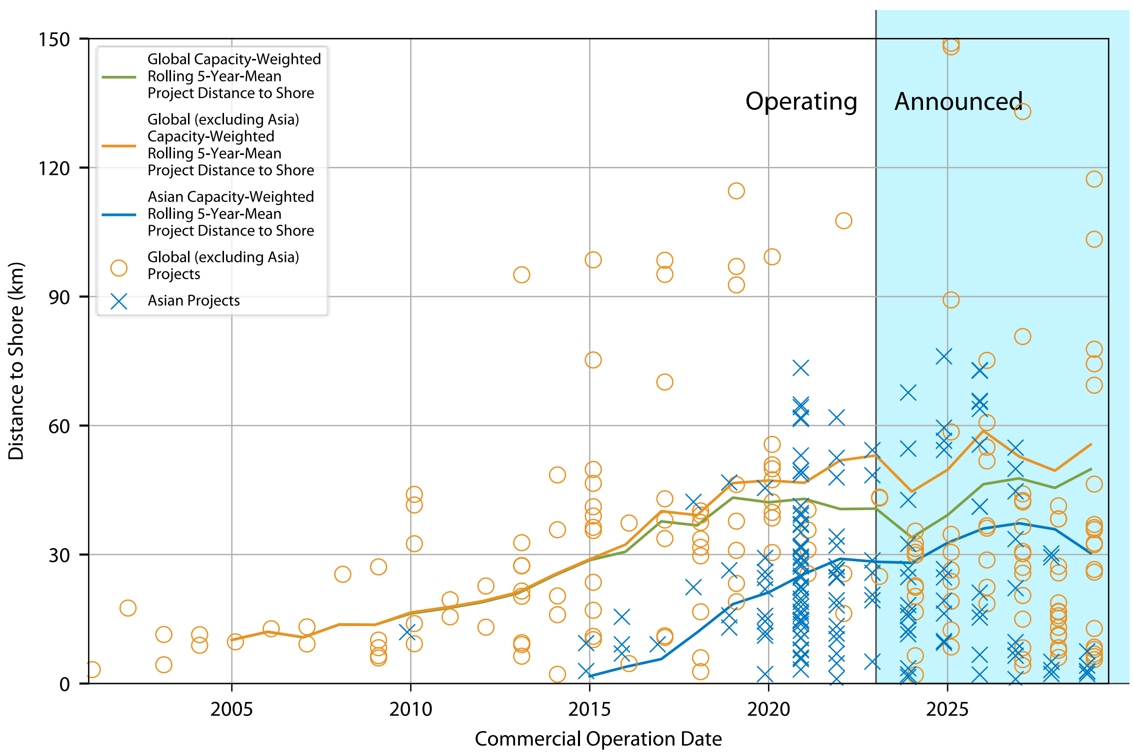

Figure 20. Distance to shore for global offshore wind energy projects (excludes floating)

Figure 20 illustrates how global projects have been installed farther from shore over time. This trend was flat in 2023 after a slight dip in the global capacity-weighted average distance from shore in 2022, which was largely due to the volume of nearshore projects coming online in

China. Projects in Asia have generally been installed closer to shore than in the rest of the world (less than 30 km vs. 50 km on average). The operational project with the greatest distance to shore in the NREL OWDB is the Hornsea I Project in the United Kingdom at nearly 115 km. For announced projects through 2028, the data indicate that projects in Asia are approaching but not yet converging with the global average distances from shore in other regions. For the rest of the world, projects coming online in the Netherlands, Denmark, France, Germany, and the United States are all less than 40 km from shore—leading to the drop in global average distance from shore through 2028. This appears to diverge in 2029, but there is a greater degree of uncertainty for projects with later CODs.

Figure 21 presents maximum project water depth for fixed-bottom projects through 2029. To date, the deepest operational fixed-bottom offshore wind turbine is installed on a jacket substructure in water that is 58.6 meters (m) deep at the Seagreen project in Scotland (Seagreen Wind Energy Limited 2023).

The data from announced projects suggest that fixed-bottom projects could be installed in maximum water depths of up to 65 m in the coming years. As observed with distance to shore, projects in Asia have generally been constructed in shallower waters than in the rest of the world (mainly Europe) to date, though projections for announced projects indicate that water depths for projects in this region may approach convergence with the global average water depth (about 38 m) in 2027.

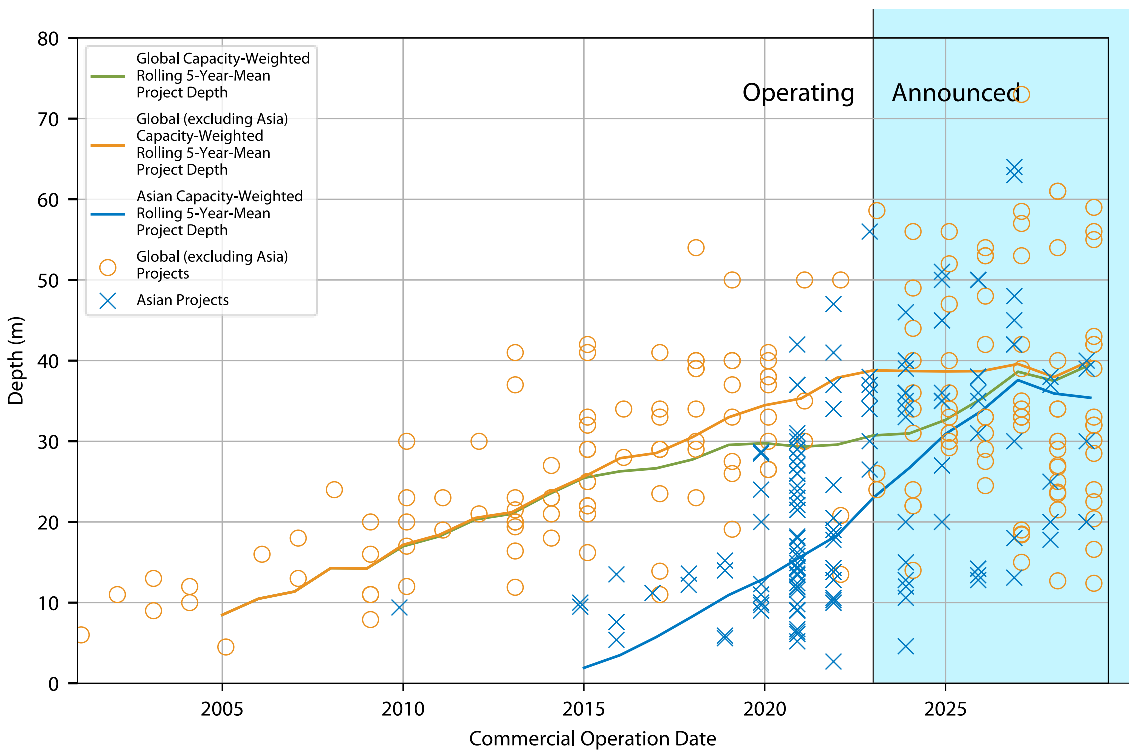

Figure 21. Maximum water depths for global fixed-bottom offshore wind energy projects (excludes floating)

4.2 Offshore Wind Energy Substructures

Most of the world's operational offshore wind capacity is installed on fixed-bottom substructures. Floating substructure technologies, which are connected to the seabed with anchors or piles and mooring lines or tendons, are rapidly maturing, as demonstrated by multiple operating demonstration-scale floating projects around the world. Figure 22 presents the substructure technology mix for operational projects worldwide.

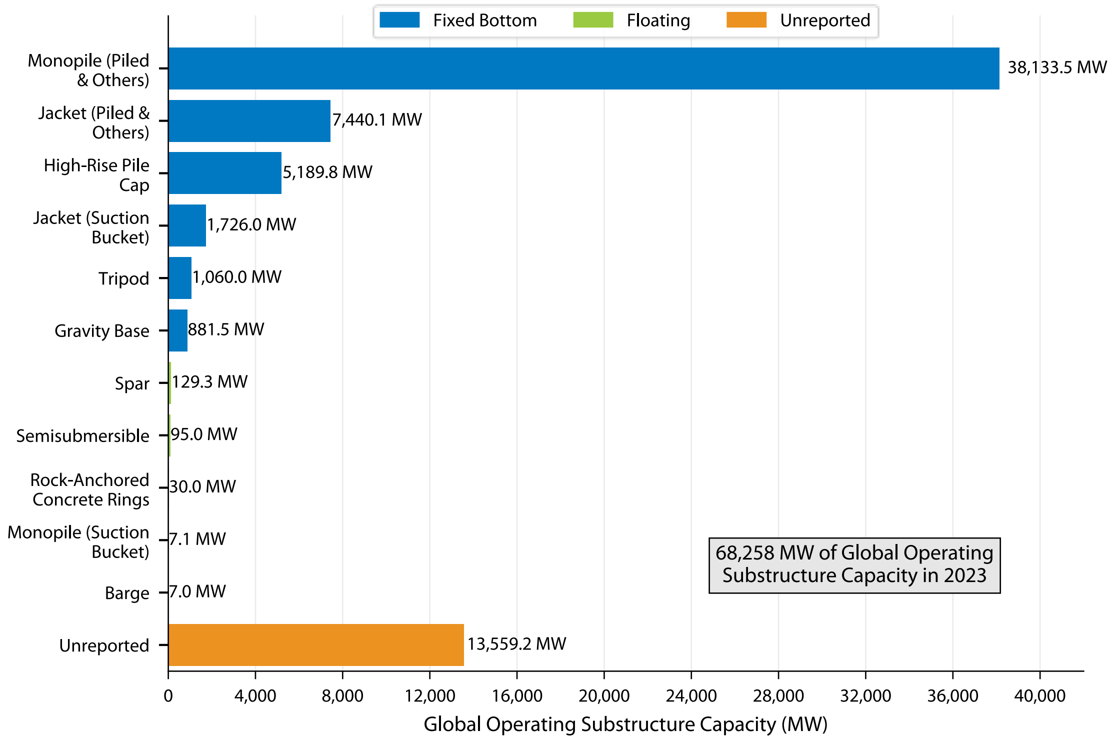

Figure 22. Offshore wind substructure technology types used in operating projects

Monopiles are the most common substructure type for installed offshore wind energy projects. Of the 68,258 MW of operational projects, monopiles represent more than half (55.6%), followed by jackets (13.4%), pile caps (7.6%), gravity-base (1.3%), and tripod (1.6%) designs; about 19.9% are unreported in the current database as of Dec. 31, 2023. Pile cap substructures are more common in Asia than Europe and include multiple piles driven into the seabed, joined by a cap to which the wind turbine tower is mounted (Wang et al. 2018).

Figure 23 examines substructure technologies for the 72,027 MW of future projects (16% of the pipeline capacity) that have publicly announced substructure choices, including both fixed-bottom (blue bars) and floating (green bars) technologies. The figure demonstrates that monopiles are expected to remain the dominant choice—with a 75.4% share of announced capacity—even as floating technologies are commercialized. Jacket substructures are expected to claim 8.8% of the announced market. With the growing pipeline of floating projects, semisubmersibles are expected to represent 14.2% share of the announced market for all substructure types.

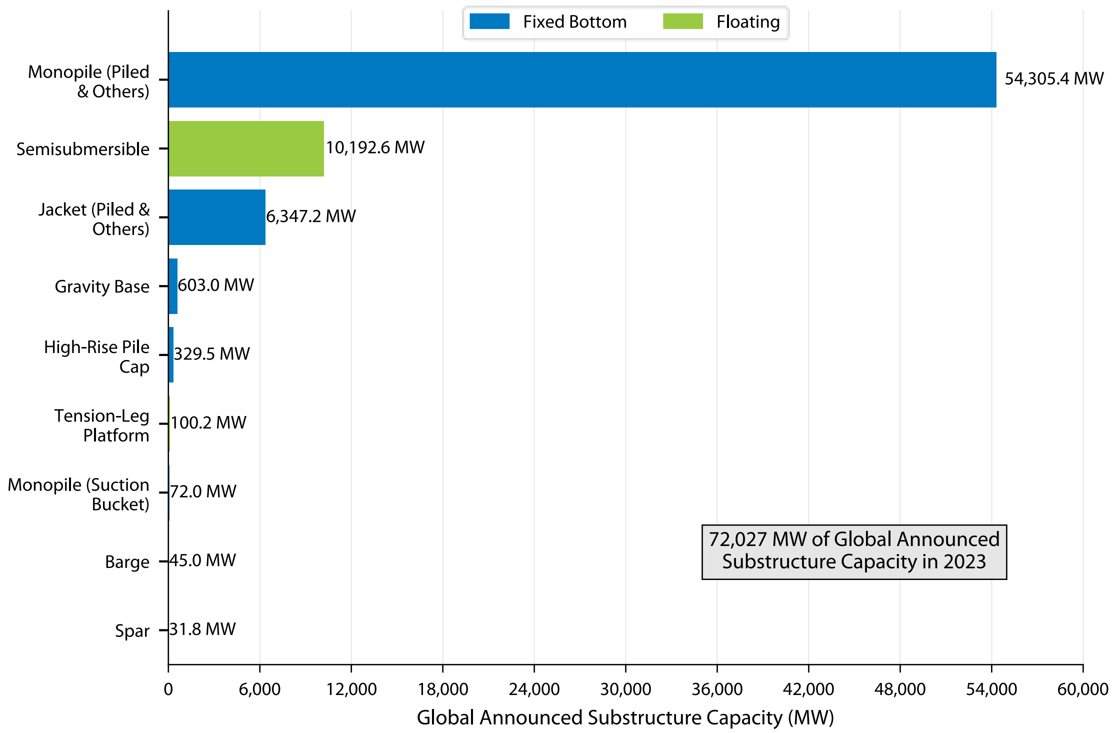

Figure 23. Announced offshore wind substructure technology for future projects

The prevalence of monopiles is largely due to the simple design and industrialization of the manufacturing process. The supply chain for monopile fabrication is the most mature and has been replicated globally, making it more cost-competitive through standardized processes and serial production. The dominance of monopiles in the future could be limited by siting projects in deeper waters, continued wind turbine upsizing and installation vessel availability, unsuitable soil types at new project locations, construction noise restrictions, and preferences for domestic content (Mathern, von der Haar, and Marx 2021; Foxwell 2023b).

Although monobuckets, or "Monopile (Suction Buckets)" as listed in Figure 23, only have 72 MW of announced capacity, BOEM approved testing of the substructure technology in the Beacon Wind Lease Area (BOEM 2024b). With this technology, suction buckets are lowered to the seafloor where water is pumped out of the bucket to embed the substructure. The process avoids the noise created by pile driving, which can pose problems for marine mammals (BOEM 2021).

Floating offshore wind energy projects are expected to move from the multiturbine demonstration scale (10 MW to 50 MW) to the commercial scale (greater than 500 MW) in the next several years. While there are as many as 135 floating substructure concepts vying for market share in the pipeline of future projects, they are broadly classified as semisubmersibles, spars, tension-leg platforms, or barges (Wood Mackenzie 2024b). Each design typology has trade-offs impacting the substructure's depth below the waterline (the draft), hydrodynamic stability, and ease of installation and repair. Semisubmersibles are the prevalent choice in both operational and announced floating offshore wind projects because of relatively shallow drafts and good stability after the wind turbine is installed on the platform. They can be assembled in port and towed out to the project location without relying on heavy-lift WTIVs. Spars are also hydrodynamically stable after installing a wind turbine but require deeper drafts to accommodate a large portion of the platform under the water surface; these deep drafts are only available at a limited number of ports globally (e.g., Norwegian fjords). Tension-leg platforms are challenging to install, but the small anchor footprint may allow for greater project capacity densities in deeper water (Cooperman et al. 2022; Mulas Hernando et al. 2023).

4.3 Offshore Wind Turbines

Figure 24 highlights how offshore wind turbine generator ratings, rotor diameters, and hub heights have increased over time. Global installations in 2023 had a capacity-weighted-average turbine rating of 9.7 MW (26% year-over-year increase), rotor diameter of 183.4 m (5% year-over-year increase), and hub height of 124.0 m (6% year-over-year increase).

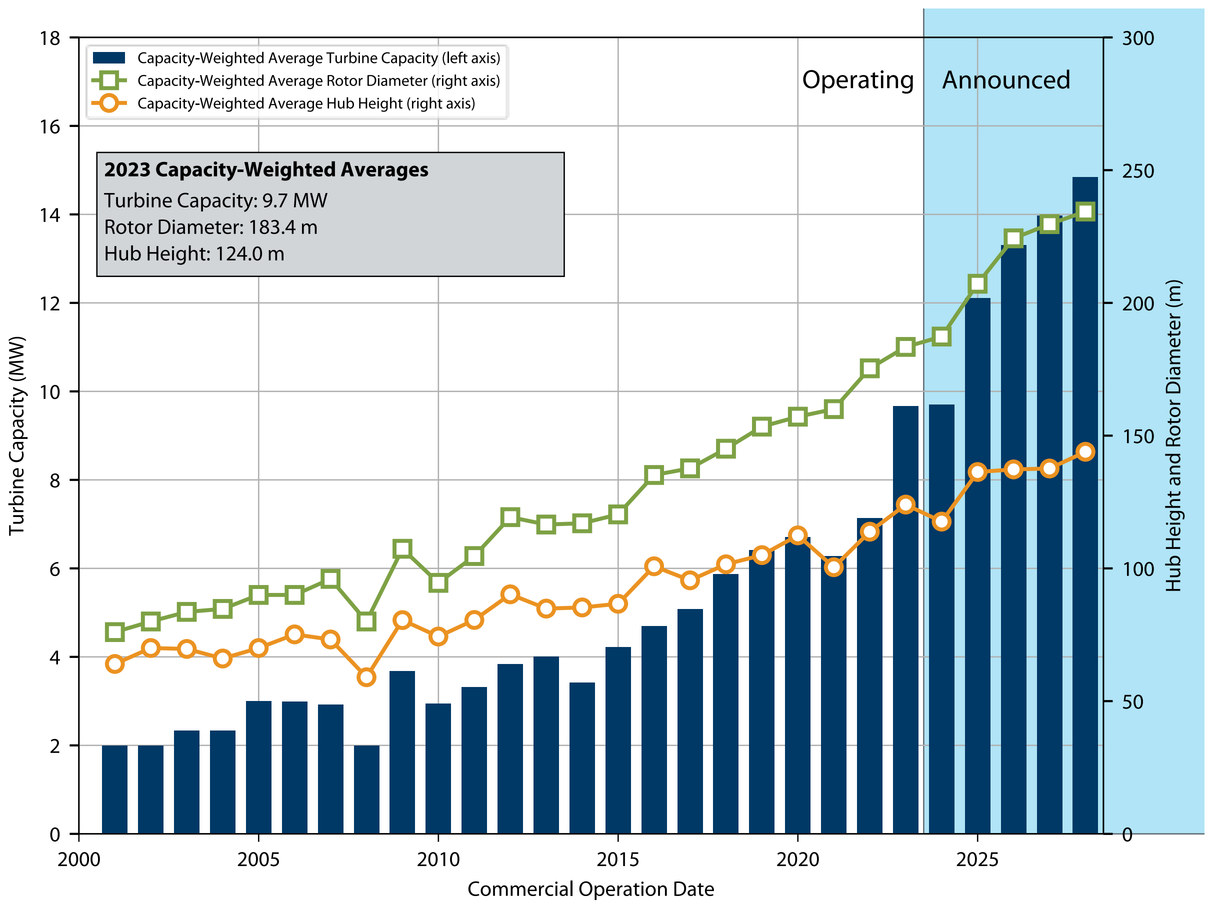

Figure 24. Global average offshore wind turbine capacities, hub heights, and rotor diameters

Historically, the primary driver for this turbine upsizing trend has been cost reductions realized through fewer turbine positions for the same project capacity (Shields et al. 2021); however, in 2023 there were public statements from industry participants regarding the pace at which turbine upsizing should occur.

Sif Netherlands B.V., an offshore foundation manufacturer, called for a temporary pause to turbine upsizing, raising concerns about the risks of providing timely delivery of foundations for larger turbine sizes (Sif Netherlands B.V. 2023). Meanwhile, Western turbine OEMs such as GE Vernova and Vestas are also taking public positions in this debate. GE Vernova is pivoting toward a product with a 15.5-MW rating around which it can center its Haliade-X platform business (U.S. Securities and Exchange Commission 2024). Similarly, Vestas is focusing on ramping up operations in anticipation of the debut of its 15-MW model, which is expected for initial deliveries in 2025 (Vestas 2024).

However, not all Western turbine OEMs have called for changes to the pace of offshore wind turbine upsizing. Filings to the European Commission indicate that Siemens Gamesa has secured grants to develop and deploy what was announced as the "world's most powerful" offshore wind prototype and plans to start operations in early 2025 (European Commission 2023). A specific rating has not been publicly disclosed by Siemens Gamesa.

In contrast to Western counterparts, Asian turbine OEMs show no signs of slowing down their pursuit of larger turbines. Mingyang Smart Energy announced plans in October 2023 to develop a 22-MW offshore wind turbine; in December 2023 they announced that they will produce components for an 18–20-MW turbine at their manufacturing base in Shanwei, China (Memija 2023c; Durakovic 2023b). This divergence in OEM activity underscores how rapidly the Chinese turbine manufacturers have scaled product offerings in recent years. Wood Mackenzie warns that China's accelerated new product introduction might not be sustainable for all involved due to rising quality concerns and warranty expenses, and advocates for a balance between standardization and innovation to ensure long-term viability in the industry (Wood Mackenzie 2024a).

While the global capacity-weighted-average turbine rating has yet to exceed 10 MW, wind turbines of up to 13 MW were operating at commercial-scale projects in Europe and North America in 2023 and early 2024, including first powers of 11-MW turbines in Hollandse Kust Noord (Netherlands) and South Fork Wind (United States) and first powers of 13-MW turbines in Dogger Bank (United Kingdom) and Vineyard Wind 1 (United States) (Memija 2023a; NYSERDA 2023a; General Electric 2023; Copenhagen Offshore Partners 2024). In addition, U.S. projects are set to commission turbines with ratings greater than the global weighted-average turbine rating in the coming years. Projects under construction such as Revolution Wind and Coastal Virginia Offshore Wind (Commercial), plan to install turbines with capacities of 11 MW and 14 MW, respectively (Durakovic 2021; SGRE 2020).

Figure 25 illustrates the upscaling trend for offshore wind turbines by comparing the dates of operational prototypes with annual capacity-weighted installed turbine ratings over time. Only wind turbine prototypes that could be verified as operational in a given year are included in the figure. Note that the newest prototypes deployed in 2023 are shown on the right side of the line between "announced" and "operating," which represents approximately the end of 2023. Also note that most prototype data are plotted above the average capacity-weighted turbine capacity bar for the year in which they were installed. The data are staggered horizontally only to allow multiple points to be plotted for the same generator capacity in the same year.

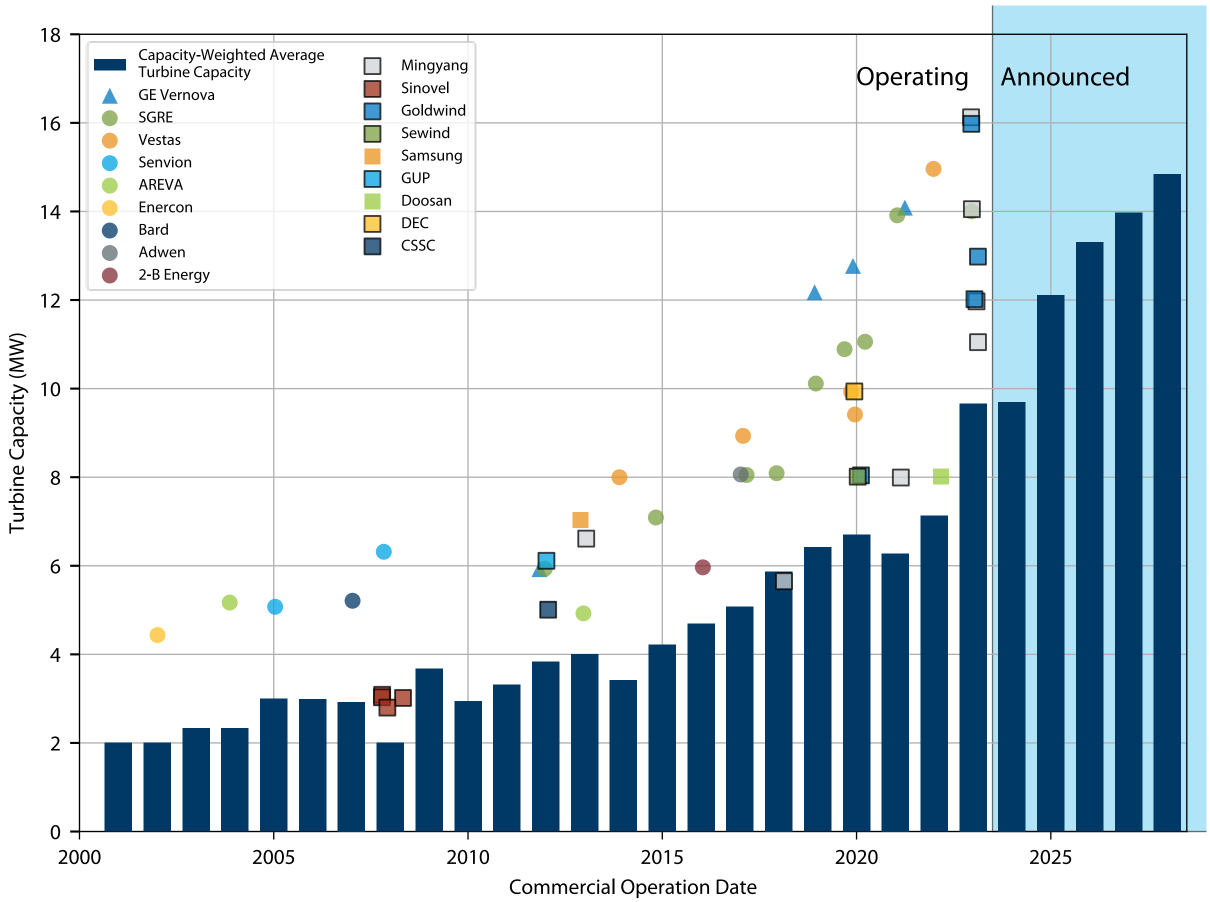

Figure 25. Comparison of offshore wind turbine prototypes with commercial offshore wind turbine capacity growth.

Note: In the figure, GE is General Electric, SGRE is Siemens Gamesa Renewable Energy, CSSC is China State Shipbuilding Corporation, DEC is Dongfang Electric Corp., and GUP is Guodian United Power Technology Co. Ltd.

The 11-MW Siemens Gamesa (SGRE) and 13-MW GE Vernova turbine models, which produced power in 2020 as prototypes (Figure 25) have produced power for the first time in large-scale projects in 2023 and early 2024, both in Europe and North America. The Vestas 15-MW model, which produced its first power near the end of 2022 as a prototype (Figure 25), was type-certified by the end of 2023 and is expecting its first deliveries in 2025 (Memija 2023b; Vestas 2024). In April 2024, the first of sixty 14-MW Siemens Gamesa turbines (with 222-m diameter and power boost technology to generate up to 14.7 MW) was installed in Scotland (Durakovic 2024). This model produced power for the first time as a prototype in 2021. These timelines demonstrate that Western turbine OEMs typically require approximately 3 years from the initial power generation of a prototype model to the first power generation at a commercial-scale project, and 3 or more years before the installed average reflects that product.

New prototypes came online in China in 2023. Mingyang Smart Energy's 16-MW model operated at full capacity for the first time in July 2023, and Goldwind's first 16-MW model, which was installed in June 2023, reported record-breaking power production in September 2023 (Buljan 2023b; Durakovic 2023a). Additionally, in June 2024, state-owned Dongfang Electric

Corporation announced the installation of an 18-MW model, which was initially launched in October 2023 (Jenkinson 2024).

Figure 26 presents offshore wind turbine market share by manufacturer for operating projects, and Figure 27 presents market share for announced projects.

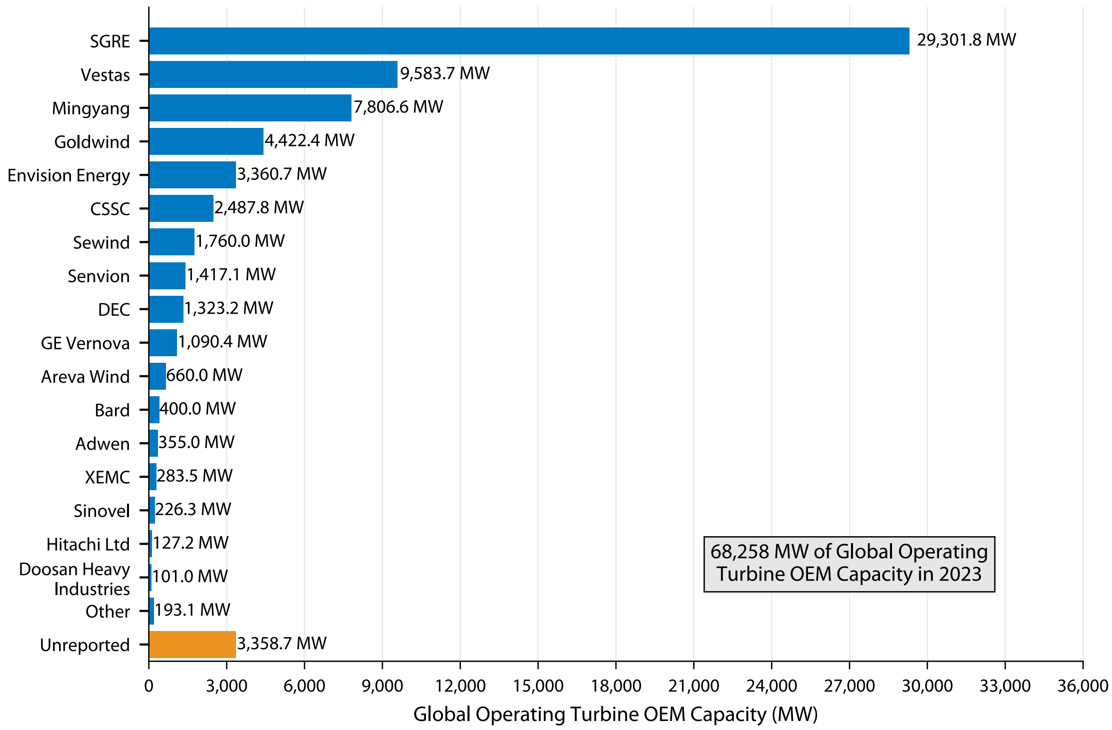

Figure 26. Offshore wind turbine manufacturer market share for operating projects

Figure 26 shows that at least 49.2% of all operational offshore wind capacity is from SGRE. Vestas wind turbines are the next-largest share of the operational market at 14%, followed by Mingyang (11.4%), Goldwind (6.5%), and Envision Energy (4.9%).

Among future projects with announced wind turbine suppliers, which accounts for 12.3% of the future pipeline (see Figure 27), SGRE is expected to hold a 39.4% share of announced capacity, followed by Vestas (32.5%), GE Vernova (18.1%), Doosan Heavy Industries (4.5%), and Mingyang (2.2%). While Chinese manufacturers have focused on the domestic market to date, Mingyang, Envision Energy, Dongfang, Goldwind, Windey, and Harbin Electric have all secured contracts for projects outside China (e.g., Vietnam, Japan, Italy, the United Kingdom, Norway, and France), representing a potential for greater competition in global offshore wind turbine markets (Barla 2023).

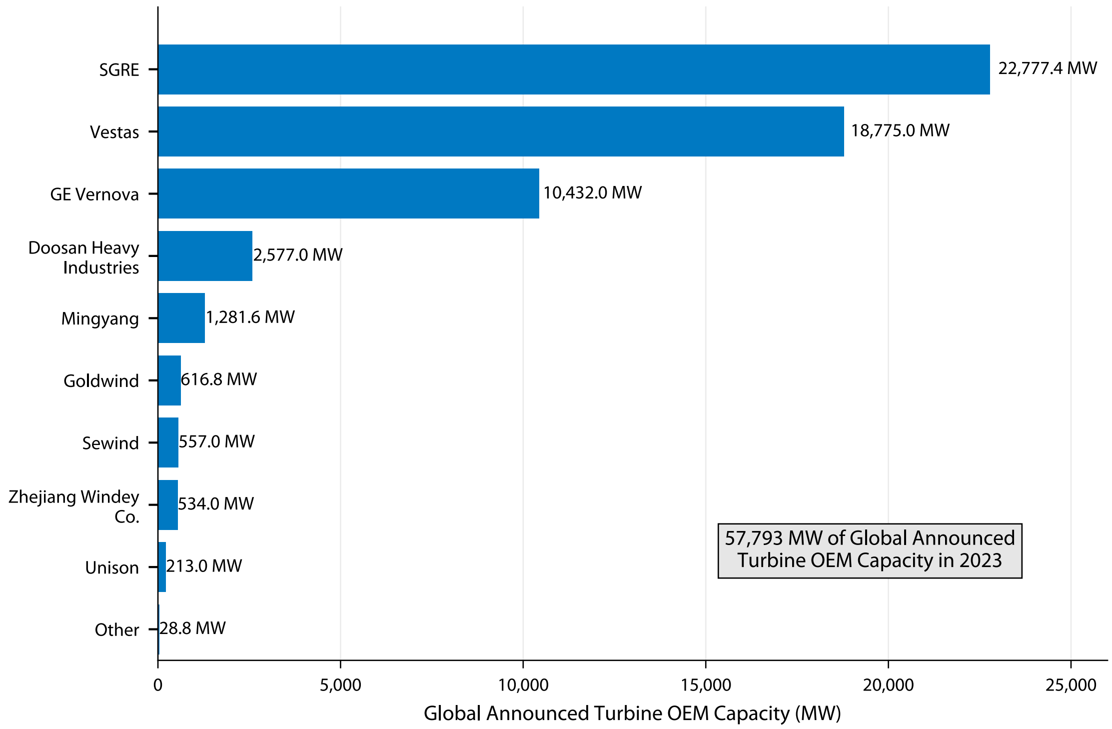

Figure 27. Global offshore wind turbine manufacturer market share for announced projects

4.4 Offshore Wind Technology Summary

The current state of offshore wind energy technology can be summarized as follows:

- Globally, projects continue to be built in deeper waters, farther from shore. This trend indicates technology is evolving to overcome siting challenges.
- Most operational projects have fixed-bottom monopile substructures. Monopiles are still the most common substructure choice for announced projects, both globally and in the United States. The market dominance of monopiles can be attributed to their simplicity and manufacturing maturity, which makes them the lowest-cost option in most markets. However, alternative substructures may be necessary in the supply chain to accommodate seabed soil types unsuitable for monopiles, mitigate construction noise, address potential installation vessel supply shortages, and meet requirements for more domestically manufactured content.
- Floating offshore wind energy represents an opportunity to tap into new markets and stronger wind resources over deeper waters. While there is strong competition among floating substructure designs, most announced floating projects have opted to use some variation of the semisubmersible platform because it is expected to be the easiest to deploy from existing ports.
- Vestas and GE Vernova signaled plans for standardizing around 15 MW of turbine capacity, while Siemens Gamesa has secured European Commission grants to deploy the "world's most powerful" offshore wind prototype, with operations set to begin in early 2025. The Chinese OEM market diverges significantly from standardizing plans, with

ongoing development announcements of turbines ranging from 18 to 20 MW to as high as 22 MW.

- Calls to slow the pace of upsizing grew as concerns about new turbine product reliability and the availability of port, vessel, and manufacturing infrastructure became more apparent, but the costs of delayed industrialization and higher technical risk have not yet been evaluated. Nevertheless, some wind turbine manufacturers claim they are moving to larger turbine nameplate ratings.
- Fierce competition persists among wind turbine manufacturers, even as Western manufacturers faced significant financial challenges, attributing billions of dollars of financial losses to supply chain constraints, geopolitical uncertainty, and warranty provisions.

5 Cost and Price Trends

5.1 Cost and Price Overview

Rising interest rates, supply chain constraints, and higher commodity prices during 2021–2023 have led to higher offshore wind energy costs globally and in the United States. Rising costs affect projects planned for commercial operation between 2023 and 2026 the most because of a lag of at least 1–3 years between the placement of supply chain orders and the start of commercial operations.[28] Projects planned for later commercial operation might be less affected because of the actions taken at the state and federal levels and may have time to wait for macroeconomic conditions to return to prior levels. This section presents cost trends from empirical project data and estimates from leading research organizations for both fixed-bottom and floating offshore wind energy technologies. The cost reporting and figures in this section focus on projects that have attained COD in 2023.

The data sources used in this section report cost trends on a regular basis and are recognized references within the offshore wind and renewables sector with at least a basic level of review and validation. The cost data presented in this section are informed by price data from recent competitive tenders for U.S. projects. Costs are often derived from bottom-up modeling or project market reporting, and price data are sourced from public tenders. When considered together, prices and costs can provide a good perspective on the economics of offshore wind energy. The project sample size varies across the cost and price metrics featured in this section.

5.2 Fixed-Bottom Offshore Wind Energy

5.2.1 Long-Term Cost Trends

For long-term trends in the levelized cost of energy (LCOE) and capital expenditures (CapEx), we rely on estimates published regularly by a set of consultancies and research entities. Reporting by these data providers suggests an unsubsidized LCOE of $125/MWh on average in 2023 (using mid-case estimates) for a hypothetical commercial-scale U.S. offshore wind project.[29] The same sources report a wide range of $75/MWh to $149/MWh across scenarios (Figure 28). These cost differences can often be explained by the represented siting conditions, such as higher wind speeds, closer proximity to port and grid infrastructure, varying financing assumptions, forecast error from a small cost record, and others. These costs represent an average increase of more than 45% when compared to the 2023 edition of this report (Musial et al. 2023). Despite recent cost increases, global offshore wind costs have still declined by more than 50% since 2013 (Moné et al. 2015). Looking ahead, fixed-bottom offshore wind LCOE is forecasted to attain an LCOE of $76/MWh on average by 2035 (using mid-case estimates only) with a narrowing spread between estimates. By 2050 (not plotted in Figure 28), forecasts are more uniform at $50/MWh on average.

[28] For individual components (e.g., high-voltage direct current substations), the lag between supply chain orders and commercial operations can exceed 3 years.

[29] Mid-case estimates refer to a baseline, business-as-usual or “most likely” scenario.

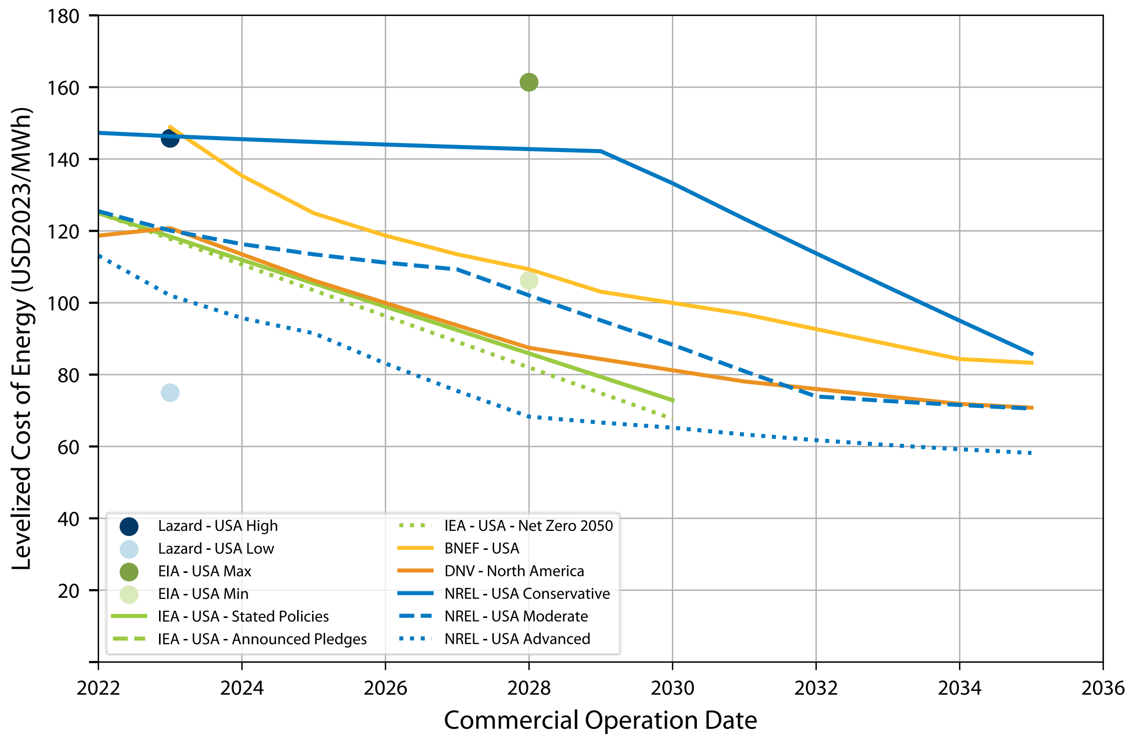

Figure 28. Unsubsidized levelized cost of energy estimates for fixed-bottom offshore wind energy in the United States.

Notes: Cost estimates have been converted into real 2023 USD. LCOE includes transmission expenditures (e.g., for the export cable and substation) but not bulk power system upgrades or tax credit benefits.

Source: Lazard (Bilicic and Scroggins 2023); EIA (U.S. Energy Information Administration 2023); BNEF (BloombergNEF 2024b); IEA (International Energy Agency 2023); DNV (DNV 2023), NREL (NREL 2024).

Many of the sources depicted in Figure 28 seem to represent longer-term cost evolution rather than capture year-to-year changes. In addition, a divergence between cost reporting at the time of commencing commercial operations versus when supply chain contracts are established makes a distinction between short- and long-term trends necessary.

5.2.2 Short-Term Cost Trends

We infer short-term cost trends from changes in recent offtake contract pricing. For the United States, we rely on the price adjustments sought by U.S. developers in 2023, particularly in New York. Price adjustments were sought by project owners across the U.S. Northeast, yet we focus on New York's contract price trends in this section for simplicity and because the state has one of the largest procurement programs for offshore wind. We feature the results of multiple rounds of offshore wind solicitations in New York between 2018 and 2023 (NY1, issued in 2018 and awarded in 2019 through NY4, issued in 2023 and awarded in 2024). U.S. developers have reported a combination of "rampant inflation, global supply chain disruptions, and soaring interest rates" (New York State Public Service Commission 2023b) as the primary causes for higher costs since 2021. As a result, major offshore wind developers in New York have sought amendments to their contracts, including higher OREC prices. Their petitions to state regulatory authorities for contract amendments were uniformly denied (e.g., New York State Public Service Commission 2023b), but they offer some insights into the cost evolution over the past few years.

For instance, compared to earlier contract prices established for the Empire Wind 1 and Sunrise Wind projects in 2018 (New York ORECRPF18-1), recent awards from 2024 (New York ORECRFP23-1) for the same projects suggest an increase of the levelized OREC contract price of 36% and 27%, respectively (Figure 29).[30] Developer petitions to the New York Public Service Commission from 2023 suggest that the incurred cost increases might be even more pronounced for the Empire Wind 2 and Beacon Wind projects. Concurrently, OREC prices released for offshore wind power projects in New Jersey have also shown significant increases. For instance, the OREC first-year (nominal) price for the Attentive Energy Two project was \$131/MWh,[31] and the Leading Light Wind project was priced at \$112.50/MWh[32] (New Jersey Board of Public Utilities 2024b, 2024c; TotalEnergies 2024). These prices, both awarded in 2024, represent a substantial jump from previous OREC prices in New Jersey. For example, Ørsted's earlier New Jersey Ocean Wind 2 project was awarded an OREC first-year (nominal) price of \$83.40/MWh in 2021.[33]

[30] NYSERDA clarified that the reported "all-in development cost" of \$150/MWh is in nominal terms (NYSERDA 2024b).
[31] With an annual escalator of 3%.
[32] With an annual escalator of 2.5%.
[33] With an annual escalator of 2%. Note that New Jersey's introduction of the State Agreement Approach in 2022 could dilute price comparisons between different state procurement rounds.

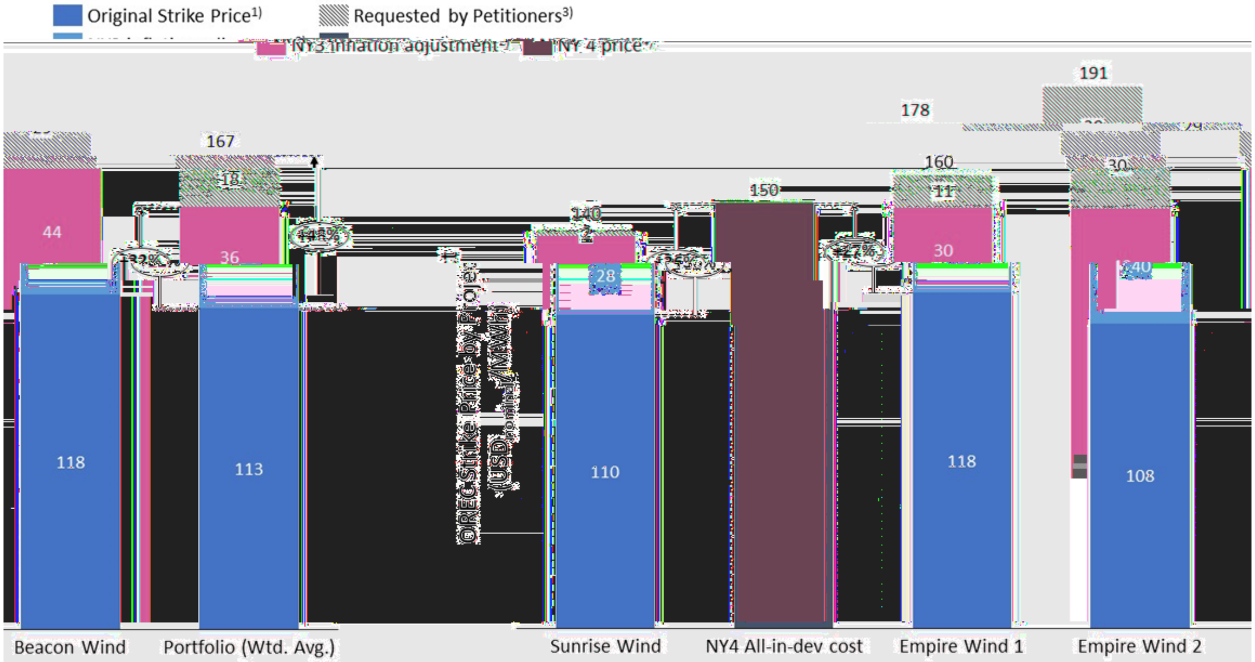

Figure 29. Developers' petitions with the NY PSC suggest offshore wind ORECs in NYSERDA's portfolio (nominal $/MWh) have increased by nearly 50% compared to their initially established contract price.

Notes: (1) Original OREC strike price agreed upon in New York's first OREC Request for Proposal (RFP) held in 2018 (ORECRFP18-1, NY1) and in New York's second RFP held in 2020 (ORECRFP20-1, NY2); (2) OREC strike price based on the inflation adjustment in New York's third OREC RFP (NY3) from 2022; (3) requested OREC price by offshore wind petitioners (i.e., Sunrise Wind, Empire Wind 1, Empire Wind 2, and Beacon Wind); (4) price results of New York's fourth RFP held in 2023 (NY4) (ORECRFP23-1, NY4).

Source: NYSERDA (2019, 2023b, 2024b); New York State Public Service Commission (2023b)

After mid-2020, several key commodities experienced a considerable price increase (Figure 30). Between 2020 and 2024, the Secured Overnight Financing Rate (SOFR, blue line in Figure 30) surged from close to 0% to nearly 5%, mirrored by other debt cost indicators (e.g., 20-year treasuries). Such increase in the cost of debt has a considerable impact on life cycle project costs. During the same period, key offshore wind commodities (Table 11) increased by approximately 34% and 38% for New York's first and second round of offshore wind solicitations (NY1 and NY2),[34] respectively. To address the mismatch between the timing of supply chain contracts and offtake price awards, several states implemented the option for contract awardees to share the risk of commodity price fluctuations with the (utility) offtaker. For instance, New York state implemented an inflation adjustment mechanism for its third large-scale offshore wind solicitation of 2022–2023 (NY 3).

[34] NY1 refers to New York's first offshore wind solicitation published in 2018 (ORECRFP18-1); NY2 refers to New York's second offshore wind solicitation published in 2020 (ORECRFP20-1).

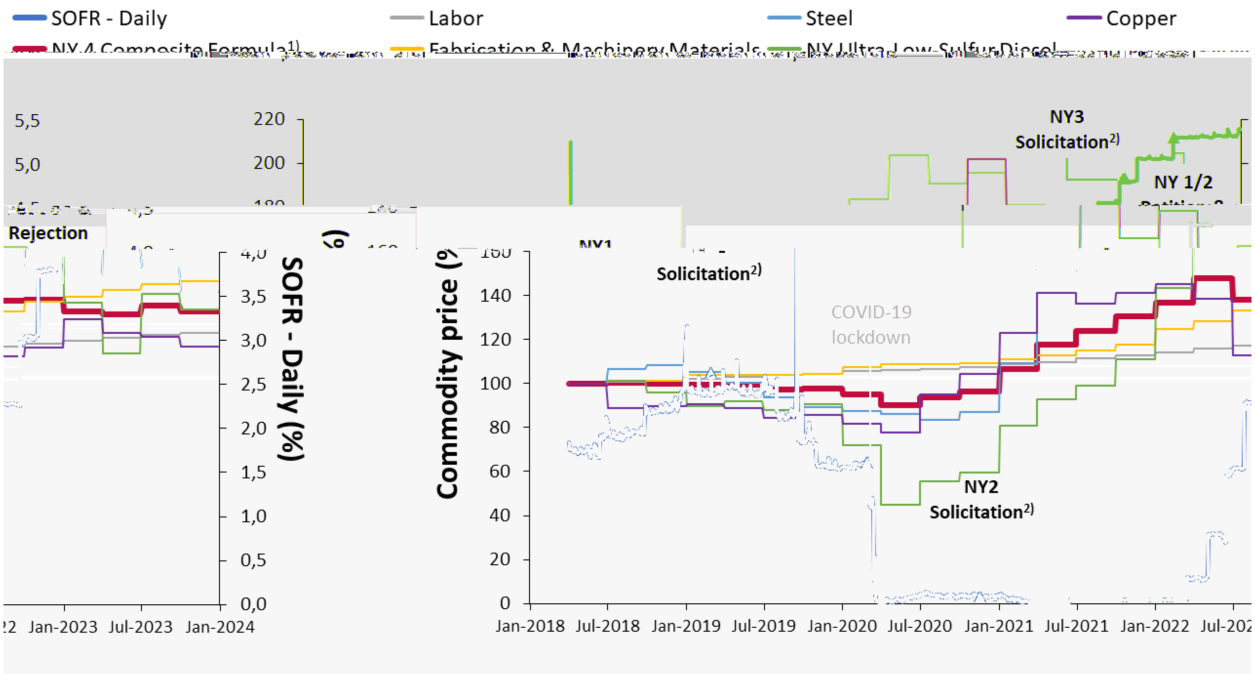

Figure 30. Offshore wind commodity price index (left axis) and SOFR (right axis), 2018–2024.

Notes: (1) NY 4 composite index was calculated based on the NY4 price formula (NYSERDA 2024b); (2) represents the time of offer proposal submission. Quarterly data.

Source: Federal Reserve Bank of St. Louis (2024a, 2024b); NYSERDA (2023b); U.S. Bureau of Labor Statistics (2024a, 2024b, 2024c); U.S. Energy Information Administration (2023)

Table 11. Indicative Change in the Price of Key Offshore Wind Commodities Between the Time of Bid Submission and the Fourth Quarter (Q4) of 2023

Source: Calculated using the inflation index formulas from NYSERDA (2024b)

	NY1 Bid Submission Through Q4 2023[a]	NY2 Bid Submission Through Q4 2023[a]
Labor	+21%	+15%
Fabrication and Machinery Material	+42%	+34%
Steel	+35%	+63%
NY Ultra-Low-Sulfur Diesel	+49%	+125%
Copper	+30%	+12%
Index	**+34%**	**+38%**

[a] Submission deadline for proposals for NY1 was Feb. 14, 2019; submission deadline for proposals for NY2 was Aug. 19, 2020.

5.2.3 Capital Expenditure Trends

CapEx are the single largest contributor to the life cycle costs of offshore wind power plants and include all expenditures incurred prior to the start of commercial operation. In this section, we show the reported CapEx over time for operational projects and for projects in various stages of the near-term project pipeline globally (Figure 31). After a period of increasing CapEx, the capacity-weighted average CapEx for global offshore wind projects has decreased since 2015, with the 5-year rolling average (2019–2023) reaching approximately $3,400 per kilowatt (kW) for projects with a COD in 2023 globally. The 5-year rolling average CapEx for projects in Europe and the United States is reported to be higher, at $3,900/kW. The 5-year rolling average CapEx for projects in Asia is approximately $3,000/kW. While the reported CapEx in 2023 is higher in Europe and the United States than in Asia, the two markets have been converging since 2014.

Reported global project data suggest 5-year rolling capacity-weighted average CapEx globally will remain roughly flat or slightly decline from $3,400/kW in 2023 to between $3,000 and $3,500/kW by the late 2020s, but recent cost increases may not be completely accounted for in these long-term projections. The annual project data (Figure 31) indicate considerable variation of CapEx within a given year.

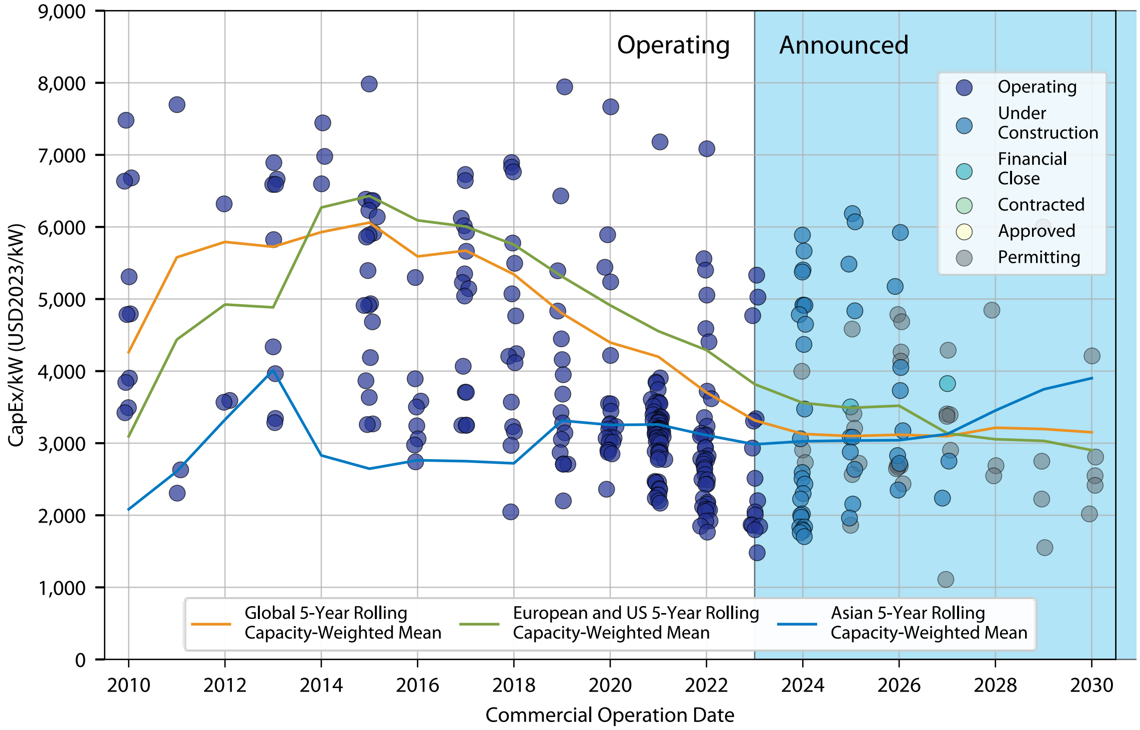

Figure 31. Capital expenditures for global offshore wind energy projects

Several factors contribute to the variations in CapEx within a given year and over time (Beiter et al. 2016), including:

- Varying spatial conditions (e.g., water depth, distance to port, point of interconnection, and wave height of sites that affect technical requirements of installing and operating a wind plant)
- Project scope (e.g., the cost of export cables and interconnection and supply chain commitments may be included in some of the cost data plotted but not others)
- Project size
- Differences in supply chains (e.g., components, vessels, and skilled labor)
- Changing prices for commodities and energy
- Macroeconomic trends, such as fluctuating exchange rates
- A change in the appreciation of the costs and risks associated with offshore wind energy project implementation.

5.3 Floating Offshore Wind Energy Cost Trends

Various research organizations estimate that the unsubsidized LCOE for U.S. floating offshore wind energy projects would decline from approximately $123–$278/MWh in 2030 to $92–$180/MWh in 2035 (Figure 32). This wide range in any given year can be attributed to differing assumptions about whether the costs pertain to commercial or precommercial projects. The cost of floating offshore wind energy technology is currently based on a small set of data from the first phase of demonstration projects. The impact from the recent macroeconomic disruptions on the floating offshore wind energy sector is unclear because most commercial-scale projects are scheduled for commercial operations in the early- to mid-2030s.

In the *Offshore Wind Market Report: 2023 Edition* (Musial et al. 2023), unsubsidized floating LCOE estimates in 2030 ranged from approximately $65/MWh to $135/MWh,[35] whereas in this year's report, 2030 estimates range from about $123/MWh to $278/MWh. This could be the result of several factors, including constrained supply chains, rising costs and interest rates, and delays in floating project planning and permitting, which results in lower levels of expected deployment (AEGIR Insights 2023, 2024). Additionally, NREL's cost projections historically assumed fully mature supply chains for all reporting years. The NREL data presented in Figure 32 were derived with a revised methodology, which represents cost impacts as the floating offshore wind energy industry matures, and which presents costs from the early 2030s when the first gigawatt-scale projects could feasibly be constructed in the United States.

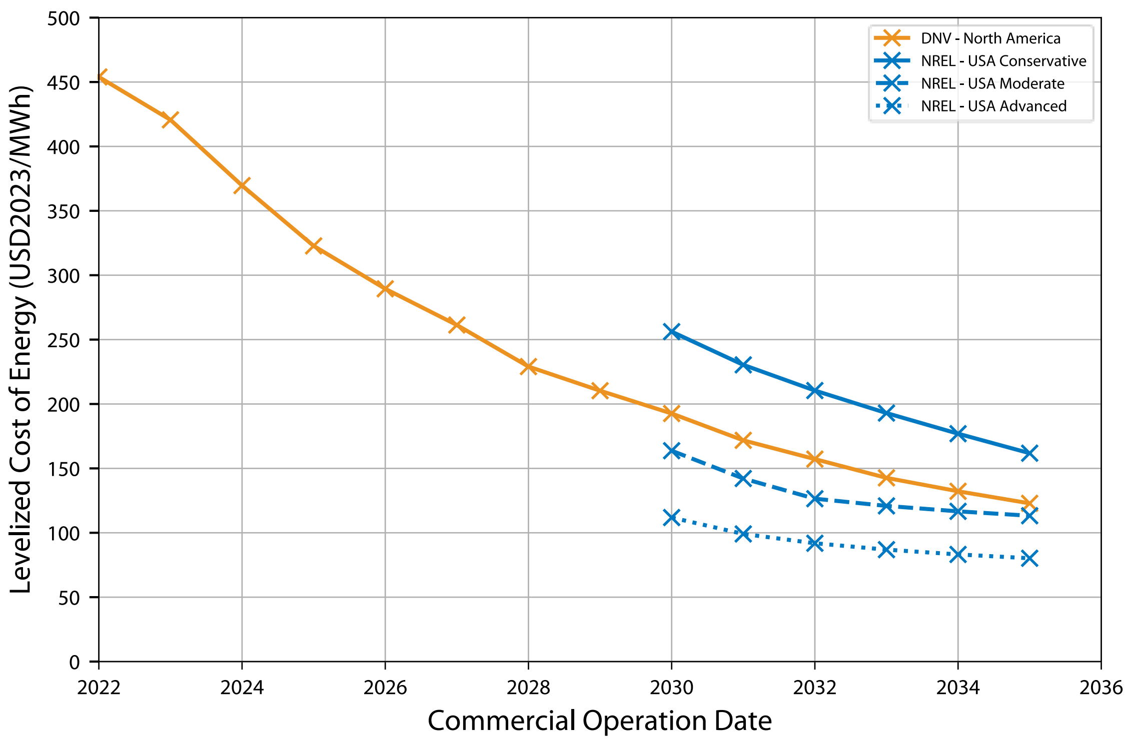

Figure 32. Unsubsidized levelized cost of energy estimates for floating offshore wind technologies in the United States.

Cost estimates have been converted into real 2023 dollars. LCOE includes transmission expenditures (e.g., for the export cable and substation, but not bulk power system upgrades or tax credit benefits.

Source: NREL (2024); DNV (2023)

Generally, floating offshore wind costs are predicted to decrease through 2050 as the industry matures (Wiser et al. 2021). This prediction is consistent with general trends for early-stage technologies, which usually experience significant cost reductions as their market expands. In addition, technological and commercial developments from fixed-bottom offshore wind systems

[35] Adjusted to 2023 USD for comparison using the Consumer Price Index.

might translate to floating offshore wind systems. Technology-specific cost reduction potential may come from a range of factors, including but not limited to the ability of floating offshore wind projects to (Beiter et al. 2020):

- Leverage cost reductions, innovations, and experience from fixed-bottom systems
- Use existing supply chains
- Optimize floating structures using lighter components and increased modularity
- Reduce the number and complexity of construction steps at sea (e.g., by assembling the wind turbine and substructure at quayside)
- Automate production and fabrication of the floating substructures
- Site projects further from shore to access higher wind speeds, which could offset the higher operations, maintenance, and installation costs associated with greater distances to shore and harsher meteorological conditions.

5.4 Offshore Wind Tax Credits

Several pieces of new guidance related to implementation of clean energy tax credits passed under the IRA were issued by the Internal Revenue Service (IRS) during 2023. The IRA provides for an investment tax credit (ITC) for offshore wind of up to 30% through at least the beginning of the 2030s[36] for projects meeting prevailing wage and apprenticeship requirements.[37] The IRA also introduced bonus credits of 10 percentage points each for projects that meet domestic content thresholds and locate facilities within "energy communities."[38] These bonus credits, when combined with the full base credit of 30%, can provide up to 50% in total of a project's eligible capital expenditures. The following subsections describe key clarifications issued by the IRS during 2023 and early 2024.

5.4.1 Eligibility for Bonus Credits

On March 22, 2024, IRS issued guidance that, among other things, updated the eligibility criteria for offshore wind projects seeking the Energy Communities Bonus Credit passed under the IRA (IRS 2024; Kearns and Daray 2024). Previously, offshore wind projects located in federal waters could qualify only if the power conditioning and transfer equipment (e.g. a substation) closest to their point of interconnection (the place on land where the electricity from the project is delivered into the grid) was located in an energy community. The March 2024 guidance expands on and clarifies this criterion:

- Offshore wind projects with multiple points of interconnection may benefit from energy community bonus credits if they locate any power conditioning and transfer equipment at one of their points of interconnection (e.g. an onshore substation at one of those points of interconnection) within an energy community.

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[36] Qualifying projects may also elect a production tax credit under the IRA.

[37] The ITC base rate is set at 6% or 30% of the cost of installed equipment, depending on project size and labor factors; projects over 1 MW must satisfy apprenticeship and prevailing wage requirements to receive the 30% ITC (DOE and BOEM 2024).

[38] Energy communities are located at sites that are historically affected by industrial pollution, communities affected by closed coal mines or coal-fired power plants, or communities that had a dependence on fossil fuel industries (through jobs or tax revenues) that are now facing higher than average unemployment. For more information, refer to https://energycommunities.gov/energy-community-tax-credit-bonus/.

- Projects now may qualify for energy community bonus credit benefits if their supervisory control and data acquisition system is situated at an "eligible project port"—one with which the project has a long-term relationship and at which the project employs staff that perform essential project functions such as operations and maintenance—within an energy community.

The guidance also amends the criteria for energy communities associated with high fossil fuel employment levels, adding new fossil fuel job categories to be tracked, which expands the number of such energy communities in which projects could be eligible for the bonus.

5.4.2 Clarification on Power Conditioning and Transfer Equipment

IRS guidance released on Nov. 22, 2023, clarifies that offshore power conditioning and transfer equipment such as export cables and onshore substations are integral to the energy property (IRS 2023) and therefore eligible for the ITC. Under previous guidance, it had been unclear whether offshore wind projects could count such property in their eligible costs for the ITC.

5.4.3 Transferability Framework

The IRA also provides projects with the ability to transfer tax credits to one or more other parties. On June 14, 2023, the IRS released guidance clarifying the rules for such transfers (Lonczak and Jones 2023). Transferability grants offshore wind developers and other eligible taxpayers a new means to monetize tax credits like the ITC. With the advent of transferability, tax equity investment might become accessible to a broader range of investors, potentially reducing the complexity that is typically associated with tax equity partnerships and increasing the pool of total available tax equity to be accessed by clean energy projects (Doherty 2023).

6 Future Trends

6.1 U.S. Offshore Wind Energy Market Forecasts to 2035

Although the U.S. pipeline grew to more than 80.5 GW, market forecasts in 2024 show less optimism for near-term development than in past years. Figure 33[39] shows two independent forecasts for offshore wind energy deployment in the United States through 2035.

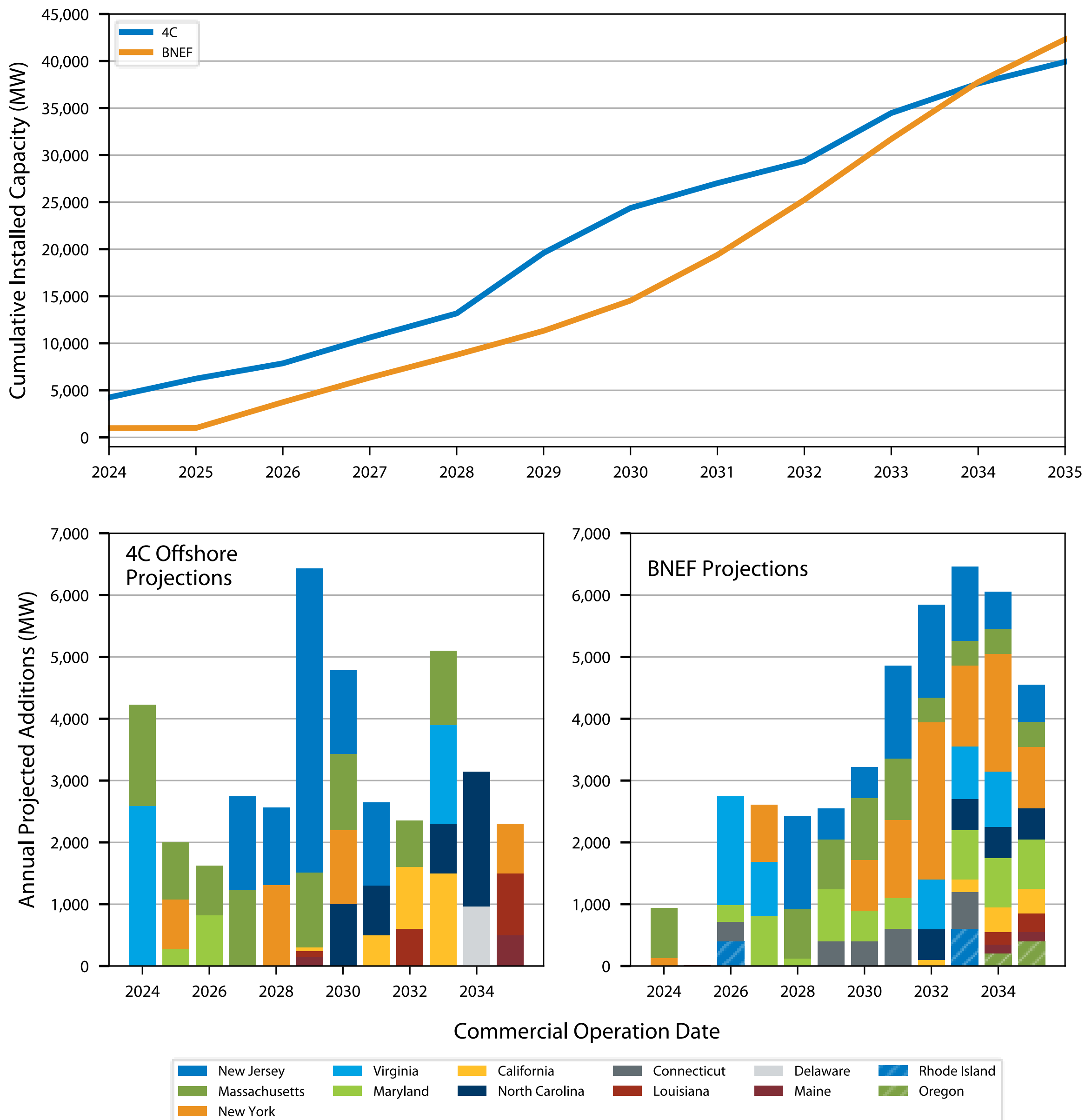

Figure 33. Industry projections of U.S. offshore wind energy development through 2035

Source: BNEF (2023) and 4C Offshore (2024).

[39] Based on 4C project opportunities pipeline as of June 2024.

The forecasts, developed by 4C Offshore (2024) and BNEF (2023), estimate U.S. offshore wind energy deployment will cumulatively reach 40 GW and 42 GW by the end of 2035, respectively. Their forecasts show lower levels of deployment relative to those reported in the *Offshore Wind Market Report: 2023 Edition* (Musial et al. 2023). The lower estimates are likely due to project delays resulting from offtake renegotiations/cancellations; project cancellations; and supply chain delays in port, manufacturing, and transmission development. The actual size and speed of U.S. offshore wind build-out will depend on continued regulatory efficiency, the availability of installation vessels and port infrastructure, proactive onshore and offshore grid planning and upgrades, the successful commercialization of 15-MW-class wind turbines and associated infrastructure, and sustained market demand.

These forecasts predict that most near-term (pre-2030) offshore wind energy deployment will occur on the East Coast in states with existing offshore wind energy procurement goals. Both forecasts predict project development in the Gulf of Mexico and floating offshore wind deployment in Maine and California starting around 2030.

6.2 Forecasted Global Projections for Offshore Wind Energy

In Figure 34,[40] independent forecasts for global offshore wind from BNEF (2023) and 4C Offshore (2024) estimate the future growth of the global offshore wind energy industry. BNEF forecasts offshore wind energy will reach 486 GW by 2035, whereas 4C Offshore estimates a projected deployment level of approximately 421 GW by 2035. Together, the forecasts illustrate some variability associated with longer-range deployment estimates, but both indicate strong global market growth with more than a fivefold increase in offshore wind energy deployment projected over the next decade.

The most prominent trend in the offshore wind energy market in the 2035 forecasts is the estimated growth of the Chinese market. 4C Offshore and BNEF differ significantly in their expectations, with 4C Offshore projecting 99.9 GW and BNEF projecting 150.3 GW of new offshore wind capacity in China by 2035, representing 24%–38% of total 2035 installed capacity. Compared to the *Offshore Wind Market Report: 2023 Edition*, BNEF has a more ambitious outlook for China. These forecasts predict other countries in Asia (e.g., Taiwan, Korea, Japan, and Vietnam) will account for an additional 13%–14% of installed capacity. European developers will build projects at an increasing rate relative to today, with Europe holding 39%–51% of the total installed global offshore wind capacity by 2035. The forecasts project the U.S. portion of installed capacity to be about 9% (both BNEF and 4C Offshore) of the global total by 2035.

[40] Based on 4C Offshore project opportunities pipeline as of June 2024.

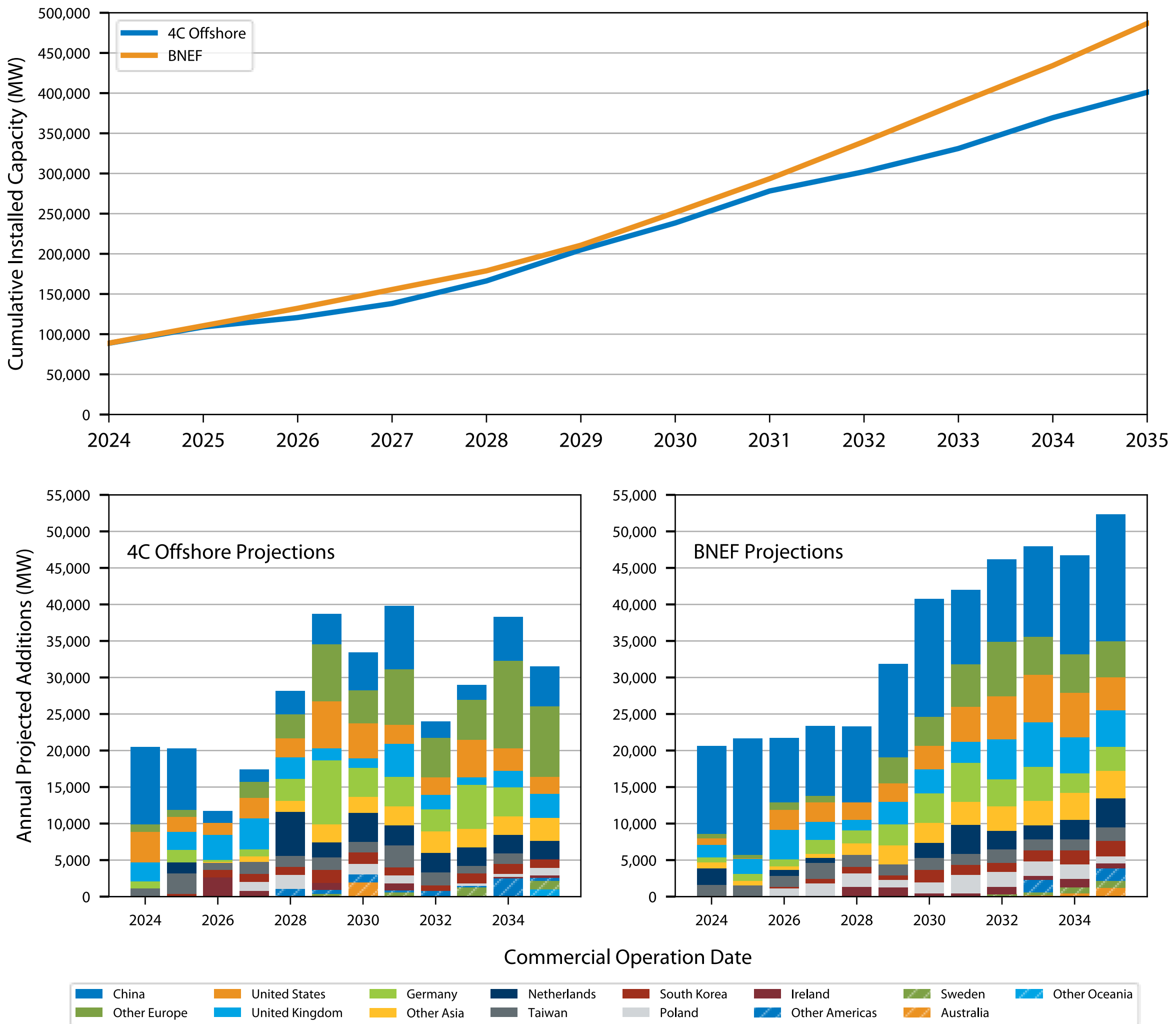

Figure 34. Industry forecasts for global offshore wind energy deployment to 2035.

Source: BNEF (2023) and 4C Offshore (2024).

Figure 35 shows floating offshore wind deployment forecasts from 2025 to 2035 from multiple independent groups. In last year's offshore wind market report, each group anticipated at least one of their estimates surpassing 10 GW of floating offshore wind capacity by 2030, and some even foresaw figures as high as 40 GW by 2030 (Musial et al. 2023). However, a notable shift has occurred in 2023, with most independent groups revising their expectations published in the second half of the year downward. The latest projections now include a range of estimates, predominantly falling between 6 and 10 GW by 2030 (4C Offshore 2024; Global Wind Energy Council 2023; DNV 2023; Wood Mackenzie 2023b). Additionally, other independent entities adopt an even more conservative approach, forecasting 2 GW of floating offshore wind capacity by 2030 (AEGIR Insights 2023; BNEF 2024a). AEGIR Insights states that the commercial takeoff of floating offshore wind has been postponed by the general uncertainties in the offshore wind market today (increased costs and interest rates and supply chain issues) and lack of route to market; they anticipate substantial growth in industrialization with the second wave in the 5 years following 2030. This 2030–2035 period is expected to welcome new entrants like developers, OEMs, and other offshore wind development players in the sector who are positioned to capitalize on the insights gained from early experiences and newly constructed infrastructure (AEGIR Insights 2023).

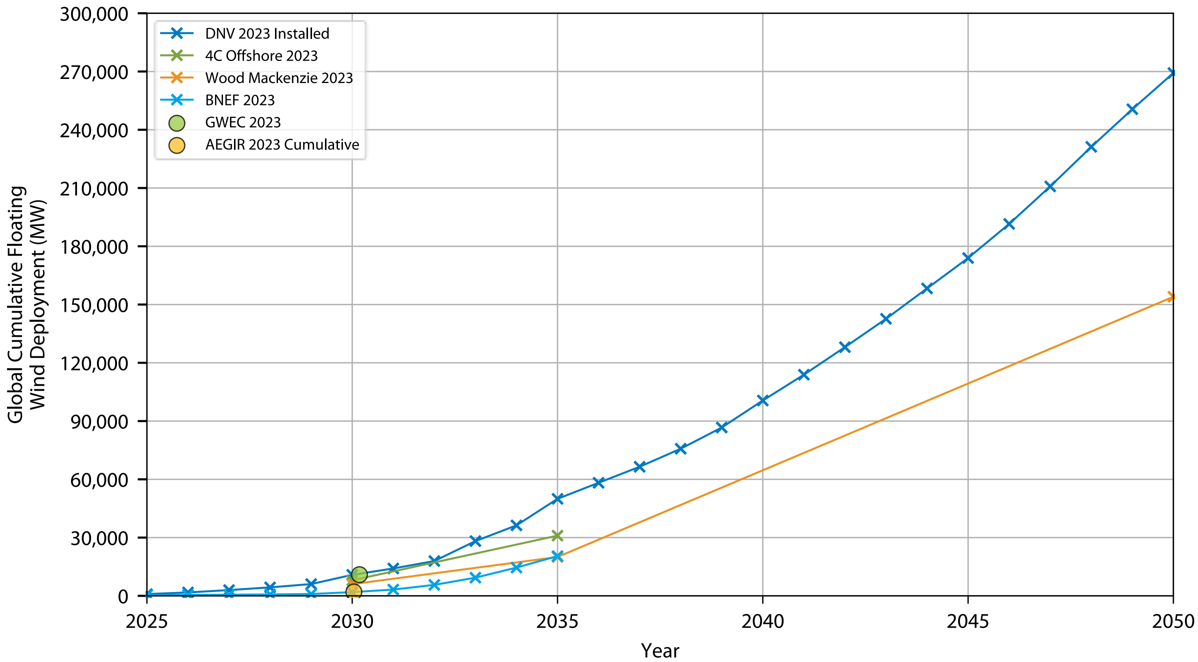

Figure 35. Long-term cumulative floating offshore wind energy deployment projections.

In the legend, GWEC stands for Global Wind Energy Council.

6.3 Summary of Key Findings and Future Trends

DOE's *The Pathway to Offshore Wind Commercial Liftoff* concludes that the offshore sector will achieve "liftoff" when it is actively contributing to decarbonization targets with a sustained project pipeline and regular deployment (DOE 2024). Given the liftoff report's findings and developments in the offshore wind industry noted above, the following is a summary of key developments and proposed paths to address headwinds in the U.S. offshore wind sector, based on extensive stakeholder engagement and modeling at both the system level and project level (DOE 2024):

- Although the U.S. pipeline grew, market forecasts in 2024 show less optimism for development in the next decade. Project delays have contributed to lower estimates in offshore wind energy deployment through 2030.
- Market challenges driven by macroeconomic conditions have caused uncertainty for supply chain development and funding gaps for sector growth. By conducting competitive rebids for canceled projects that secured offtakes prior to 2023 market downturns and revising current projects to align with current market conditions, states can lead the way toward resolving macroeconomic impacts (DOE 2024).
- Early projects carry the risk of cost and execution to set the foundation for long-term industry buildout. Risk can be mitigated by improving the path of permitting to offtake

and improving the path for non-project-specific organizations to make targeted investments in infrastructure (DOE 2024).

- The industry lacks market visibility to plan long-term investment for supply chain needs. Long-term investments and priorities could be established if (1) procurement schedules were shared publicly, (2) collaborations occurred for regional supply and transmission buildout, and (3) consensus was reached on standards (DOE 2024).
- Economic incentives can be used to coordinate the identification of points of interconnection and solicitations for onshore upgrades across multiple projects by tailoring project sizes and standards to low-cost offshore transmission and efficient interconnection, and by initializing interregional transmission planning (DOE 2024).
- Despite the near-term decrease in offshore wind energy deployment, both the BNEF forecast and the 4C Offshore projected deployment indicate strong global market growth over the next decade, with the U.S. portion of installed capacity forecasted be about 9% of the global total by 2035.

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Appendix A. Global Offshore Wind Energy Targets

Table A-1. National Offshore Wind Energy Targets for Countries in Europe

Country	Installed Capacity in 2023 (GW)	Planning Targets		Key Developments or Procurements	Source
		Capacity (GW)	Year		
Belgium	2.26	5.4–5.8	2030	The objective is to realize an additional production of 3.15–3.5 GW in the Princess Elisabeth Zone. The Minister of Energy has stated a desire for a future potential target of 8 GW by 2030.	Government of Belgium (2023); Wind Europe (2022a)
Denmark	2.65	10 35	2030 2050	The Danish government signed a joint declaration to make the North Sea a green powerhouse in Europe.	ESG Today (2022)
Finland	0.04	-	-	The national climate and energy strategy to become carbon neutral by 2035 intends to have the first large-scale offshore wind energy projects operational by 2030, and several more in production by 2035.	Ministry of Economic Affairs and Employment of Finland (2022)
France	0.98	18 40	2035 2050	The French government signed an offshore sector deal with the wind energy industry to organize auctions for a minimum of 2 GW of new offshore wind capacity each year starting in 2025 and build more than 50 offshore wind plants by 2050.	Wind Europe (2022b)
Germany	8.28	30 50 70	2030 2035 2045	The current statutory targets in Germany are for offshore wind to reach a cumulative installed capacity of 30 GW in 2030, 40 GW in 2035, and 70 GW in 2045 as per the reformed Wind Energy at Sea Act 2022.	Reuters (2023a); Ivanova (2022)
Greece	0.00	2	2030	The parliament approved Greece's first offshore wind law.	Tisheva (2023)
Ireland	0.03	7	2030	The Irish government increased the 2030 offshore wind target from 5 to 7 GW.	renews.biz (2022)

Country	Installed Capacity in 2023 (GW)	Planning Targets		Key Developments or Procurements	Source
		Capacity (GW)	Year		
Italy	0.03	2.1	2030	Italy sent its revised energy and climate plan to the European Union setting a target of 2.1 GW of offshore wind capacity by 2030.	Reuters (2023b)
Lithuania	0.00	1.4	2030	The Lithuanian government approved legislation amendments by the Ministry of Energy to expedite renewable energy development. By 2030, Lithuania aims for a total green energy capacity of 7 GW, including 1.4 GW from offshore wind.	Baltic Wind (2022)
Norway	0.09	30	2040	Norway's prime minister announced the country's goal of 30 GW of offshore wind capacity by 2040.	Wind Europe (2022c)
Poland	0.00	5.9 11	2030 2040	The EU Commission endorsed Poland's offshore wind farm support system, allowing installation of 5.9 GW capacity by 2030 in the initial phase and facilitating up to 11 GW capacity by 2040. There are discussions of increasing the 2030 target to 12 GW.	Ministry of Climate and Environment Republic of Poland (2021)
Portugal	0.03	2	2030	The Portuguese government has ambitions for 2 GW in operation and 10 GW of leased projects by 2030.	Norwegian Offshore Wind (2024)
Spain	0.01	3	2030	The Spanish government has approved an offshore wind roadmap that aims to install up to 3 GW of floating offshore wind energy in Spanish waters by 2030.	Wind Europe (2021)
Sweden	0.19	-	-	The Swedish government has launched a search for areas to support the plan to generate 120 terawatt-hours annually.	Durakovic (2022)

Country	Installed Capacity in 2023 (GW)	Planning Targets		Key Developments or Procurements	Source
		Capacity (GW)	Year		
The Netherlands	3.12	4.5 21 70	2023 2030 2050	The Climate Agreement (2019) and the coalition agreement (2021) include a commitment to maintain the offshore wind energy policy. The government has presented its offshore wind energy roadmap.	Government of the Netherlands (n.d.); Buljan (2022)
United Kingdom	14.75	50	2030	The UK Energy Strategy aims to dedicate 5 GW to floating offshore wind.	Wind Europe (2022d)

Table A-2. National Offshore Wind Energy Targets for Countries in Asia

Country	Installed Capacity in 2023 (GW)	Planning Targets		Key Developments or Procurements	Source
		Capacity (GW)	Year		
China	38.62	60 90	2025 2030	Mainland China has provincial 5-year targets, for a cumulative 60 GW by 2025, and the regional cumulative targets by 2030 increased to 90 GW.	Wood Mackenzie (2023a); BNEF (2024a)
India	0.00	30	2030	The Union Ministry of New and Renewable Energy has set a target of installing 30 GW by 2030.	Infrastructure Investor (2018)
Japan	0.27	10 30–45	2030 2040	The Japanese government aims to deploy 45 GW by 2040 as part of its 2050 decarbonization target.	Muto (2022)
South Korea	0.14	12	2030	South Korea's president reaffirms goal of 12 GW of offshore wind energy by 2030. The Framework Act on Low Carbon, Green Growth sets an optimistic scenario of 18–20 GW by 2030.	InfoLink Consulting (2021); Skopljak (2020)
Philippines	0.00	21	2040	The Department of Energy of the Philippines published its Offshore Wind Roadmap to aim for 21 GW by 2040.	Pinsent Masons (2022)
Taiwan	1.21	15	Between 2026 and 2035	The Ministry of Economic Affairs said that 1.5 GW of offshore wind capacity would be added each year from 2026 until 2035, instead of the previously planned 1 GW.	Upstream (2021); BNEF (2024a)
Vietnam	1.18	7	2030	The Ministry of Industry and Trade of Vietnam published a new Power Development Plan VIII draft with new capacity targets.	Global Wind Energy Council (2022)

Table A-3. National Offshore Wind Energy Targets for Countries in Other World Regions

Country	Installed Capacity in 2023 (GW)	Planning Targets		Key Developments or Procurements	Source
		Capacity (GW)	Year		
United States	0.04	30	2030	The current midterm national target is 30 GW by 2030. Achieving this target could unlock a pathway to 110 GW by 2050.	The White House (2021)
Canada	0.00	5	2030	Nova Scotia has set a target to offer leases for 5 GW of offshore wind energy by 2030.	Nova Scotia (2022)
Australia	0.00	2 4 9	2032 2035 2040	The Victorian Offshore Wind Policy Directions Paper sets nation-leading policy targets.	The Victorian Government (2022)
Brazil	0.00	16	2050	Brazil's government long-term energy expansion plan sees the potential to deploy 16 GW by 2050.	Radowitz (2020)
Colombia	0.00	0.2–1 0.5–3 1.5–9	2030 2040 2050	The Colombian Ministry for Mines and Energy launched the Roadmap for the Deployment of Offshore Wind Energy in Colombia. The roadmap shows the offshore wind potential from a low-case to a high-case scenario.	Argus (2022)

Appendix B. Global Pipeline Database Updates

The NREL database underlying the global offshore wind energy pipeline was updated significantly due to numerous accounting adjustments and project recharacterizations that were made by 4C Offshore since the *Offshore Wind Market Report: 2023 Edition* (Musial et al. 2023). These updates are reflected in the *Offshore Wind Market Report: 2024 Edition.* This appendix describes these accounting adjustments, which are distinguished from the actual market developments presented in the body of the report. Differences stem from correcting uncertainties in project statuses and total capacities based on new information or updates to previously limited information about project statuses. Most of the affected capacity was in China. This resulted in a 2,924-MW net increase (to 61,933 MW) in capacity categorized as operational by the end of 2022 compared to what we reported in the *Offshore Wind Market Report: 2023 Edition* (59,009 MW operational through 2022). Globally, 12 MW in pilot projects were also recategorized as decommissioned in the same period.

The year-over-year differences in the total pipeline are primarily driven by the following adjustments to the project database in addition to numerous unlisted smaller changes throughout:

- For operating projects in COD years 2021 and 2022:
  - 1.1 GW of capacity was listed as under construction with expected completion in 2023 but was corrected to be operational in 2021. Similarly, 0.9 GW was recharacterized to be operational in 2022.
  - 0.6 GW of capacity was downgraded or removed for operational projects in 2022.
  - 1.4 GW of unlisted capacity is now listed as operational in 2021, with an additional 1.5 GW for 2022.
- For COD years 2022 to 2028 (32.6 GW of net capacity loss):
  - 47 projects comprising approximately 13.3 GW of capacity were added to the pipeline.
  - 81 projects comprising nearly 46 GW of capacity were removed from the pipeline or delayed. Most of the removed or delayed projects came from the planning phase (least certain) and were in countries with smaller deployment (new markets).
- For COD 2029 and beyond (35.3 GW of net capacity gains):
  - Projects from countries with fewer deployments were continually shifted further down the pipeline, contributing to much of the change.
  - 58 projects were added or shifted to a 2029 expected COD, accounting for 23.9 GW of capacity, while another 81 projects (58.7 GW) were removed.

In the floating offshore wind pipeline through 2029, there are approximately 323 MW of projects under construction. In 2023 the capacity in the permitting phase increased to 9,507 MW. The total capacity of floating projects in the planning stage is 88,296 MW. Table B-1 shows the breakdown of floating offshore wind energy projects by project phase for 18 countries.

Table B-1. Global Floating Offshore Wind Energy Pipeline by Country and Project Phase

Country	Operating (MW)	Under Construction (MW)	Permitting (MW)	Site Control (MW)	Planning (MW)	Total (MW)
Australia					11,250.0	11,250.0
Bulgaria					5.0	5.0
China	23.0	216.6	12.0		800.0	1,051.6
France	2.0	90.2			2,063.0	2,155.2
Ireland					5410.0	5,410.0
Italy					11,186.0	11,186.0
Japan	5.0	16.8			225.0	246.8
New Zealand					2,000.0	2,000.0
Norway	100.9				95.0	195.9
Philippines					6,420.0	6,420.0
Portugal	25.0					25.0
Saudi Arabia					500.0	500.0
South Korea			2,445.0		1,570.0	4,015.0
Spain	2.0				1,543.5	1,545.5
Sweden			12,200.0		6,450.0	18,650.0
Taiwan					1,890.0	1,890.0
United Kingdom	77.5		950.4		11,270.0	12,297.9
United States				6,042.0	19,074.0	25,116.0
Total	**235.4**	**323.6**	**15,607.4**	**6,042.0**	**81,751.5**	**103,959.9**

Appendix C. Commissioned U.S.-Flagged Vessels

Table C-1 lists the commissioned U.S.-flagged vessels to date with the companies backing the vessel construction according to DOE's Clean Energy tracking efforts (DOE n.d.).

Table C-1. Commissioned U.S.-Flagged Vessels To Serve the Offshore Wind Energy Industry

Vessel Category[a]	Companies Backing	Commissioning
CTV - Gripper	American Offshore Services, Blount Boats	Not listed
CTV - Atlantic Pioneer	Atlantic Wind Transfers, Blount Boats Inc., Chartwell Marine Ltd.	2016
CTV - Atlantic Endeavor	Atlantic Wind Transfers, Blount Boats Inc., Chartwell Marine Ltd.	Not listed
CTV	Coast Line Transfers	2023
CTV - Gaspee	McAllister Towing	Not listed
CTV - Roger Williams	McAllister Towing	Not listed
CTV - Courageous	WINDEA CTV LLC	2023
CTV - Intrepid	WINDEA CTV LLC	2023
CTV - Enterprise	WINDEA CTV LLC	2023
CTV - Journey	WindServe Marine	Not listed
CTV - Explorer	WindServe Marine	2024
CTV - Odyssey	WindServe Marine, Ørsted	2020
CTV - Genesis	WindServe Marine, Ørsted, Senesco	Not listed
SOV - ECO Edison	Edison Chouest Offshore, Ørsted	2024
SOV - Paul Candies	Siemens Gamesa, US Otto Candies, LLC	2018 (retrofit)
SOV - Cade Candies	US Otto Candies, LLC	2010 (retrofit)
Barge - 455-8	Crowley Maritime Corporation	2010
Barge - Marmac 400	Foss Maritime	2001
Barge - Prevailing Winds	Foss Maritime	Not listed
Tug - Ocean Sky	Crowley Maritime Corporation	2013
Tug - Michele Foss	Foss Maritime	2015
Tug - Nicole Foss	Foss Maritime	2017

[a] CTV = crew transfer vessel; SOV = service operation vessel

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