



U.S. DEPARTMENT OF
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Office of
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Offshore Wind Market Report: 2021 Edition

EXECUTIVE SUMMARY

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Executive Summary

Since 2015, maturing technology, rapidly evolving supply chains, increased competition, and experience from utility-scale installations have driven costs down and broadened the deployment of offshore wind energy across the globe. The “Offshore Wind Technologies Market Report: 2021 Edition” provides detailed information on the U.S. and global offshore wind energy industries to inform policymakers, researchers, and analysts about technology and market trends. The scope of the report covers the status of over 200 global operating offshore wind energy projects through December 31, 2020, and provides the status of, and analysis on, a broader global pipeline of projects in various stages of development. To provide the most up-to-date discussion of this evolving industry, this report also tracks the most significant domestic developments and events from January 1, 2020, through May 31, 2021.

U.S. Offshore Wind Energy Market

In 2020, the U.S. offshore wind energy project development and operational pipeline grew to a potential generating capacity of 35,324 megawatts (MW). Specifically, the pipeline experienced a 24% increase in 2020, up from 28,521 MW in 2019 (National Renewable Energy Laboratory [NREL] Offshore Wind Database 2020¹). The 35,324 MW that make up the U.S. offshore wind energy project pipeline comprise two operating projects: the Block Island Wind Farm (30 MW) and the Coastal Virginia Offshore Wind (CVOW) pilot project (12 MW). Beyond this, one project—Vineyard Wind 1 [800 MW]—is fully approved, and has received all permits, an offtake contract to sell the power, and an interconnection agreement to deliver it to the grid. In addition, there are 15 projects in the pipeline that have reached the permitting phase, with either a Construction and Operations Plan² (COP) or an offtake mechanism for the sale of electricity, 16 commercial leases in federal waters that have gained exclusive site control, and seven wind energy areas that can be leased at the discretion of the federal government in the future. The Bureau of Ocean Energy Management (BOEM)—the government agency that regulates energy development in federal waters—has also designated nine Call Areas where future offshore wind energy development is being considered. The pipeline includes three projects located in state waters: the operating Block Island Wind Farm, the Aqua Ventus I floating wind project in Maine, and the Lake Erie Energy Development Corporation Icebreaker Wind project. A map of the current pipeline activity is shown in Figure ES-1.

Further, the Biden Administration announced a 30-gigawatt (GW)-by-2030 national offshore wind energy goal and states continue to adopt their own offshore wind procurement mandates (White House 2021). The federal target to install 30 GW of capacity by 2030 is the first U.S. national offshore wind energy goal. To make progress toward this goal, BOEM aims to evaluate at least 16 COPs by 2025 and work with the U.S. Department of Energy, U.S. Department of Commerce, and industry stakeholders to minimize environmental impacts and ensure the coexistence of offshore wind energy with other ocean users. Beyond the national level goal, states are aiming to procure at least 39,298 MW of offshore wind capacity by 2040. These

¹ All project data from this report come from NREL’s internal offshore wind database, which contains information on more than 2,079 offshore wind energy projects located in 49 countries and totaling approximately 831,991 MW of announced project capacity (both active and dormant).

² A COP describes all the proposed activities and planned facilities that an offshore wind energy developer intends to construct and use for a project under a commercial lease. BOEM must approve the plan before construction can begin (BOEM 2020).

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federal and state deployment goals can help provide the U.S. offshore wind industry with more confidence that a sustained market will develop, increasing new investment in domestic manufacturing, vessels, and ports necessary for sustained, long-term deployment.

Additional progress made in the 2020/21 domestic offshore wind energy industry includes the following.

BOEM created five new wind energy areas (WEAs) in the New York Bight. Most of the growth in the pipeline during 2020/21 came from the addition of five new WEAs³ in the New York Bight, positioning them for auction under the competitive leasing process (Figure ES-1).

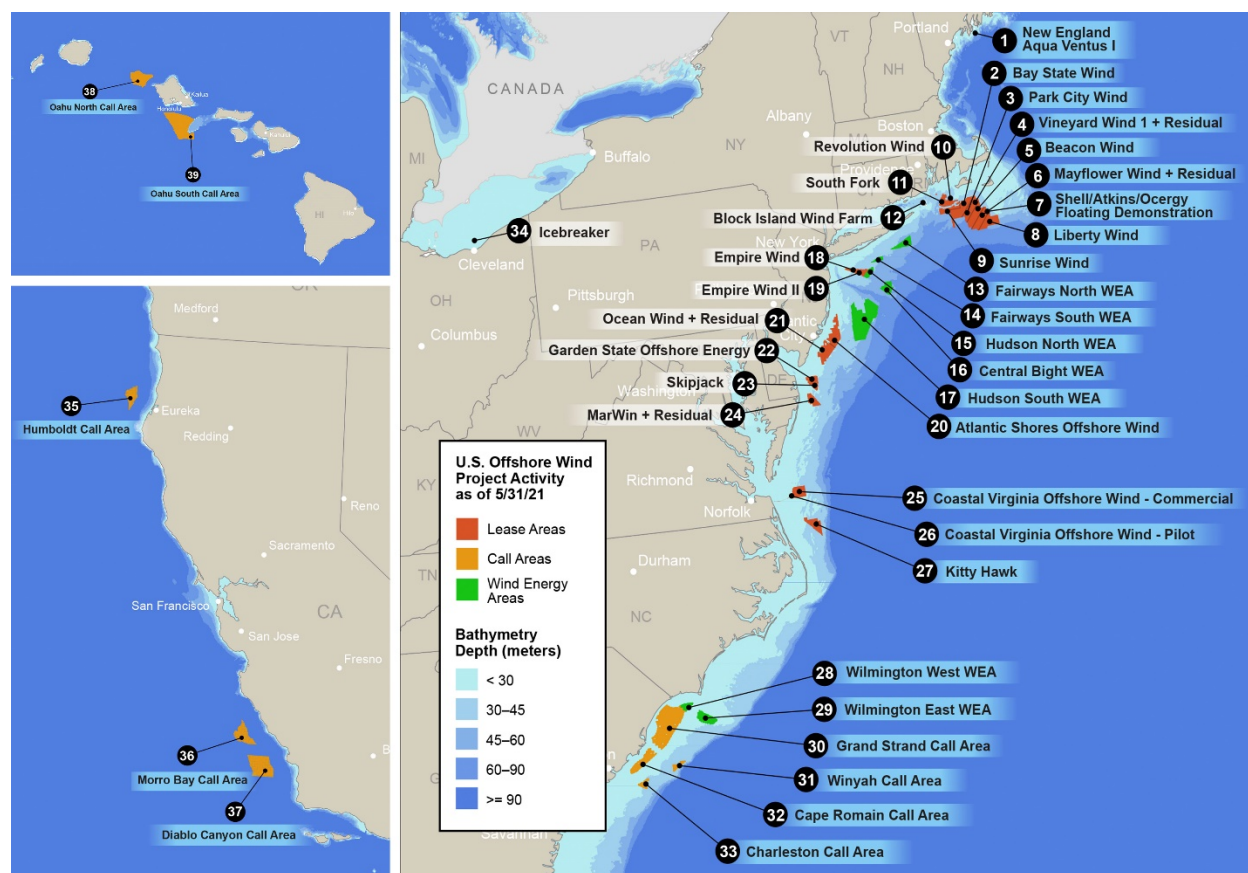


Figure ES-1. Locations of U.S. offshore wind pipeline activity and Call Areas as of May 31, 2021. Map created by NREL

These new WEAs were part of the previously identified New York Bight Call Areas (BOEM 2021). In aggregate, these yet-to-be-leased WEAs have the potential to hold about 9.8 GW of offshore wind capacity. In June 2021, BOEM issued a proposed sales notice that could potentially transform the Hudson North, Central Bight, and Hudson South WEAs into eight new wind energy lease areas. A final sales notice will be issued after a period of public comment.

³ WEAs are ocean areas on the Atlantic Outer Continental Shelf that are not only the most suitable for commercial wind energy activities but may also present the fewest apparent environmental and user conflicts. BOEM has the authority to competitively lease WEAs to offshore wind energy developers.

CVOW pilot successfully connected to the grid. The 12-MW demonstration project (cover photo) was connected to the grid at Birdneck Substation near Camp Pendleton, Virginia, and started generating power in October 2020 and was fully commissioned in January 2021. The CVOW pilot was constructed by Ørsted using Jan De Nul's Vole-au-Vent wind turbine installation vessel. The project is owned by Dominion Energy and comprises two Siemens Gamesa 6-MW turbines mounted on EEW monopile substructures. It is the second U.S. offshore wind energy project to install commercial-scale wind turbines and the first project to be permitted and constructed in federal waters under the jurisdiction of BOEM.

Vineyard Wind 1 became the first fully approved commercial offshore wind energy project in the United States. After 3 years of review, Avangrid and Copenhagen Infrastructure Partners' 800-MW Vineyard Wind 1 project received a Record of Decision, indicating the approval of the project's COP in May 2021 (BOEM 2021). The project had previously completed state and local permitting requirements in June 2019 and received an interconnect agreement from the Independent System Operator-New England in July 2020. With a revision to its COP in December 2020, Vineyard Wind reported it was switching from MHI-Vestas 9.5-MW wind turbines to GE 13-MW Haliade-X wind turbines. The project has reported plans to be fully connected to the grid by 2024.

Two U.S.-flagged offshore wind installation and support vessels were announced.

Construction of the first U.S.-flagged wind turbine installation vessel, Charybdis, began at the Keppel AMFELS shipyard in Brownsville, Texas, in 2020 (Dominion Energy 2020). The new vessel is 472 feet long and designed by GustoMSC. Lloyd's Register and Northeast Technical Services Co., Inc. also announced plans to construct a U.S.-flagged wind turbine installation vessel; however, as of May 31, 2021, construction has not yet started (Lloyd's Register 2020).

Table ES1 includes nine Call Areas located in three regions, but the capacity of the Call Areas is not calculated or counted in the total pipeline capacity because these areas are considered preliminary and are likely to change in size and location. In total, there are 39 sites in the United States (as shown on the maps) where there is significant offshore wind energy development activity. Among this activity are three projects in state waters, including the operating Block Island Wind Farm in Rhode Island, New England Aqua Ventus I in Maine, and the Lake Erie Energy Development Corporation (LEEDCo) Icebreaker project located just north of Cleveland. Both Aqua Ventus and Icebreaker were originally funded under the DOE Advanced Technology Demonstration Project program, which began in 2012 (DOE 2021).

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Table ES1. U.S. Offshore Wind Pipeline

(In the table, N/A = not applicable; OCS = Outer Continental Shelf; OREC = offshore renewable energy certificate; PPA = power purchase agreement; ROD = Record of Decision; SAP = site assessment plan; and TBD = to be determined).

\	Lease/WEA /Call Area Location	Project Name	Developer	Status	Lease Area	Foundation Type	Wind Turbine	Permit Status	Offtake Agreement	Approved Interconnect Location	Estimated Commercial Operation Date	Operating (MW)	Approved (MW)	Permitting (MW)	Site Control (MW)	Planning (MW)
1	ME	New England Aqua Ventus I	Univ. of Maine/RWE/Mitsubishi	Permitting	State Lease	Floating	TBD	State Approved	PPA (ME)	TBD	2023			12		
2	MA	Bay State Wind	Ørsted/Eversource	Site Control	OCS-A 0500	Fixed Bottom	TBD	COP	TBD	Brayton Point	TBD				2,277	
3	MA	Park City Wind	Avangrid/Copenhagen Infrastructure Partners	Permitting	OCS-A 0501	Fixed Bottom	TBD	COP	PPA (CT)	TBD	2025			804		
4	MA	Vineyard Wind 1 + Residual	Avangrid/Copenhagen Infrastructure Partners	Approved	OCS-A 0501	Fixed Bottom	13-MW GE Haliade-X	ROD	PPA (MA)	Barnstable	2023		800		421	
5	MA	Beacon Wind	Equinor/BP	Permitting	OCS-A 0520	Fixed Bottom	TBD	SAP	OREC (NY)	TBD	2026			1,230		
6	MA	Mayflower Wind + Residual	Energias de Portugal Renováveis/Shell	Permitting	OCS-A 0521	Fixed Bottom	TBD	COP	PPA (MA)	TBD	2025			804	747	
7	MA	Shell/Atkins/Ocergy Floating Demonstration	Shell/Atkins/Ocergy	Permitting	OCS-A 0521	Floating	TBD	TBD	PPA (MA)	TBD	2025			10		
8	MA	Liberty Wind	Avangrid/Copenhagen Infrastructure Partners	Site Control	OCS-A 0522	Fixed Bottom	TBD	SAP	TBD	TBD	TBD				1,607	
9	MA	Sunrise Wind	Ørsted/Eversource	Permitting	OCS-A 0487/0500	Fixed Bottom	TBD	COP	OREC (NY)	TBD	2024			880		
10	RI	Revolution Wind	Ørsted/Eversource	Permitting	OCS-A 0486	Fixed Bottom	8-MW SG DD-167	COP	PPA (RI & CT)	TBD	2023			704		
11	RI	South Fork	Ørsted/Eversource	Permitting	OCS-A 0517	Fixed Bottom	TBD	COP	PPA (NY)	East Hampton	2023			130		
12	RI	Block Island Wind Farm	Ørsted/Eversource	Operating	State Lease	Fixed Bottom	6-MW GE Haliade 150 m	State Approved	PPA (RI)	Block Island	2016	30				
13	NY	Fairways North WEA	N/A	WEA	N/A	Fixed Bottom	TBD	N/A	N/A	N/A	N/A					1,071
14	NY	Fairways South WEA	N/A	WEA	N/A	Fixed Bottom	TBD	N/A	N/A	N/A	N/A					289
15	NY	Hudson North WEA	N/A	WEA	N/A	Fixed-Bottom	TBD	N/A	N/A	N/A	N/A					523
16	NY	Central Bight WEA	N/A	WEA	N/A	Fixed Bottom	TBD	N/A	N/A	N/A	N/A					1,028
17	NY	Hudson South WEA	N/A	WEA	N/A	Fixed Bottom	TBD	N/A	N/A	N/A	N/A					6,890
18	NY	Empire Wind	Equinor/BP	Permitting	OCS-A 0512	Fixed Bottom	TBD	COP	OREC (NY)	TBD	2024			816		

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\	Lease/WEA /Call Area Location	Project Name	Developer	Status	Lease Area	Foundation Type	Wind Turbine	Permit Status	Offtake Agreement	Approved Interconnect Location	Estimated Commercial Operation Date	Operating (MW)	Approved (MW)	Permitting (MW)	Site Control (MW)	Planning (MW)
19	NY	Empire Wind II	Equinor/BP	Permitting	OCS-A 0512	Fixed Bottom	TBD	COP	OREC (NY)	TBD	2028			1,260		
20	NJ	Atlantic Shores Offshore Wind	EDF/Shell	Site Control	OCS-A 0499	Fixed Bottom	TBD	COP	OREC (NJ)	TBD	TBD				2,500	
21	NJ	Ocean Wind + Residual	Ørsted/PSEG	Permitting	OCS-A 0498	Fixed Bottom	13-MW GE Haliade-X	COP	OREC (NJ)	TBD	2024			1,100	847	
22	DE	Garden State Offshore Energy	Ørsted/PSEG	Site Control	OCS-A 0482	Fixed Bottom	TBD	SAP	TBD	TBD	TBD				1,050	
23	DE	Skipjack	Ørsted	Permitting	OCS-A 0519	Fixed Bottom	13-MW GE Haliade-X	COP	OREC (MD)	TBD	2026			120		
24	MD	MarWin + Residual	US Wind	Permitting	OCS-A 0490	Fixed Bottom	TBD	COP	OREC (MD)	Indian River	2023			248	718	
25	VA	Coastal Virginia Offshore Wind - Commercial	Dominion Energy	Permitting	OCS-A 0483	Fixed Bottom	14-MW SG 222 m	COP	Utility Owned	Fentress 500 kilovolts	2024			2,640		
26	VA	Coastal Virginia Offshore Wind - Pilot	Dominion Energy	Operating	OCS-A 0497	Fixed Bottom	6-MW SWT 164 m	State Approved	Utility Owned	Birdneck	2021	12				
27	NC	Kitty Hawk	Avangrid	Permitting	OCS-A 0508	Fixed Bottom	TBD	COP	TBD	TBD	2024				1,485	
28	NC	Wilmington West WEA	N/A	WE A	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	N/A					627
29	NC	Wilmington East WEA	N/A	WEA	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	N/A					1,623
30	SC	Grand Strand Call Area	N/A	Call Area	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	N/A					N/A
31	SC	Winyah Call Area	N/A	Call Area	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	N/A					N/A
32	SC	Cape Romain Call Area	N/A	Call Area	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	N/A					N/A
33	SC	Charleston Call Area	N/A	Call Area	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	N/A					N/A
34	OH	Ice Breaker	LEEDCo/Fred Olsen	Permitting	State Lease	Fixed Bottom	TBD	State Approved	PPA	TBD	2023			21		
35	CA	Humboldt Call Area	N/A	Call Area	N/A	Floating	N/A	N/A	N/A	N/A	N/A					N/A
36	CA	Morro Bay Call Area	N/A	Call Area	N/A	Floating	N/A	N/A	N/A	N/A	N/A					N/A
37	CA	Diablo Canyon Call Area	N/A	Call Area	N/A	Floating	N/A	N/A	N/A	N/A	N/A					N/A
38	HI	Oahu North Call Area	N/A	Call Area	N/A	Floating	N/A	N/A	N/A	N/A	N/A					N/A
39	HI	Oahu South Call Area	N/A	Call Area	N/A	Floating	N/A	N/A	N/A	N/A	N/A					N/A
												42	800	10,779	11,652	12,051
												Total Pipeline - 35,324 MW				

Global Offshore Wind Energy Market

Globally, the offshore wind energy industry installed 5,519 MW of capacity in 2020. Much of the added global generating capacity can be attributed to 2,174 MW of new deployments in the Chinese market, followed by 1,503 MW commissioned in the Netherlands, 714 MW in the United Kingdom, 706 MW in Belgium, 315 MW in Germany, and 107 MW divided among the rest of the world (NREL Offshore Wind Database 2020). By the end of 2020, cumulative global offshore wind installed capacity grew to 32,906 MW from 200 operating projects. Projections indicate that annual global capacity additions in 2021 and beyond will accelerate, with 23,415 MW of projects currently under construction. As of December 31, 2020, the global pipeline for offshore wind energy development capacity was assessed to be 307,815 MW.

Global Floating Offshore Wind Energy Market

The global pipeline for floating offshore wind energy more than tripled in 2020. Overall, the 2020 global floating offshore wind pipeline grew from 7,663 MW to 26,529 MW, representing 18,866 MW of growth since the “2019 Offshore Wind Technologies Data Update.” This growth is attributed to several projects beginning their planning phase during 2020, especially in Asian markets.

No additions are made to the installed capacity for floating wind in 2020. Despite a surge of floating wind energy projects entering the early planning stages of the pipeline, the global market did not expand its installed capacity in 2020.

Offshore Wind Energy Technology Trends

The three leading wind turbine manufacturers have announced the development of larger offshore wind turbines ranging from 12 to 15 MW. The expected 12- to 15-MW offshore wind turbine class is now under full development, with Siemens Gamesa, Vestas, and GE all reporting their intention to have wind turbines at these nameplate ratings available for purchase by 2024 or sooner. U.S. orders indicate that most projects in the current pipeline will obtain wind turbines from one of these original equipment manufacturers.

Historic wind turbine size increases in Asia lag those in western markets while Asian projects also report lower capital costs. Prototype development data indicate that new Asian prototype wind turbine capacities are about 25% lower than their western counterparts, but upscaling in both markets is occurring at approximately the same rate. Based on developer reports, Asian offshore wind energy projects expect to achieve lower wind turbine and project costs, although cost data from Chinese markets are more difficult to verify and compare to project cost data from other parts of the world.

Offshore Wind Energy Cost and Price Trends

Globally, the average levelized cost of energy (LCOE)⁴ of fixed-bottom offshore wind energy installations is now below \$95/megawatt-hour (MWh). This cost level for projects that began commercial operations in 2020 represents a reduction of 16% on average, compared to NREL

⁴ LCOE is the cost per unit of energy of generating electricity during an assumed project design life that allows for the recovery of all project expenses and meets investor return expectations (Wiser et al. 2016).

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reporting in 2019. LCOE for wind projects that have a commercial operations date⁵ in 2020 range between \$78/MWh and \$125/MWh. Offshore wind LCOE has declined by 28%-51% between 2014 and 2020 (Wiser et al. 2021). By 2030, the surveyed experts predict LCOE levels of approximately \$56/MWh, declining further to a range of \$44/MWh to \$72/MWh by 2050.

The levelized procurement price of U.S. offshore wind energy projects ranges between \$96/MWh (Vineyard Wind 1) and \$71/MWh (Mayflower Wind) for projects commencing commercial operations between 2022 and 2025. These prices from power purchase agreements and offshore renewable energy certificates are based on a total of 5.5 GW of signed agreements. Mayflower Wind's (all-inclusive) procurement price of \$71/MWh is among the lowest-priced offshore wind energy projects announced globally. During 2020, the number of corporate power purchase agreement off-takers⁶ also increased, indicating a new trend in diversifying offshore procurement options. In 2020 and early 2021, nearly 4 GW were procured with corporate off-takers in northern Europe.

Floating offshore wind LCOE is predicted to decline from approximately \$160/MWh in 2020 to \$60–\$105/MWh in 2030.⁷ These estimated cost reductions are related to an expected floating deployment trajectory that spans from multiple wind turbine demonstration projects expected to come online through 2023 to medium- to full-scale commercial projects announced for commercial operation after 2023.

Future Outlook

Global offshore wind energy deployment is expected to accelerate in the future, with forecasts from 4C Offshore and Bloomberg New Energy Finance indicating a sevenfold increase in global cumulative offshore wind capacity—to 215 GW or more by 2030 (BNEF 2020; 4C Offshore 2021). As part of that predicted surge, the U.S. offshore wind energy market continues to expand, primarily driven by increasing state-level procurement targets in the Northeast and mid-Atlantic, an increased number of projects clearing major permitting milestones, as well as growing vessel, port, and infrastructure investments needed to keep pace with development. Moreover, a new national target of 30 GW of offshore wind energy by 2030, set in March 2021, could help illuminate the potential for future U.S. market growth. As the number of projects in the advanced permitting and approval phases now exceeds 11 GW, the first phase of U.S. development is well underway. However, despite the new national offshore wind energy deployment goal, fluctuating policy support, stakeholder concerns, constrained global supply chains, and land-based grid limitations pose challenges that could potentially temper the industry's progress.

Over the next few years, the frontiers for offshore wind energy development in the United States are likely to expand from the North Atlantic into other regions; each with their own challenges. In the near-term, new WEAs are likely to be identified in the Gulf of Maine where deeper waters

⁵ The commercial operations date is the year the project is commissioned and begins producing full power.

⁶ A corporate offtaker is a commercial or industrial electricity user that purchases power directly from the wind project.

⁷ Research organizations making these predictions include NREL (Musial et al. 2019, 2021), DNV GL (2020), ORE Catapult (2021), and over a hundred industry experts surveyed by Lawrence Berkeley National Laboratory (Wiser et al. 2021).

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require floating offshore wind technologies. In the Gulf of Mexico, wind speeds tend to be lower and hurricane risks need to be addressed, but regulatory activity has been initiated for possible leasing by the end of 2022. On the Pacific Coast and Hawaii, floating offshore wind energy Call Areas are advancing toward commercial leasing. Although markets in these regions may not reach their full stride for a decade, actions taken today could support future deployments. The Biden Administration's 30-GW-by-2030 goal could also set the industry on a trajectory to deploy 110 GW of offshore wind energy in the United States by 2050 (The White House 2021). This level of offshore wind energy deployment would be a substantial part of a comprehensive decarbonization strategy to combat climate change.

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Cover details: Dominion Energy's Coastal Virginia Offshore Wind 12-MW pilot project located 27 miles off the coast of Virginia Beach, Virginia. Photo courtesy of Lyfted Media for Dominion Energy.