U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2017 Offshore Wind Technologies Market Update

September 2018

Acknowledgments

This update was produced by Philipp Beiter, Paul Spitsen, Jake Nunemaker, Tian Tian, Walt Musial, Eric Lantz, and Vahan Gevorgian, and edited by Sheri Anstedt of the U.S. Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL). We greatly appreciate the input, review, and support of Dan Beals, Alana Duerr, Patrick Gilman, Liz Hartman, Gary Norton, Mikayla Rumph, and Valerie Reed of DOE, Doug Arent, Garrett Barter, Paul Schwabe, Brian Smith, Tyler Stehly, and Amy Robertson (NREL), as well as James Glennie (Consulate General of Denmark), Seb Rae (The Renewables Consulting Group), Gavin Smart and Andrew McDonald (ORE Catapult), Liz Burdock (Business Network for Offshore Wind), Nils Bolgen (Massachusetts Clean Energy Center), Stephen Boutwell (Bureau of Ocean Energy Management), Cheri Hunter and John Cushing (Bureau of Safety and Environmental Enforcement), Knut Aanstad and Peggy Brown (Equinor ASA), Jeff Kehne (Magellan Wind), Doreen Harris (New York State Energy Research and Development Authority), and Stephanie McClellan (University of Delaware). Cover photo provided by Equinor.

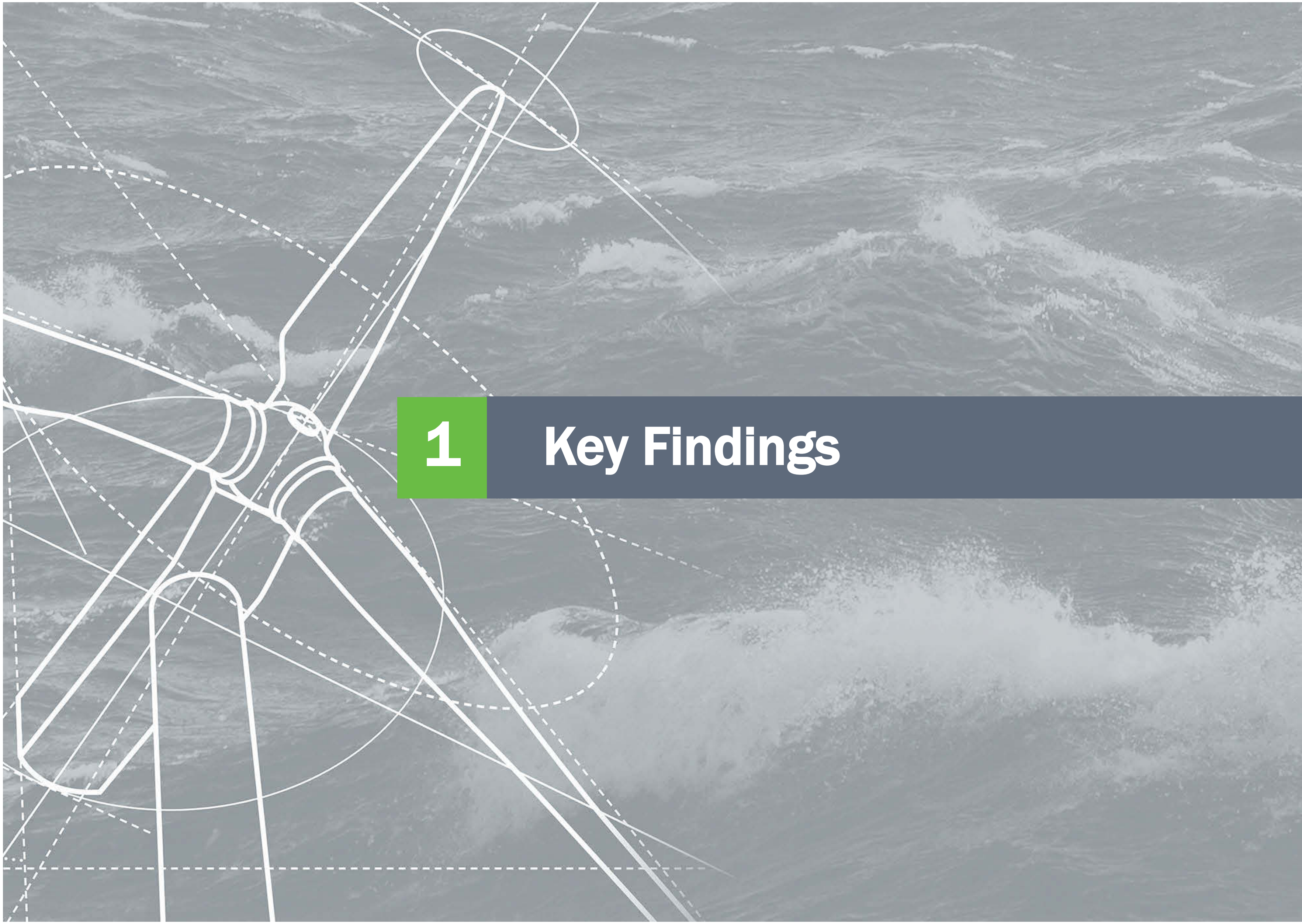
Notes

The Alliance for Sustainable Energy, LLC (Alliance) is the manager and operator of the National Renewable Energy Laboratory (NREL). NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. This work was authored by the Alliance and supported by the U. S. Department of Energy under Contract No. DE-AC36-08GO28308. Funding was provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, Wind Energy Technologies Office.

Preface

- The *2017 Offshore Wind Technologies Market Update* was developed by NREL for DOE's Office of Energy Efficiency and Renewable Energy, Wind Energy Technologies Office.
- This update complements the biennial *Offshore Wind Technologies Market Report* (Musial et al. 2017), which includes a more detailed discussion of the key trends and statistics included in this update.
- This work provides decision-makers, regulators, developers, financiers, and supply chain participants with quantitative information about the offshore wind market, technology, and cost status worldwide and in the United States.

Table of Contents



1 Key Findings

Key Findings

United States

U.S. Offshore Wind Projects Advance in Development While Total Project Pipeline Remains Relatively Constant

The U.S. offshore wind market continues to evolve as state-level offshore wind deployment targets and procurement policies are introduced, projects advance in permitting and offtake processes, supply chain constraints are mitigated, and research and development (R&D) investments are made. Including the 30 megawatts (MW) of installed capacity, the United States now has a project pipeline of 25,464 MW of offshore wind.[1]

- Developers have announced that roughly 2,000 MW of new offshore wind capacity is expected to be operational by 2023.
- The U.S. pipeline continues to be led by projects along the U.S. Eastern Seaboard, of which a number have made steps toward a more advanced stage of development during 2017 and the first half of 2018.

[1] Potential capacity includes installed projects, projects under construction, projects moving through permitting and offtake processes, projects with site control, the Bureau of Ocean Energy Management's unleased wind energy areas, and unsolicited lease applications submitted by developers. See Section 3 for a detailed discussion.

Key Findings (continued)

Continued State Activity in U.S. Offshore Wind Development

Dedicated state-level procurement and offtake mechanisms support U.S. offshore wind development:

- New Jersey increased the state's 2030 offshore wind commitment from 1,100 MW to 3,500 MW, initiated new legislation to restart the review process for Fishermen's Energy Atlantic City project, and directed the Board of Public Utilities to implement the state's offshore renewable energy credits (ORECs) (New Jersey State Legislature 2018a).
- Massachusetts' *Energy Diversity Act* (2016) mandated the procurement of 1,600 MW of offshore wind via competitive solicitations by 2027. The first round of solicitations was completed on May 23, 2018, with Vineyard Winds' 800-MW proposal selected as the winner. The next solicitation is expected to be held before 2020 (General Court of the Commonwealth of Massachusetts 2016).
- As part of the Massachusetts solicitation, Rhode Island was able to evaluate offshore wind project proposals. Rhode Island selected Deepwater Wind's 400-MW Revolution Wind proposal to support the state's goal of adding 1,000 MW of renewables by 2020 (Office of the Governor 2018).
- In February 2018, Connecticut issued a request for proposal (RFP) for 825,000 megawatt-hours (MWh) per year of renewable energy from offshore wind. Connecticut's Department of Energy and Environmental Protection selected Deepwater Wind's 200-MW Revolution Wind proposal. The project will be incremental to Deepwater's 400-MW Revolution Wind proposal approved by Rhode Island (Connecticut Department of Energy & Environmental Protection 2018).
- New York's clean energy standard requires 50% renewable energy by 2030, and Governor Cuomo has identified a 2,400-MW offshore wind target to help achieve that goal (New York State 2017).
- Maryland has a 2.5% offshore wind renewables portfolio standard (RPS) carve out supported by offshore ORECs (House Bill 226 2013).

Key Findings (continued)

Proposed Additions of New Wind Energy Areas (WEAs) in the Atlantic Are Underway

Until March 2017, the Bureau of Ocean Energy Management (BOEM) has held seven competitive leases and has 12 active wind energy areas with roughly 17 gigawatts (GW) of potential capacity (BOEM 2018a).

- In response to state requests, BOEM has identified four new call areas in the New York Bight off the south coast of Long Island (BOEM 2018b).
- As part of BOEM's *Renewable Energy Path Forward* on the Atlantic, the organization is conducting a high-level evaluation of all areas on the Atlantic Coast for offshore wind development (BOEM 2018a).
- The U.S. Department of the Interior plans to auction the two unleased portions of the Massachusetts WEA (BOEM 2018c).
- The U.S. Department of the Interior's Royalty Policy Committee recommended BOEM should develop 20 GW of offshore wind by issuing 2 GW of new leases annually, starting in 2024, to ensure the development of a robust domestic supply chain (U.S. Department of the Interior 2018).

Offshore Wind Industry Developers Are Working With the U.S. Department of Defense (DOD), BOEM, and the States of California and Hawaii to Resolve Potential Project Siting Obstacles

- In California, DOD has indicated that offshore wind turbines may interfere with ocean-facing radar arrays and offshore training areas (U.S. Department of the Navy 2018). These issues may impact the development of potential lease sites currently under consideration in central California, including Morro Bay. Offshore wind developers have announced they will continue to work with DOD officials to minimize the impact of offshore wind development (Nikolewski 2018).
- Some developers are also considering potential projects in northern California, including Humboldt Bay, that are not anticipated to interfere with military training areas or radar (Redwood Coast Energy Authority [RCEA] 2018).

Key Findings (continued)

U.S. Offshore Wind Technology Investments Aim to Spur Domestic Development and Overcome U.S. Deployment Barriers

- DOE's Advanced Demonstration Projects, Lake Erie Energy Development Corporation's (LEEDCo's) Icebreaker, and the University of Maine's Aqua Ventus I continue to advance and aim to demonstrate novel offshore wind technologies by 2022.
- Developers included energy storage solutions in their proposals submitted to Massachusetts 83C and 83D solicitations (Massachusetts Clean Energy 2017 and 2018).
- DOE announced on June 15, 2018, that it will begin negotiations with the New York State Energy Research and Development Authority (NYSERDA) to form an Offshore Wind Research Consortium. The award resulted from a $20.5 million DOE funding opportunity to encourage public-private offshore wind partnerships that address U.S. offshore wind technology issues.

U.S. Supply Chain Seeing Some Early Activity Even Before Execution of Major Power Purchase Agreements

- Clemson University and MHI/Vestas have signed a 5-year partnership agreement to test the V164-9.5 MW turbine's drivetrains (Clemson University 2017).
- Zentech/Renewable Resources International, AllCoast/AK Suda, and Aelous Energy Group all intend to deploy a U.S.-flagged turbine installation vessel before 2020.
- Developers and state agencies are actively assessing port infrastructure requirements and evaluating potential investment opportunities. For example, New York's Master Plan identified New York Harbor, the Hudson River, and Long Island as potential sites for manufacturing, staging, or operation and maintenance (O&M) activities.

Key Findings (continued)

Global

In 2017, 3,387 MW of Offshore Wind Capacity Was Commissioned Globally, Resulting in a Cumulative Installed Global Capacity of 16.3 GW

- The United Kingdom is still the largest offshore wind market with 5,824 MW of cumulative installed capacity, followed by Germany (4,667 MW), China (1,823 MW), Denmark (1,399 MW), and the Netherlands (1,124 MW).
- France, Poland, and Italy have all shown renewed interest in offshore wind given its increased level of cost competitiveness.
- While China continues to be the largest offshore wind market in Asia, Taiwan signed agreements with Ørsted,[2] WPD, Copenhagen Infrastructure Partners, Northland Power, and Yushan Power for 3,800 MW of capacity. Japan, South Korea, and India also continue to be emerging players in Asia's offshore wind market.

Globally, Auction Prices Continue To Fall: Developers Have Placed Four Bids that Were Termed as "Zero-Subsidy" to Date

- Bids in the most recent Dutch auction (700–750 MW, March 2018) and the German Borkum Riffgrund West 1 project (420 MW, April 2018) were entered as "zero-subsidy" bids.[3]
- Despite higher prices in the past, the recent 2017 U.K. offshore wind auction saw bids prices fall in line with global averages.

[2] DONG Energy changed its name to Ørsted in October 2017. This update will refer to Ørsted from here on.

[3] Note that the Dutch and German auctions do not include the grid connection costs.

Key Findings (continued)

Globally, Turbines Continue To Grow in Capacity, Hub Height, and Rotor Diameter—Decreasing Overall Project Costs

- General Electric (GE) announced the development of a 12-MW wind turbine, the first original equipment manufacturer (OEM) to go above 10 MW (rotor diameter of 220 meters (m), 260 m total height), which the company expects to be available by 2021. Senvion and Siemens Gamesa have also announced 10-MW+ turbine designs.

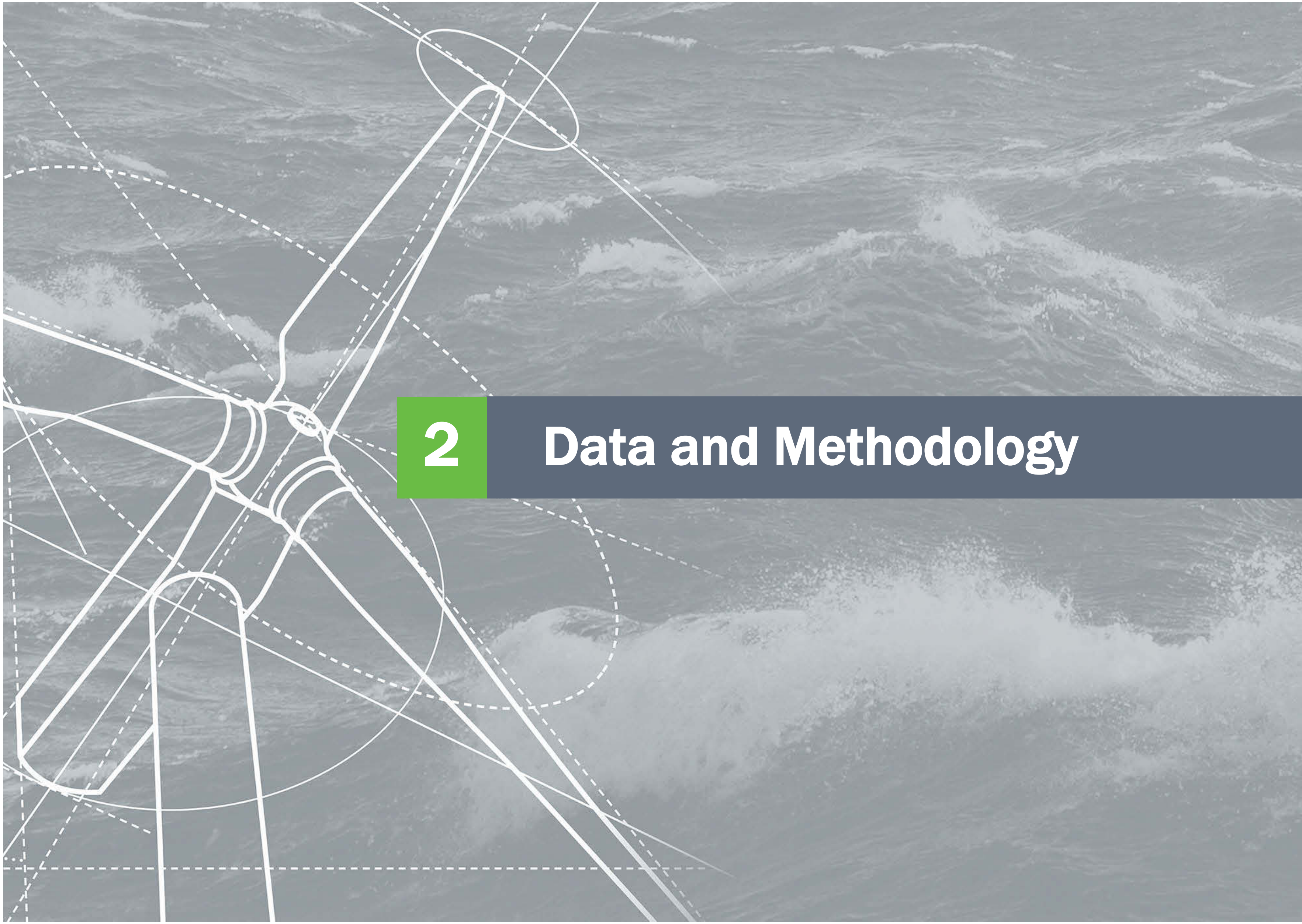
Developers Continue To Test New Fixed-Bottom Substructures To Overcome Geotechnical, Environmental, Domestic Content, and Installation Challenges

- EDF Renewables deployed the first cement gravity-based foundations at its Blyth Offshore Demonstrator in the United Kingdom. Jysk Energi deployed gravity-based foundations at Nissum Bredning in Denmark as part of a joint demonstration project with Siemens. Vattenfall installed its suction bucket and jacket substructure at its European Offshore Wind Deployment Centre in Aberdeen Bay, Scotland.

Numerous Floating Substructure Configurations Continue To Be Evaluated and Demonstrated

- Equinor[4] successfully installed its five-turbine, 30-MW Hywind, which uses a spar substructure, off the coast of Scotland in October 2017.
- Senvion and Principle Power LLC have partnered to test floating platforms capable of supporting offshore wind turbines that are 10 MW or larger in real-world conditions by 2021.
- Ideol's Floatgen 2-MW demonstration project was assembled in port, towed to sea, moored to the seafloor at Le Croisic (France), and connected to the grid in May 2018.

[4] Statoil ASA changed its name to Equinor ASA in March 2018. This update will refer to Equinor from here on.



2 Data and Methodology

Data and Methodology

- This update draws data from NREL's internal offshore wind database, which is built on internal research and a wide variety of data sources, including peer-reviewed literature, press releases, industry news reports, manufacturer specification sheets, and global offshore wind project announcements. For the database, NREL has verified and sourced data from the following publications:
  - The 4C Offshore Wind Database (4C Offshore 2018)
  - Recharge News (Recharge Wind 2018)
  - WindEurope Annual Market Update (WindEurope 2018)
  - Bloomberg New Energy Finance (BNEF) Renewable Energy Project Database (BNEF 2018)
  - MAKE Consulting Global Offshore Wind Database (MAKE Consulting 2018).

Data and Methodology (continued)

- The scope of the report covers the global fleet of operating projects through December 31, 2017. However, the report emphasizes recent developments and events in the United States through the second quarter of 2018.
- Any estimates of capacities and project dates are shown as reported by project developers and state/federal agencies.
- All dollar amounts are reported in 2017 U.S. dollars, unless indicated otherwise.
- In this analysis, U.S. pipeline capacity refers to the sum of project-specific capacities and the undeveloped lease area potential capacities.
- For further discussion on methodology and data sources, please refer to the *2016 Offshore Wind Technologies Market Report* (Musial et al. 2017).

Data and Methodology (continued)

Acronyms and Abbreviations

AC	alternating current
BOEM	Bureau of Ocean Energy Management
CapEx	capital expenditures
CFD	contract for difference
COD	commercial operation date
DOE	U.S. Department of Energy
DOD	U.S. Department of Defense
FID	final investment decision
GW	gigawatt
HVAC	high-voltage alternating current
kV	kilovolt
kW	kilowatt
LEEDCo	Lake Erie Energy Development Corporation
LIPA	Long Island Power Authority
LLC	limited liability company
m	meter(s)
MHI	Mitsubishi Heavy Industries
MW	megawatt
MWh	megawatt-hour
NREL	National Renewable Energy Laboratory
O&M	operation and maintenance
OCS	Outer Continental Shelf
OEM	original equipment manufacturer
OpEx	operational expenditures
OREC	offshore renewable energy certificate
OTM	offshore transmission module
PPA	power purchase agreement
R&D	research and development
RCEA	Redwood Coast Energy Authority
RFP	request for proposal
RES	renewable energy systems
TBD	to be determined
TSO	transmission system operator
WEA	wind energy area

Data and Methodology (continued)

- For the global and U.S. project pipeline, the following classification was applied (see Musial et al. 2017 for more details).

Criteria for Pipeline Classification[5] of Offshore Wind Projects

Step	Phase Name	Phase Start Criteria	Phase End Criteria
1	**Planning**	Starts when developer or regulatory agency initiates formal site control process	Ends when a developer obtains development rights to a site (e.g., through competitive auction or a determination of no competitive interest in the United States)
2	**Site Control**	Begins when developer obtains development rights to a site (e.g., through competitive auction or a determination of no competitive interest in the United States)	Ends when the developer files major permit applications (e.g., a construction operations plan for projects in federal waters in the United States)
3	**Permitting/ Offtake Agreement**	Starts when the developer files major permit applications (e.g., construction operation plan for projects in federal waters in the United States)	Ends when a regulatory body(s) grants authorization to proceed with construction or when the project has signed an offtake agreement
4	**Approved**	Starts when the project has been approved by the relevant regulatory bodies and is fully authorized to proceed with construction or when the project has a signed offtake agreement	Ends when sponsor announces FID and has signed contracts for major construction work packages
5	**Financial Close**	Begins when sponsor announces final investment decision (FID) and has signed unconditional contracts for major construction work packages	Ends when project begins offshore construction work
6	**Under Construction**	Starts when offshore construction work is initiated	Ends when project has been connected to the power grid and all units fully commissioned; COD marks the official transition from construction to operations
7	**Operating**	Commences when project has been connected to the power grid and all units are fully commissioned; commercial operation date (COD) marks the official transition from construction to operations	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 a formal process to decommission and stops feeding power to the grid	Ends when the site has been restored and lease payments are no longer being made, or if the site has been repowered
9	**On Hold/Canceled**	Starts if a sponsor stops development activities (i.e., discontinues lease payments) and/or abandons a prospective site	Ends when the sponsor announces the restart of project development activities

[5] This pipeline classification is not intended to correspond to the terms and definitions used by federal or state authorities. For more details, see Musial et al. (2017).

3 U.S. Offshore Wind Market Update

U.S. Highlights

United States

- The U.S. offshore wind industry took a large leap forward as commercial-scale projects were competitively selected in Massachusetts (800 MW), Rhode Island (400 MW), and Connecticut (200 MW). As of June 2018, the U.S. market has 1,906 MW of capacity that developers have announced to commence operations by 2023 and 25,464 MW of potential capacity in the aggregate pipeline.
- U.S. offshore wind development is primarily driven by state procurement mechanisms, such as ORECs employed in New Jersey and Maryland and competitive solicitations employed in Massachusetts, Rhode Island, and Connecticut.

Massachusetts

- In December 2017, Bay State Wind, Deepwater Wind, and Vineyard Wind submitted responses to the Massachusetts Section 83C of the *Green Communities Act* RFP (400–800 MW of capacity) (Massachusetts Clean Energy 2017).
- On May 23, 2018, Massachusetts Department of Energy Resources in conjunction with the state's electric distribution companies selected Vineyard Wind's 800-MW proposal as the winner of the 83C RFP. Vineyard Wind has until July 31, 2018, to submit an offtake agreement for the Massachusetts' Department of Public Utilities' approval (Massachusetts Clean Energy 2018).
- Despite not being selected, Bay State Wind will continue to develop its project and plans to participate in future solicitations in Massachusetts and neighboring states (Bay State Wind 2018a).

U.S. Highlights (continued)

Massachusetts (continued)

- On December 1, 2017, Cape Wind Associates announced their intention to relinquish its lease with BOEM and ceased development of the proposed offshore wind project in Nantucket Sound.
- On April 11, 2018, BOEM issued a Proposed Sale Notice for companies interested in acquiring Massachusetts lease areas OCS-A 0502 and OCS-A 0503, the two unsold lease areas in the Massachusetts WEA (BOEM 2018c).
- On February 13, 2018, the Federal Energy Regulatory Commission authorized Anbaric Development Partners to charge negotiated rates for an offshore transmission network comprised of a 1,000-MW high-voltage direct-current transmission line to the Southeast Massachusetts Load Zone and two 1,000-MW offshore platforms with alternating current (AC) switching stations (Walton 2018).
- Vineyard Wind announced it will provide $2 million in funding to develop an offshore wind labor force in Massachusetts (Demetre 2018) and was granted an Environmental Notification Form certificate for a transmission cable to a substation on Cape Cod.
- Multiple offshore wind project proposals in Massachusetts also included energy storage. Although neither project was selected, Deepwater Wind included a 40-MW/40-MWh Tesla battery with its proposed 144-MW Revolution Wind project for the state's 83D RFP, and Bay State Wind included a 55-MW/110-MWh NEC Energy Solutions battery as part of its 83C RFP bid.

Rhode Island

- As part of Governor Raimondo's goal to acquire 1,000 MW of renewable capacity by 2020, Rhode Island issued a 400-MW offshore wind RFP in February 2018. As members of Massachusetts' RFP review team, Rhode Island energy officials were ultimately able to select Deepwater Wind's 400-MW Revolution Wind project as the winner of Rhode Island's RFP (Office of the Governor 2018).

U.S. Highlights (continued)

New York

- After signing a power purchase agreement (PPA) with the Long Island Power Authority in 2017, Deepwater Wind's 90-MW South Fork project continues to advance through state and federal environmental permitting processes and is expected to commence operations in 2022.
- In his 2018 State of the State address, Governor Cuomo announced that New York will issue an RFP to add at least 800 MW of new offshore wind capacity in 2018–2019, in support of its goal of 2.4 GW of offshore wind by 2030. He has also directed NYSERDA to fund $15 million of clean energy workforce development (New York State 2018).
- New York's Department of Public Service opened a docket for public comments on the state's preferred offshore wind offtake mechanism (New York State Department of Public Service 2018).
- The NYSERDA *Offshore Wind Masterplan* was released on January 29, 2018. The plan identifies areas for consideration of potential offshore wind energy development and contains a series of environmental, infrastructure, workforce, procurement mechanism, and cost analyses (NYSERDA 2018).
- BOEM published a Call for Information and Nominations on April 11, 2018, to understand interest from companies that might consider commercial wind energy leases within its proposed area in the New York Bight (BOEM 2018b).

New Jersey

- In January 2018, Governor Murphy signed Executive Order #8 directing the Board of Public Utilities to move toward a goal of developing 3,500 MW of offshore wind by 2030 and fully implement the *Offshore Wind Economic Development Act* (2010) by immediately offering ORECs for up to 1,100 MW of capacity to eligible projects (State of New Jersey 2018). In April 2018, New Jersey also expanded its RPS goal to 50% by 2030 and codified its 3.5-GW offshore wind carve out (New Jersey State Legislature 2018a).

U.S. Highlights (continued)

New Jersey (continued)

- Fishermen's Energy was not able to secure a PPA by December 31, 2016, to be eligible for another round of DOE's Offshore Wind Advanced Demonstration Project funding. EDF Renewable Energy reached a preliminary agreement to acquire the fully permitted Fishermen's Energy project (24 MW). Governor Murphy signed S-1217, requiring New Jersey's Board of Public Utilities to accept an application from Fishermen's Energy and review it for approval within 90 days (New Jersey State Legislature 2018b).

Connecticut

- In January 2018, the Connecticut Department of Energy and Environmental Protection issued an RFP for 825,000 MWh/yr of offshore wind. On June 14, 2018, the state selected Deepwater Wind's Revolution Wind 200-MW proposal. The project will be incremental to Deepwater's 400-MW Revolution Wind proposal approved by Rhode Island (Connecticut Department of Energy & Environmental Protection 2018).

Maryland

- US Wind continues to advance through federal and state permitting processes and is installing a meteorological (met) tower in 2018 in the Maryland WEA. Deepwater Wind plans to submit a Site Assessment Plan in 2019 for its 120-MW Skipjack offshore wind project located in the Delaware WEA (BOEM 2018e), which plans to sell power to Maryland.

Virginia

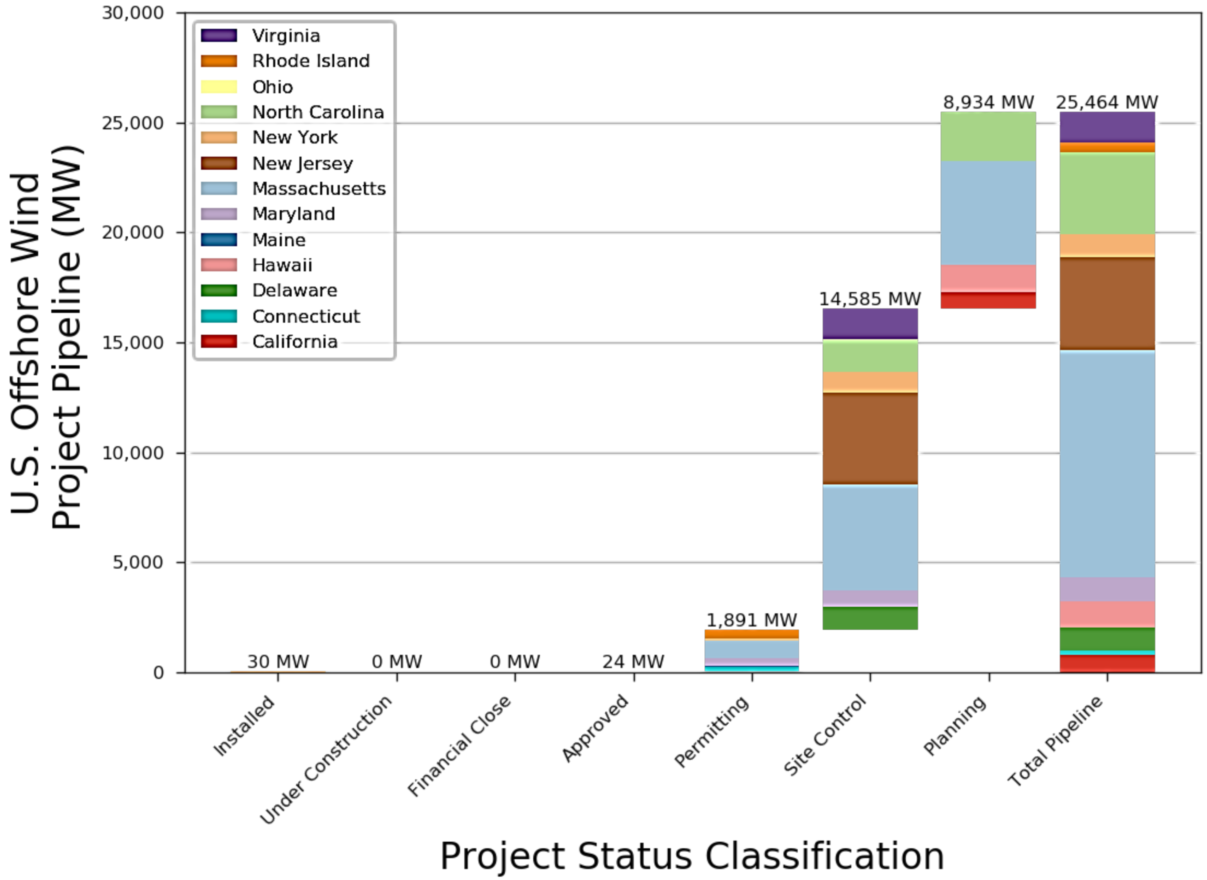
- Ørsted and Dominion signed an engineering, procurement, and construction contract to develop their Coastal Virginia Offshore Wind 12-MW demonstration project, which originated in the DOE Offshore Wind Advanced Technology Demonstration Project program.

Pacific Coast

- BOEM, state officials, and developers continue to plan for the deployment of a commercial floating offshore wind energy project off the Pacific Coast. RCEA proposed a project off the coast of Humboldt Bay, California, and signed a public-private partnership with an industry consortium led by Principle Power LLC. The group plans to submit an unsolicited lease proposal to BOEM in the summer of 2018 (RCEA 2018). Please note that this project is not included in the overall pipeline because the developers have not submitted an application to BOEM.

Project Development Pipeline

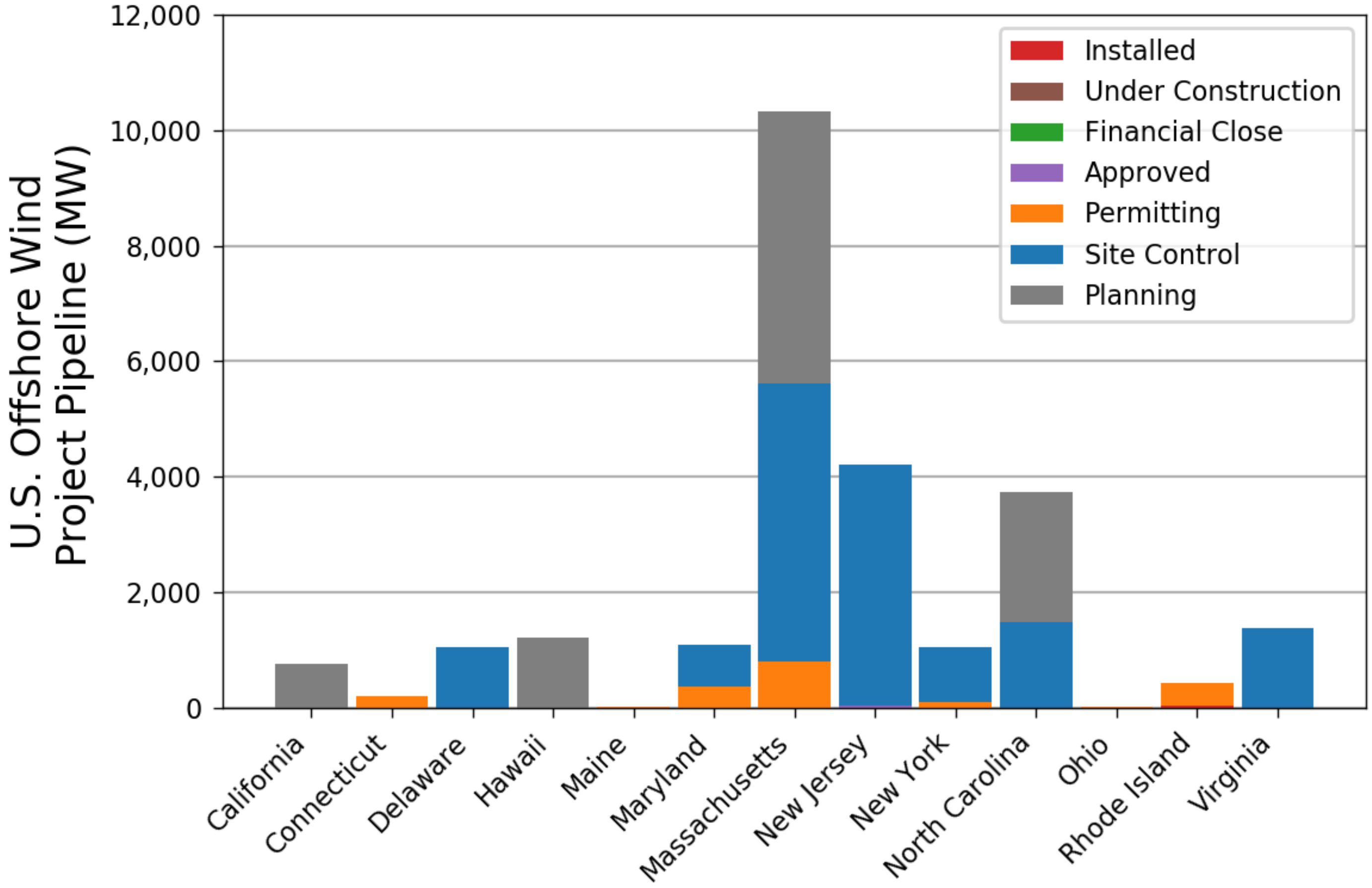
- The total U.S. project pipeline grew by 1,299 MW in 2017. This brings the grand total of the U.S. pipeline to 25,464 MW as of June 2018 with 30 MW already installed. The overall pipeline is comprised of 3,922 MW of project-specific capacity and 21,542 MW of undeveloped lease area potential capacity. Major changes were the Cape Wind (468 MW) lease termination and the addition of Deepwater Wind's Garden State offshore wind energy project (600 MW).



U.S. Offshore Wind Project Pipeline by Project Status as of June 2018

Project Development Pipeline (continued)

- The U.S. pipeline continues to be led by projects along the U.S. Eastern Seaboard; a number of these projects advanced in the project development process during 2017 and the first half of 2018.



U.S. Project Pipeline by State as of June 2018

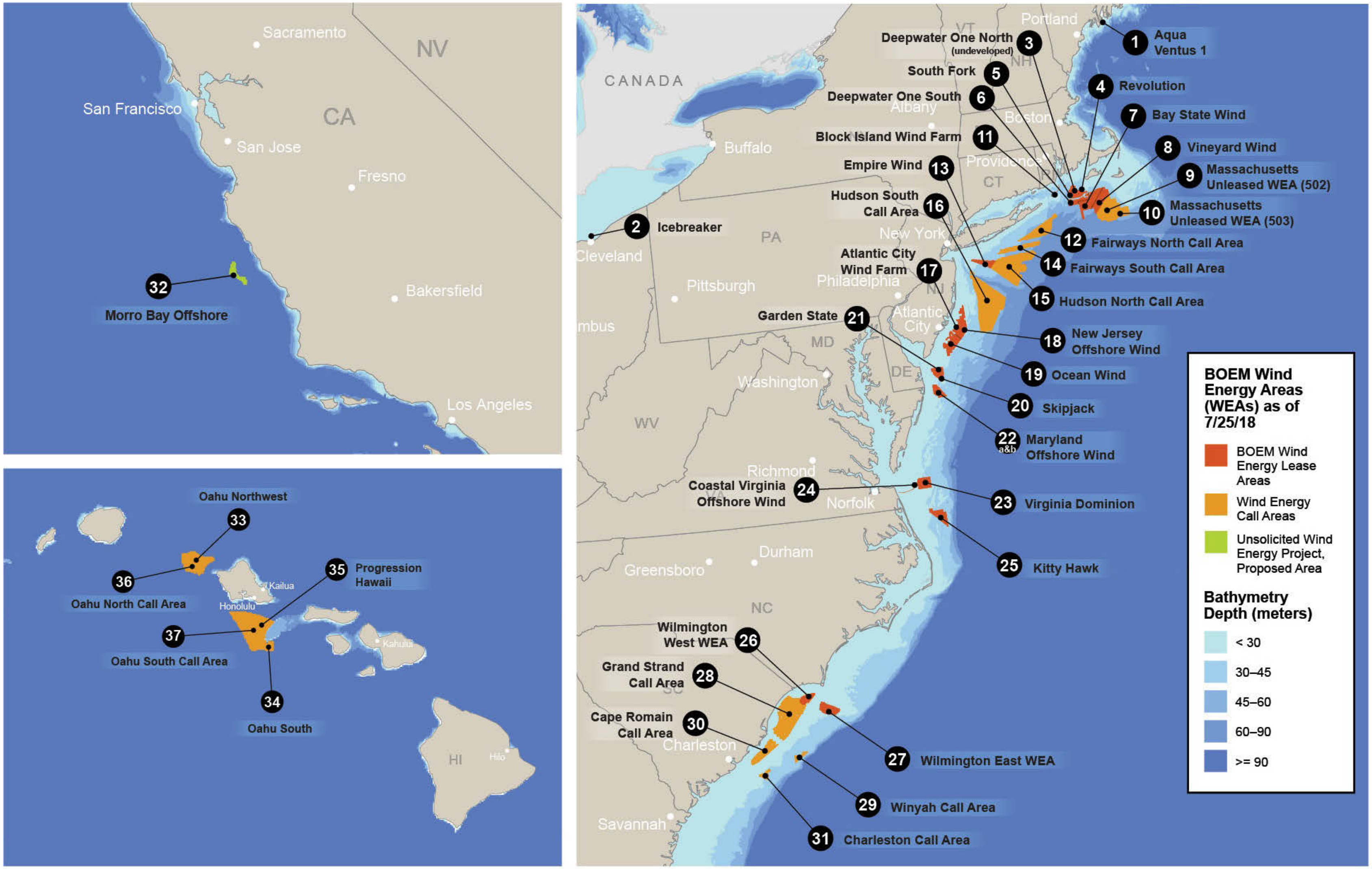
U.S. Project Pipeline Status

			Permitting					
Stage	**Planning**	**Site Control**	**Procurement Initiated**	**Contract Awarded**	**Approved**	**FID**	**Under Construction**	**Operating**
Projects	AW Oahu Northwest (HI) 400 MW	Undeveloped[6] Portion of Deepwater ONE North (MA) 495 MW	Maine Aqua Ventus I (ME) 12 MW	South Fork (NY) 90 MW	Fishermen's Energy (NJ) 24 MW			Block Island Wind Farm (RI) 30 MW
	AW Oahu South (HI) 400 MW	Deepwater ONE South (MA) 816 MW	Vineyard Wind (MA) 800 MW	Skipjack (MD) 120 MW				
	Progression Hawaii (HI) 400 MW	Bay State (MA) 2,277 MW	Revolution Wind (RI and CT) 600 MW	US Wind (MD) 248 MW				
	Morro Bay (CA) 765 MW	Undeveloped[6] Portion of Vineyard Wind (MA) 1,225 MW	Icebreaker (OH) 21 MW					
	WEA Wilmington East (NC) 1,623 MW	Empire Wind (NY) 963 MW						
	WEA Wilmington West (NC) 627 MW	Ørsted Ocean Wind (NJ) 1,947 MW						
	Massachusetts WEA 502 (MA) 3,012 MW	US Wind (NJ) 2,226 MW						
	Massachusetts WEA 503 (MA) 1,707 MW	Deepwater Garden State (DE) 1,050 MW						
		US Wind (MD) 718 MW						
		Dominion (VA) 1,371 MW						
		Coastal Virginia Offshore Wind (CVOW) (VA) 12 MW						
		Avangrid Kitty Hawk (NC) 1,485 MW						
Total	8,934 MW	14,585 MW	1,433 MW	458 MW	24 MW			30 MW

Estimated Capacity | Project-Specific Capacity

[6] Defined as sections of a lease area without current development activity

U.S. Lease and Call Areas



Map of U.S. Offshore Wind Lease and Call Areas

Note: Please refer to slides 26 and 27 for details on the depicted U.S. lease and call areas

U.S. Lease and Call Areas (continued)

Note: Project numbering corresponds to page 25. Pipeline capacity is the sum of project-specific capacity and undeveloped lease area potential capacity.

	#	Lease and Call Area	Project Name	Developer	Offtake State	Current Status	Project-Specific Capacity (MW)	Undeveloped Lease Area Potential Capacity (MW)	Pipeline Capacity (MW)	Lease Area (km^2)	Winning Bid	Date Announced	Water Depth (m)	Average Wind Speed (m/s)
North Atlantic	1	Maine State Lease	Maine Aqua Ventus I	University of Maine	ME	Permitting	12	0	12	9	N/A	6/4/2009	61–110	8.75
	N/A	OCS-A 0478	Cape Wind	Cape Wind Associates	MA	Canceled[9]	N/A	N/A	N/A	119	N/A	10/6/2010	1–18	8.7
	3	Deepwater One North OCS-A 0486	Undeveloped[8]	Deepwater Wind	MA	Site Control	0	495	1,185	395	$3,089,461	10/1/2013	30–46	9.1
	4		Revolution		RI and CT	Permitting	600	0				5/23/2018	30–46	9.1
	5		South Fork		NY	Permitting	90	0				1/25/2017	31–36	9.2
	6	Deepwater One South OCS-A 0487	Deepwater One South	Deepwater Wind	MA	Site Control	0	816	816	272	N/A	10/1/2013	30–46	9.2
	7	OCS-A 0500	Bay State Wind	Ørsted and Eversource	MA	Site Control	0	2,277	2,277	759	$281,285	4/1/2015	39–50	9.3
	8	OCS-A 0501	Vineyard Wind	CIP and Avangrid	MA	Site Control	800	1,225	2,025	675	$150,197	4/1/2015	36–58	9.3
	9	OCS-A 0502	Unleased WEA	N/A	N/A	Planning	0	3,012	3,012	1,004	N/A	N/A	34–62	9.3
	10	OCS-A 0503	Unleased WEA	N/A	N/A	Planning	0	1,707	1,707	569	N/A	N/A	34–62	9.4
	11	Rhode Island State Lease	Block Island Wind Farm	Deepwater Wind	RI	Operational	30	0	30	10	N/A	N/A	23–28	9.7
	12	N/A	Fairways North Call Area	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	13	OCS-A 0512	Empire Wind	Equinor	NY	Site Control	0	963	963	321	$42,469,725	12/16/2016	20–40	9.3
	14	N/A	Fairways South Call Area	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	15	N/A	Hudson North Call Area	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	16	N/A	Hudson South Call Area	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	17	New Jersey State Lease	Atlantic City Wind Farm	Fishermen's Energy and EDF	NJ	Approved	24	0	24	8	N/A	6/5/2011	8–12	8.3
	18	OCS-A 0499	New Jersey Offshore Wind	US Wind	NJ	Site Control	0	2,226	2,226	742	$1,006,240	3/1/2016	17–34	8.6
	19	OCS-A 0498	Ocean Wind	Ørsted	NJ	Site Control	0	1,947	1,947	649	$880,715	3/1/2016	17–34	8.4
	20	OCS-A 0482	Skipjack	Deepwater Wind	MD	Permitting	120	0	1,170	390	$24,108	12/1/2012	9–33	8.3
	21		Garden State		DE	Site Control	0	600						
	22a	OCS-A 0489[7]	Maryland Offshore Wind	US Wind	MD	Permitting	248	148	396	132	$3,841,538	12/1/2014	16-29	8.2
	22b	OCS-A 0490[7]			MD	Site Control	0	570	570	190	$4,859,560	12/1/2014	14-37	8.3
		North Atlantic Subtotal: 18,360 MW					1,924 MW	16,436 MW	18,360 MW	6,244 km^2	$56,602,829			

[7] Effective March 1, 2018, US Wind's commercial leases OCS-A 0489 and OCS-A 0490 were merged into a single lease, retaining lease number OCS-A 0490. These are still shown separately here to depict the difference in status of the formerly separate lease areas.

[8] Defined as sections of a lease area without current development activity. [9] On December 1, 2017, Cape Wind Associates announced their intention to relinquish its lease with BOEM.

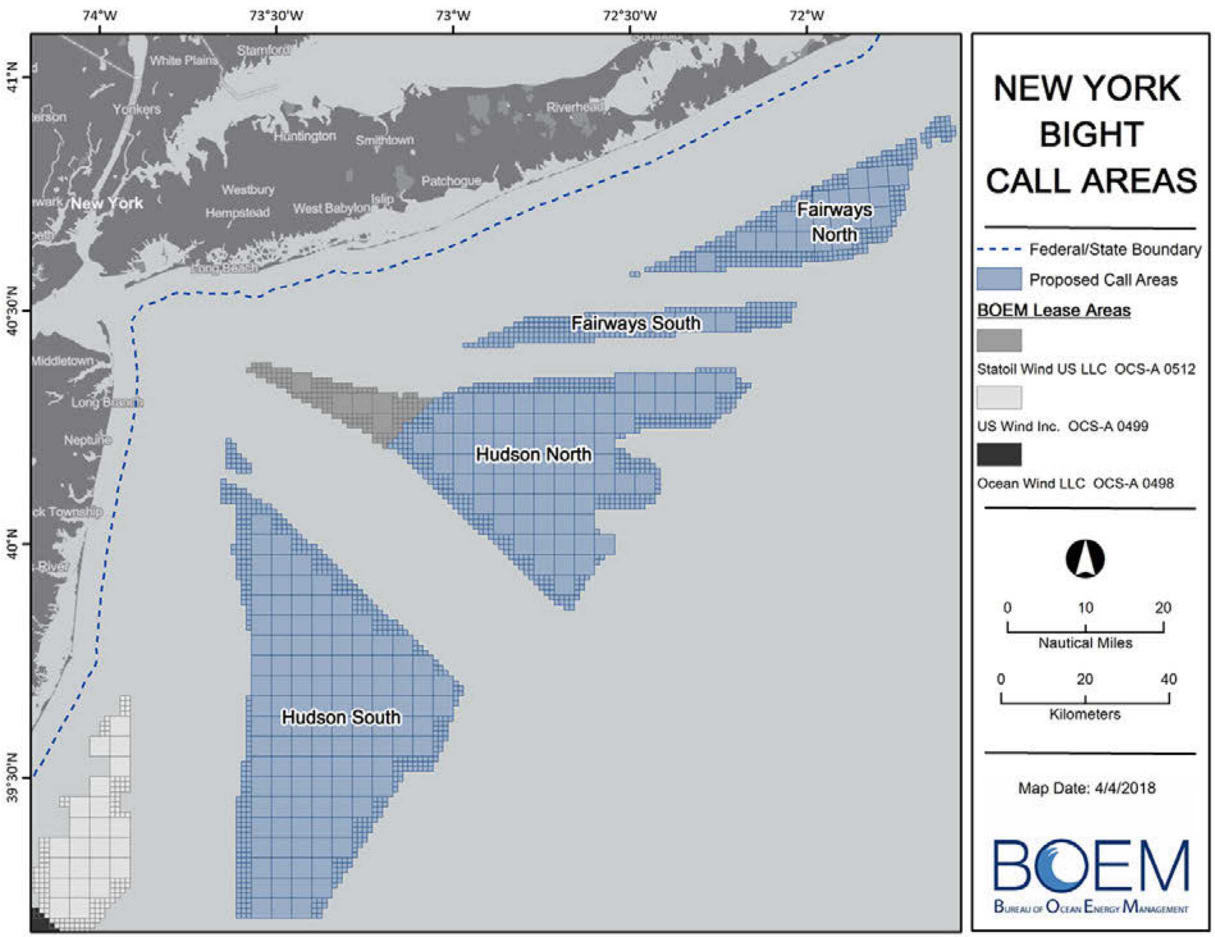
U.S. Lease and Call Areas (continued)

Note: This table reflects information available by the end of Q2 2018. Call Areas (shaded in light gray below) are not counted toward pipeline totals.

	#	Lease and Call Area	Project Name	Developer	Offtake State	Current Status	Project - Specific Capacity (MW)	Undeveloped Lease Area Potential Capacity (MW)	Pipeline Capacity (MW)	Lease Area (km²)	Winning Bid	Date Announced	Water Depth (m)	Average Wind Speed (m/s)
South Atlantic	23	OCS-A 0483	Virginia Dominion	Dominion	VA	Site Control	0	1,371	1,371	457	$1,600,000	11/1/2013	18–33	8.5
South Atlantic	24	CVOW Research Lease OCS-A 0497	Coastal Virginia Offshore Wind	Ørsted and Dominion	VA	Site Control	12	0	12	6	N/A	11/2015	20–26	8.3
South Atlantic	25	OCS-A 0508	Kitty Hawk	Avangrid Renewables	NC	Site Control	0	1,485	1,485	495	$9,066,550	3/17/2017	31–43	8.5
South Atlantic	26	Wilmington West WEA	N/A	N/A	NC	Planning	0	1,623	1,623	541	N/A	N/A	14–20	8.3
South Atlantic	27	Wilmington East WEA	N/A	N/A	NC	Planning	0	627	627	209	N/A	N/A	15–29	8.4
South Atlantic	28	N/A	Grand Strand Call Area	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
South Atlantic	29	N/A	Winyah Call Area	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
South Atlantic	30	N/A	Cape Romain Call Area	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
South Atlantic	31	N/A	Charleston Call Area	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	South Atlantic Subtotal: 5,118 MW						12 MW	5,106 MW	5,118 MW	1,708 km²				
Pacific	32	Unsolicited Application	Morro Bay Offshore	Trident Wind	CA	Planning	765	0	765	275	N/A	N/A	461–996	7.81
Pacific	N/A	N/A	Humboldt Bay	Principle Power/EDPR/RCEA	CA	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pacific	33	Unsolicited Application	Oahu Northwest	Alpha Wind	HI	Planning	400	0	400	133	N/A	N/A	N/A	8.3
Pacific	34	Unsolicited Application	Oahu South	Alpha Wind	HI	Planning	400	0	400	133	N/A	N/A	N/A	8.4
Pacific	35	Unsolicited Application	Progression Hawaii	Progression	HI	Planning	400	0	400	133	N/A	N/A	N/A	8.4
Pacific	36	N/A	Oahu North Call Area	N/A	HI	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.3
Pacific	37	N/A	Oahu South Call Area	N/A	HI	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.4
	Pacific Subtotal: 1,965 MW						1,965 MW	0	1,965 MW	724 km²				
Great Lakes	2	Ohio State Lease	Icebreaker	LEEDCo	OH	Permitting	21	0	21	10	N/A	N/A	16–19	8.1
	Great Lakes Subtotal: 21 MW						21 MW	0	21 MW	10 km²				
	Total U.S. Pipeline Capacity: 25,464 MW						3,922 MW	21,542 MW	25,464 MW	8,816 km²	$67,269,379			

U.S. Lease and Call Areas (continued)

- BOEM published a Call for Information and Nominations on April 11, 2018, to understand interest from companies that might consider commercial wind energy leases within its proposed area in the New York Bight (shown below).



BOEM Map of New York Bight Call Areas

Source: Reprinted from BOEM (2018)

U.S. Lease and Call Areas (continued)

Atlantic

- BOEM issued a Request for Feedback on the Proposed Path Forward for Future Offshore Renewable Energy Leasing on the Atlantic Outer Continental Shelf (OCS) to determine specific areas off the Atlantic Coast that are optimal for offshore wind development and to identify factors that increase the likelihood of projects being constructed (BOEM 2018a).

Massachusetts

- BOEM issued a Proposed Sale Notice for companies interested in acquiring lease areas OCS-A 0502 and OCS-A 0503—the two unsold lease areas in the Massachusetts WEA were originally part of the auction held in January 2015 (BOEM 2018c).
- BOEM issued a Notice of Intent for an Environmental Impact Statement on Vineyard Wind's construction and operations plan to operate an 800-MW project offshore Massachusetts. If the statement finds the construction and operations plan to be appropriate, Vineyard Wind can advance toward project construction (Federal Register 2018a).
- On May 10, 2018, BOEM approved Vineyard Wind's Site Assessment Plan for OCS-A 0501, allowing the company to install up to two Fugro SEAWATCH Wind lidar metocean buoys (BOEM 2018d).
- On June 29, 2017, BOEM approved Bay State Wind's Site Assessment Plan for OCS-A 0500 to install two floating lidar buoys and one metocean/current buoy (BOEM 2018d).

U.S. Lease and Call Areas (continued)

Rhode Island and Massachusetts Area of Mutual Interest

- On October 12, 2017, BOEM approved Deepwater Wind's Site Assessment Plan for lease area OCS-A 0486 to install an AXYS floating lidar 6M meteorological buoy (BOEM 2018c).

New York

- BOEM published a Call for Information and Nominations on April 11, 2018, to obtain nominations from companies interested in commercial wind energy leases within its four proposed areas in the New York Bight (Federal Register 2018b).

Maryland

- On March 22, 2018, BOEM approved US Wind's Site Assessment Plan for OCS-A 0490 to install a twisted jacket met tower designed by Keystone Engineering and deploy a seabed-mounted acoustic Doppler current profiler and conductivity, temperature, and depth sensors (BOEM 2018e).

California

- RCEA issued a request for qualifications to identify a qualified entity or group to enter into a public-private partnership that could develop an offshore wind project off the coast of Northern California (RCEA 2018).
- RCEA selected a consortium including Principle Power, EDPR Offshore North America, Aker Solutions, H.T. Harvey & Associates, and Herrera Environmental Consultants to lead the development of a 100- to 150-MW offshore wind project 20 miles off the coast of Eureka, California (RCEA 2017).

Siting and Environmental Developments

Environmental

- In September 2017, the Fisheries Survival Fund and other plaintiffs filed a lawsuit against BOEM regarding their current Empire Wind lease. Plaintiffs claim that BOEM did not adequately assess the project's impact on local fish populations, habitats, and shoreside communities.
- In March 2018, LEEDCo conducted additional assessments on the potential impact to avian species after local environmental groups voiced concerns about the Icebreaker project's potential negative influence on the local bird and bat populations.

Visual

- In March 2018, officials representing Ocean City proposed Maryland House Bill 1135, which prohibits turbine installation closer than 26 nautical miles from shore because of the potential negative visual impact on tourism industries. The proposed legislation did not pass through the committee.

Military

- Currently, offshore wind industry developers are working with DOD, BOEM, and the state of California to resolve potential conflicts with military operations, training, and radar that cover a wide portion of the OCS in central California, as well as Hawaii. Offshore wind development is being considered in portions of these areas.

Procurement Mechanisms

- NYSERDA published the *New York State Offshore Wind Master Plan*, outlining a framework to develop 2,400 MW of offshore wind capacity. The plan identified several potential procurement mechanisms, including fixed renewable energy certificates (RECs), bundled and split PPAs, utility-owned generation, market ORECs, indexed ORECs, and forward ORECs (New York State 2018). In January 2018, New York's Department of Public Service opened a 60-day docket for public comments about implementing offshore wind procurement mechanisms.
- The Connecticut Department of Energy & Environmental Protection issued an RFP for up to 825,000 MWh/yr of offshore wind. On June 14, 2018, the agency selected Deepwater Wind's 200-MW Revolution Wind proposal. The proposal will add to Deepwater's 400-MW Revolution Wind project approved by Rhode Island, growing the project's overall size to 600 MW (Connecticut Department of Energy & Environmental Protection 2018).
- In April 2018, Governor Phil Murphy signed New Jersey's new RPS legislation targeting 50% renewable energy and the procurement of 3,500 MW of offshore wind by 2030. The Governor's Executive Order #8 directed the Board of Public Utilities to implement the 2010 *Offshore Wind Economic Development Act* by immediately offering ORECs for up to 1,100 MW of capacity to eligible projects (New Jersey State Legislature 2018a).
- To help meet the Massachusetts' procurement goal of 1,600 MW by 2027, the state's Department of Energy Resources selected Vineyard Wind's 800-MW proposal in the first round of its competitive solicitation.

State Offshore Wind Procurement Targets

- **Massachusetts' target:** 1,600 MW by 2027. Massachusetts will hold competitive solicitations at least every 2 years to meet their target.
- **Connecticut's target:** 825,000 MWh/yr. Offshore wind projects will be acquired via RFPs.
- **New York's target:** 2,400 MW by 2030. New York's Public Service Commission opened a docket to receive public comment on the optimal offshore wind procurement mechanism.
- **New Jersey's target:** 3,500 MW by 2030. The state will obtain offshore wind capacity by holding RFPs and offering the winners New Jersey ORECs.
- **Maryland's target:** 2.5% of the state's total retail electric sales. Capacity will be acquired by holding RFPs and offering the awardees Maryland ORECs.

Project-Specific Offtake Agreements

Project Name	Offtake State	Offtake Mechanism	Details
Aqua Ventus I	ME	PPA	A term sheet was approved by the Maine Public Utilities Commission in 2013. This has not been executed into a PPA. In 2018, the Maine Public Utilities Commission reopened the previously agreed-upon term sheet because of significant changes in the energy market since 2013.
Revolution Wind	RI	PPA	Rhode Island's Department of Energy Resources evaluated project proposals within Massachusetts 83C RFP in an effort to help meet Rhode Island's 1,000-MW-by-2020 goal and selected Deepwater Wind's 400-MW Revolution Wind project. Deepwater has until July 31, 2018, to reach an offtake agreement with an electric distribution company.
Block Island Wind Farm	RI	PPA	Block Island's PPA is a 20-year agreement with National Grid for 30 MW of capacity. The price of electricity increases 3.5% annually.
Revolution Wind	CT	PPA	Connecticut issued a competitive solicitation in 2018 to potentially obtain a maximum of 825,000 MWh annually (~200 MW) from offshore wind under a PPA with a maximum duration of 20 years. Project(s) must connect into ISO New England. Deepwater Wind's 200-MW proposal was selected as the winner. PPA negotiations with electric distribution companies are ongoing.
Vineyard Wind	MA	PPA	Massachusetts issued an RFP to obtain between 200 and 800 MW of offshore wind capacity. Vineyard Wind's 800-MW proposal was selected as the winner. Vineyard Wind has until July 31, 2018, to reach an offtake agreement with an electric distribution company.
South Fork	NY	PPA	South Fork's PPA is a 20-year agreement with Long Island Public Power Authority for 90 MW of capacity at a yet-to-be-determined price. Harrington (2017) reports that the PPA is estimated to be around $160/MWh.
Skipjack	MD	MD ORECs	Skipjack was awarded ORECs that are 20 years' worth of MD ORECs for 120 MW of capacity. Each year, 455,482 ORECs will be sold with each credit valued at $131.93/MWh.
US Wind	MD	MD ORECs	US Wind was awarded ORECs that are 20 years' worth of MD ORECs for 248 MW of capacity. Each year, 913,845 ORECs will be sold with each credit valued at $131.93/MWh.
Icebreaker	OH	PPA	Signed a memorandum of understanding to provide Cleveland with 25% of its generation at an undisclosed price. American Municipal Power agreed to purchase 30% of its generation. Cuyahoga County signed a 10-year PPA to buy 8.6% of the project's output.

Research and Development

- DOE provided $20.5 million and selected NYSERDA to administer a public-private R&D consortium focused on addressing U.S.-specific offshore wind research (June 2018).
- DOE's two Offshore Wind Advanced Demonstration Projects, LEEDCo's Icebreaker (OH), and University of Maine's Aqua Ventus I (ME) continue to progress through permitting and offtake processes.
- Clemson and MHI Vestas Offshore Wind agreed to utilize the Clemson 15-MW dynamometer to test and validate the V164-9.5-MW turbine's drivetrain (October 2017); the Clemson dynamometer facility development was supported with DOE funds (Clemson University 2017).
- The *New York State Offshore Wind Master Plan* presented a collection of 24 analyses that identified the best areas for offshore wind development, described potential economic and environmental benefits, evaluated procurement mechanisms, analyzed cost reduction pathways, explored impact mitigation options, assessed infrastructure/supply chain requirements, and identified workforce development opportunities (December 2017).

Research and Development (continued)

- NYSERDA issued a $5 million RFP to collect metocean data in potential offshore wind development sites off New York's coast using two floating lidar buoys (NYSERDA 2018).
- Bay State Wind signed agreements with the International Brotherhood of Electrical Workers; the Utility Workers Union of America; the International Association of Bridge, Structural, Ornamental, and Reinforcing Iron Workers; Bristol Community College; and the Massachusetts Maritime Academy to develop an offshore wind workforce training center (Bay State Wind 2018c).
- Bay State Wind announced $2 million in grants for programs and R&D to protect New England fisheries and whale populations and mitigate the potential impact of offshore wind activities (Bay State Wind 2018d).
- Vineyard Wind announced a $10 million offshore wind industry supply chain accelerator, a $2 million workforce development program, and a $3 million program to develop innovative ways to mitigate marine mammals from offshore wind installation activities (Vineyard Wind 2018).
- The Commonwealth of Virginia Department of Mines, Minerals and Energy issued an RFP to conduct an offshore wind supply chain and port infrastructure assessment to inform the long-term development of offshore wind in Virginia (Commonwealth of Virginia Department of Mines, Minerals and Energy 2018).
- The California Energy Commission signed a memorandum of understanding with the Danish Energy Agency to share knowledge, data, and best practices relevant to developing offshore wind energy (California Energy Commission 2018).

4 Global Market Update

Highlights

Europe

- During 2017, offshore wind auctions were held in Germany, the Netherlands, and the United Kingdom for projects with commissioning dates between 2021 and 2025. Auction prices were significantly lower than those from prior years and resulted in auction results that were termed as “zero-subsidy” bids in the German and Dutch auction (see additional detail in the Costs and Pricing Trends section).
- The Crown Estate announced that new seabed rights might be made available for offshore wind projects in late 2018 or early 2019 off the coast of England, Wales, Scotland, and Northern Ireland. As of May 31, 2018, it is no longer accepting applications for offshore wind farm extensions.
- The “Provence Grand Large” (24 MW) and “Groix & Belle-Ile” (24 MW) floating projects have submitted their consent applications, while results from France’s third round of floating auctions (“Dunkirk”) for bids of 250–750 MW were announced in March 2018.
- The Equinor/Masdar Hywind floating project in Scotland (30 MW) commenced commercial operation in 2017 and achieved a capacity factor of 65% in its first 3 months of operation (November–January) (Equinor 2018).
- After its merger, Siemens Gamesa is now the largest OEM, with a market share of 68% of globally installed offshore wind capacity using Siemens Gamesa turbines.

Highlights (continued)

Asia

- China's offshore wind industry has seen gradual growth since 2015, increasing grid-connected capacity to 1.2 GW in 2017, making the country the third-largest offshore wind market in the world. As projects from the *2014–2016 National Offshore Development Plan* continue to progress toward construction and commissioning, the pipeline is projected to grow steadily up until 2020. In addition, nine provinces have developed offshore goals totaling 75 GW.
- China's offshore industry has evolved from installing turbines at intertidal sites* to deeper offshore wind marine sites as its supply chain has matured. In 2017, most of the Chinese turbine OEMs supplied 3- to 4-MW turbines, whereas GE and Siemens supplied 5- to 6-MW models. Chinese manufacturers are developing 5- to 6-MW models; however, most are still in the prototype phase.
- In April 2018, the Taiwanese Bureau of Energy awarded a total of 3,836 MW of grid connection capacity to 11 offshore wind farms proposed by seven developers. Of this total, 738 MW will be completed by 2020, with 3,098 MW to be installed between 2021 and 2025. All the projects have been awarded feed-in-tariff contracts. International developers captured 85% of the grid capacity and local developers were awarded 15% (BNEF 2018).

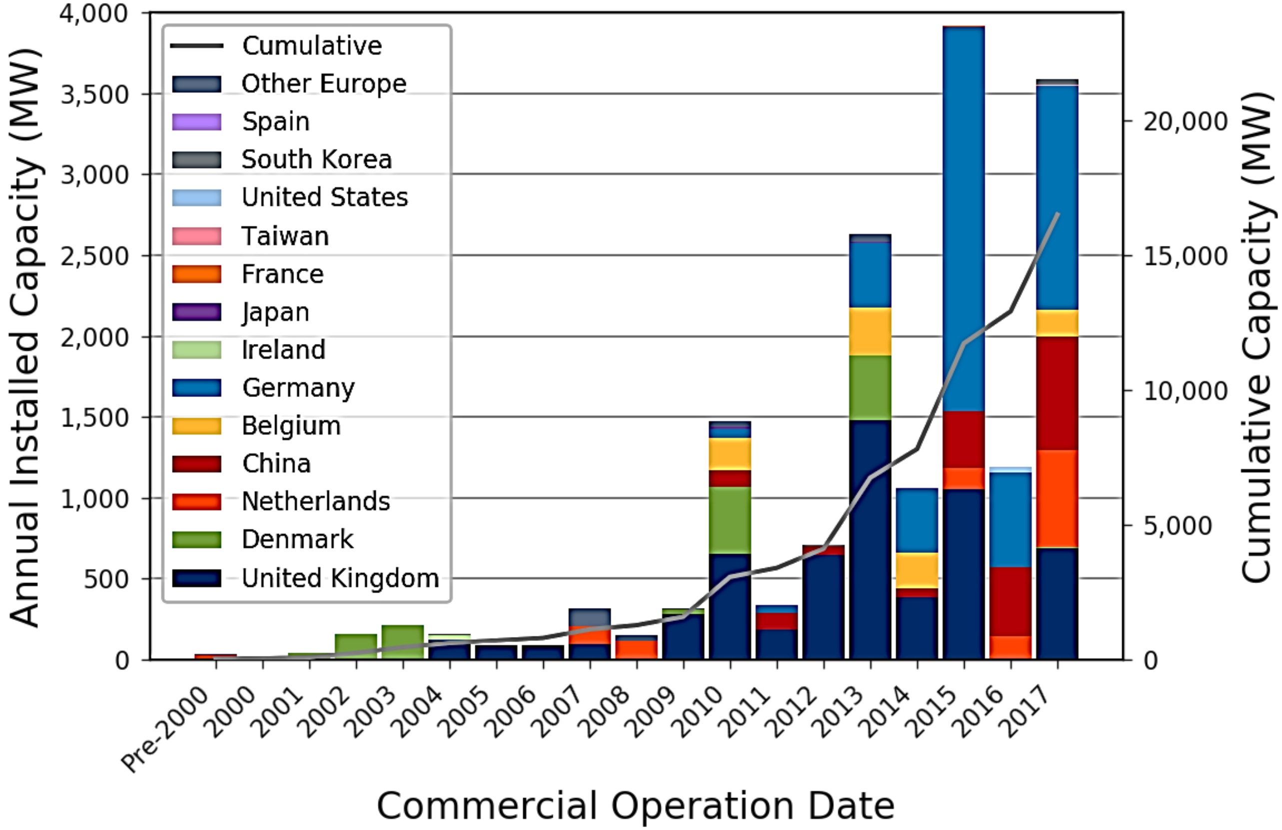
* Intertidal regions are coastal regions where turbine foundations may not always be submerged.

Highlights (continued)

- In 2018, Taiwan embarked on a clean energy transition, aiming to add 25 GW of renewable energy by 2025, including 5.5 GW of offshore wind (Jacobsen 2018).
- Taiwan launched the “thousand wind turbines project” in 2012, which established targets for land-based and offshore wind. At the end of 2017, Taiwan had installed two demonstration turbines. Taiwan established a feed-in tariff for offshore wind of NT$6.0437 (approximately USD$0.20) per kilowatt-hour, which has attracted interest from experienced European developers as well as local developers.
- Planned Asian projects are more frequently located in deeper waters than installed projects elsewhere in the world but at a similar distance from shore.

Installed Capacity

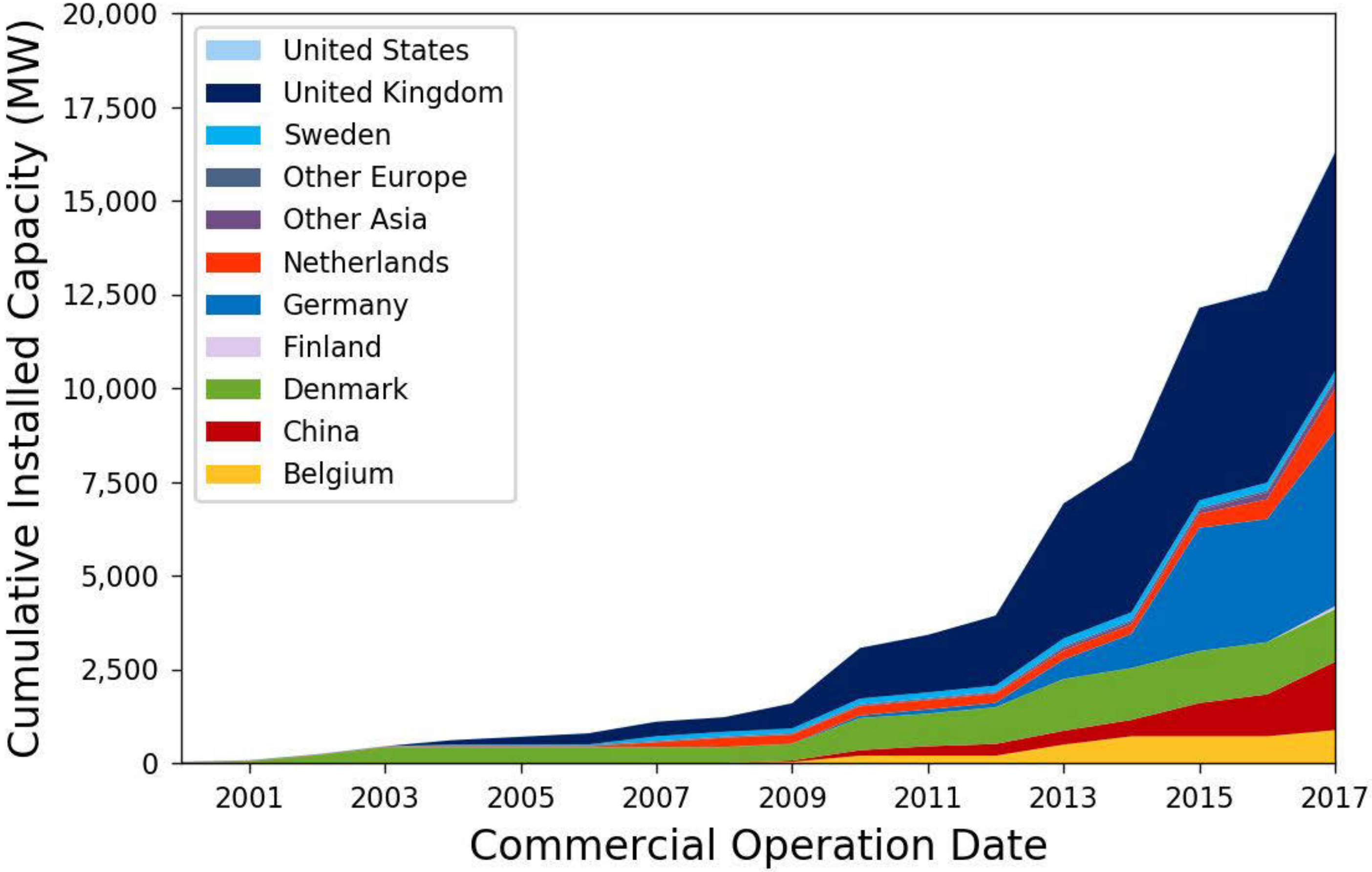
- During 2017, more than 3.5 GW of installed capacity was added, making the cumulative offshore wind installed capacity 16.3 GW by year's end. The Netherlands added the largest percentage of installed capacity with 115%, followed by China (65%), and Germany (36%), among established markets.



Operating Global Offshore Wind Capacity by Market (Annual and Cumulative)

Note: The cumulative totals reported on pages 41 and 42 in comparison to pages 43 and 45 differ by 186 MW. A new data sourcing methodology was introduced in this year's market update. The reported cumulative total on pages 43 and 45 reflect this new data sourcing methodology. For better comparison with the *2016 Offshore Wind Technologies Market Report* (Musial et al. 2017), the annual totals (and cumulative total) shown on pages 41 and 42 still correspond to the data sourcing methodology documented in Musial et al. (2017).

Installed Capacity (continued)

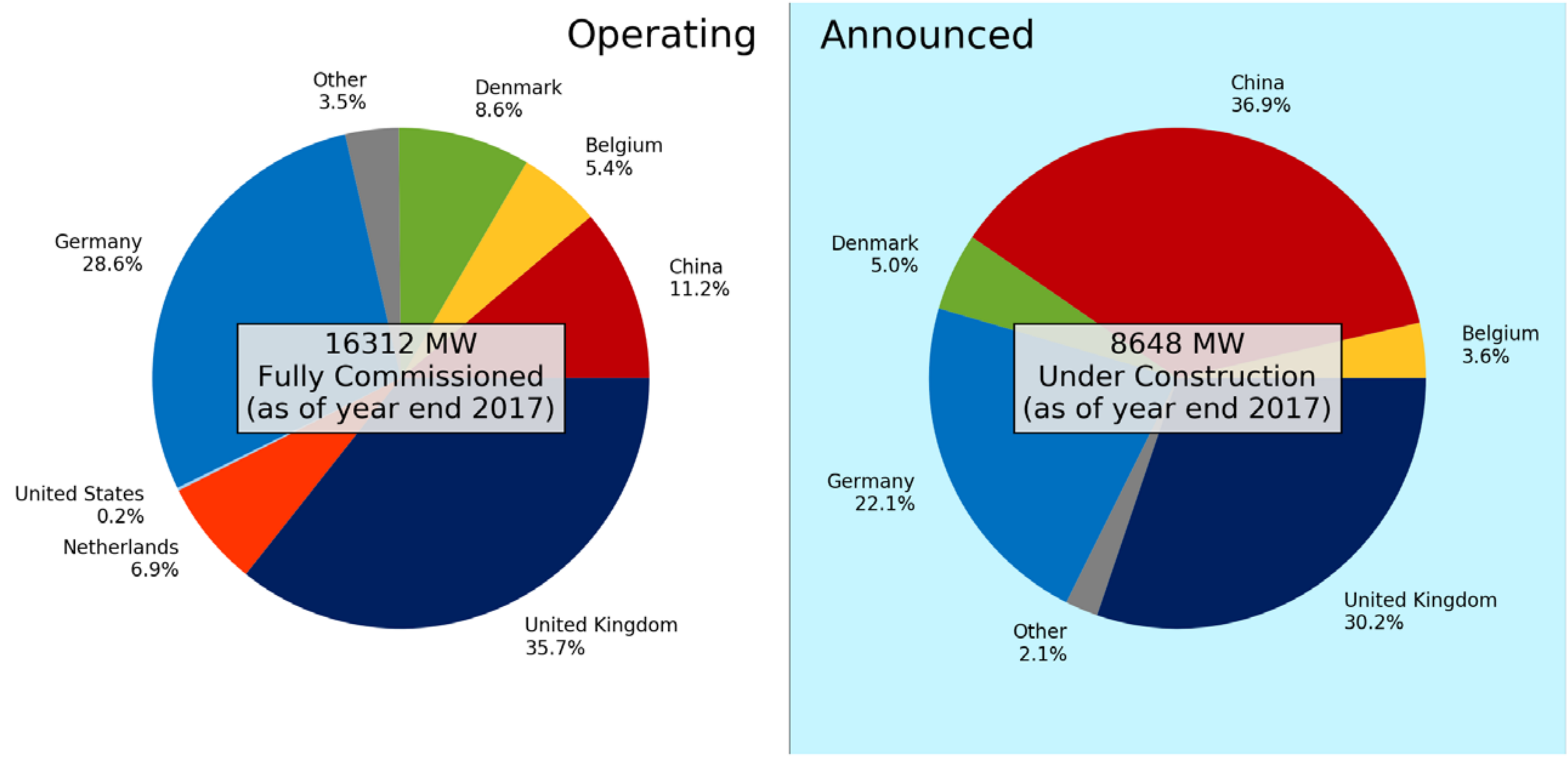


Share of Cumulative Installed Offshore Wind Capacity by Country

Note: The cumulative totals reported on pages 41 and 42 in comparison to pages 43 and 45 differ by 186 MW. A new data sourcing methodology was introduced in this year's market update. The reported cumulative total on pages 43 and 45 reflect this new data sourcing methodology. For better comparison with the *2016 Offshore Wind Technologies Market Report* (Musial et al. 2017), the annual totals (and cumulative total) shown on pages 41 and 42 still correspond to the data sourcing methodology documented in Musial et al. (2017).

Installed Capacity (continued)

- Offshore wind projects in China comprised only 11.2% of the installed global capacity at the end of 2017; however, China has the largest capacity of offshore wind projects under construction (3.2 GW), followed by the United Kingdom (2.6 GW) and Germany (1.9 GW).

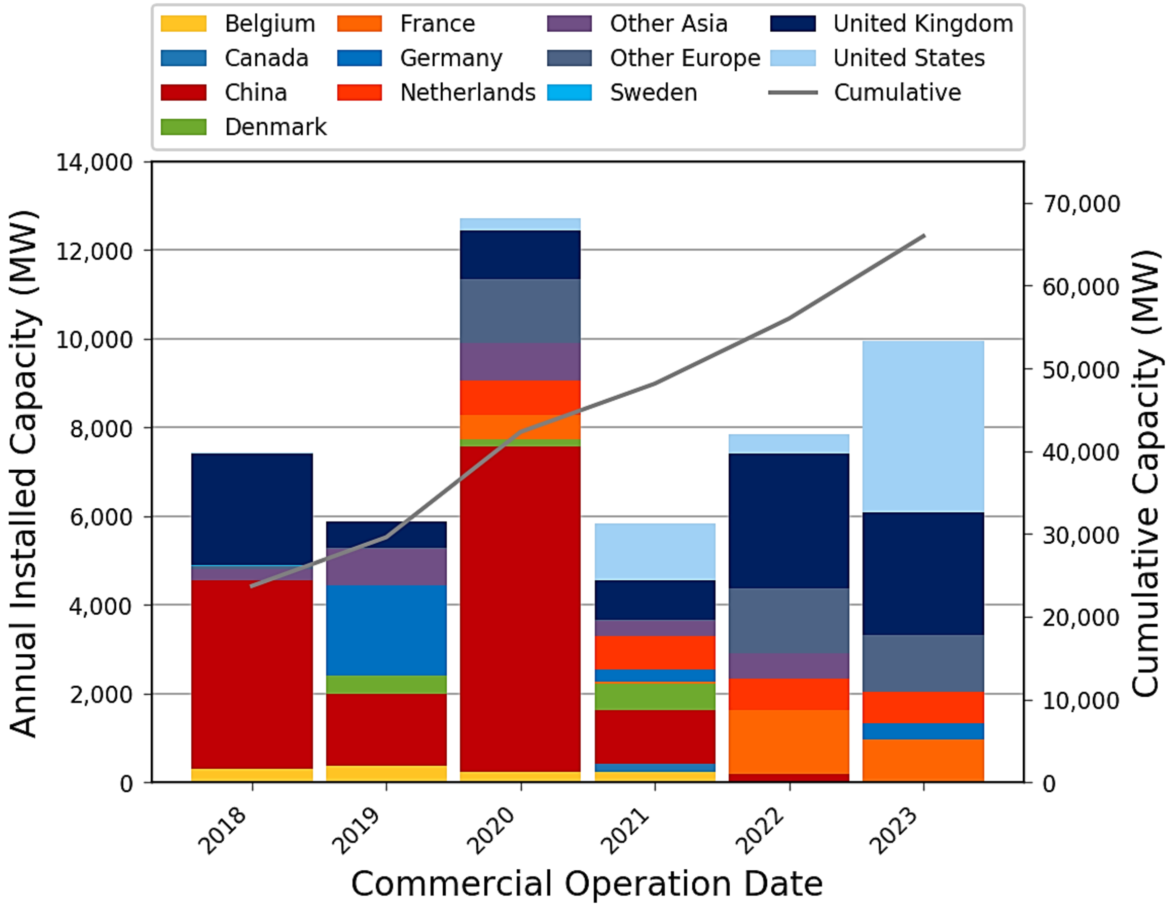


Comparison of Market Share for Projects that Operating vs. Under Construction

Note: The cumulative totals reported on pages 41 and 42 in comparison to pages 43 and 45 differ by 186 MW. A new data sourcing methodology was introduced in this year's market update. The reported cumulative total on pages 43 and 45 reflect this new data sourcing methodology. For better comparison with the *2016 Offshore Wind Technologies Market Report* (Musial et al. 2017), the annual totals (and cumulative total) shown on pages 41 and 42 still correspond to the data sourcing methodology documented in Musial et al. (2017).

Project Development Pipeline

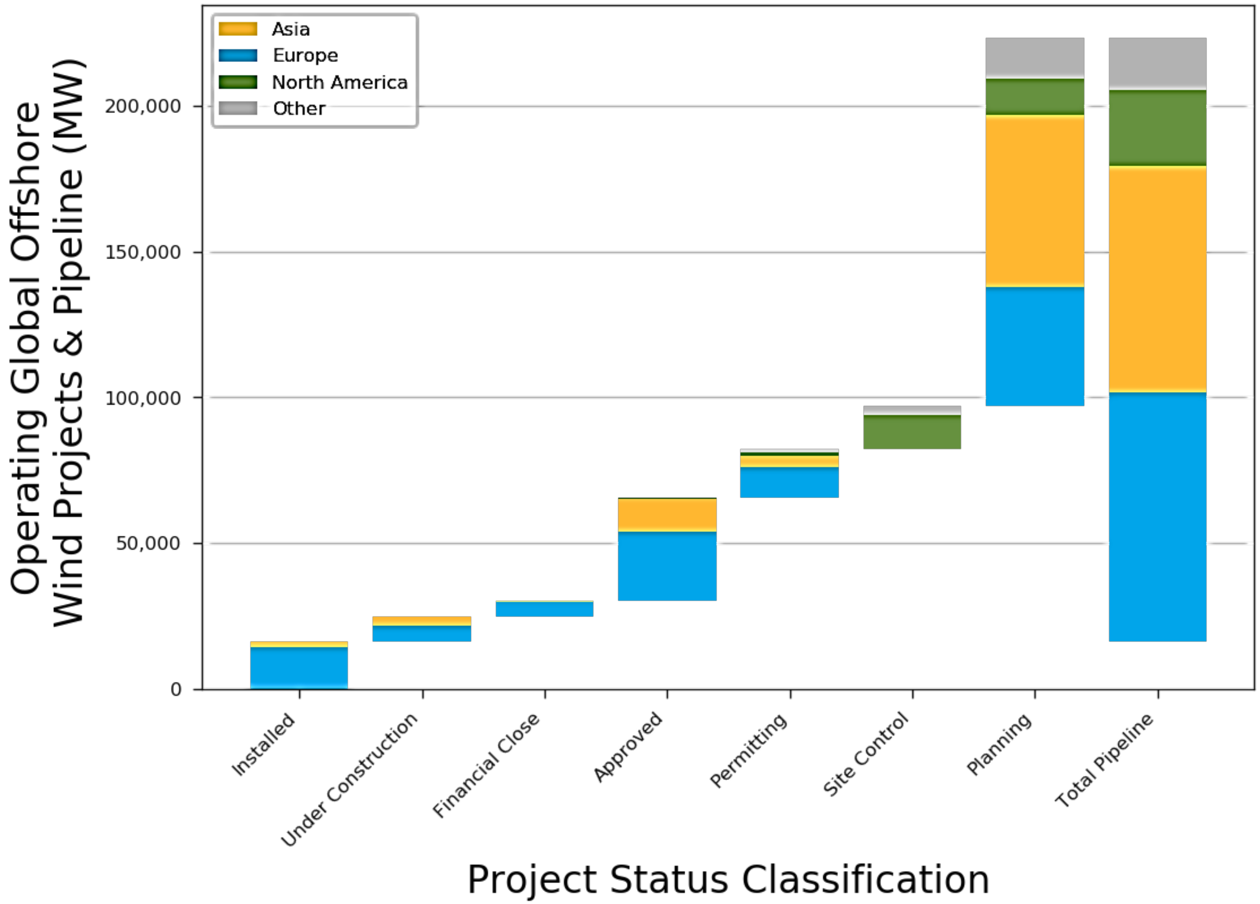
- Developer announcements indicate the global project development pipeline will grow annually by 24% (compound annual growth rate) through 2023. This growth rate is supported by an uptick in global installations in 2020, when 5.6 GW of Chinese offshore wind projects are scheduled to commence commercial operation.



Developer-Announced Project Pipeline through 2023

Project Development Pipeline (continued)

- The project pipeline in Europe is the most advanced, whereas a relatively large share of Asian and North American projects are in the planning stages.



Operating and Developmental Pipeline for Offshore Wind Projects by Global Region

Note: The cumulative totals reported on pages 41 and 42 in comparison to pages 43 and 45 differ by 186 MW. A new data sourcing methodology was introduced in this year's market update. The reported cumulative total on pages 43 and 45 reflect this new data sourcing methodology. For better comparison with the *2016 Offshore Wind Technologies Market Report* (Musial et al. 2017), the annual totals (and cumulative total) shown on pages 41 and 42 still correspond to the data and sourcing methodology documented in Musial et al. (2017).

5 Cost and Pricing Trends

Highlights

- During 2017 and the first half of 2018, offshore wind auctions were held in Germany, the Netherlands, and the United Kingdom for projects with commissioning dates from 2021 to 2025. The auction results support a trend of continuing price reductions over time and resulted in awards that were termed as "zero-subsidy"[10] in Germany and the Netherlands.
- Vattenfall/Nuon was awarded the permit to construct and operate the Dutch Hollandse Kust Zuid I and II projects (700–750 MW) on March 19, 2018. The site is scheduled for commercial operation by 2022, which, if successfully delivered, would make it the first offshore wind farm globally to be constructed without a subsidy.[11]
- Germany awarded several zero-subsidy bids in its two offshore wind auctions held during 2017–2018. No negative bids were allowed in Germany's most recent offshore wind auction.
- Invitations to submit applications for the next two offshore wind permit procedures in the Netherlands are planned for 2018 (Hollandse Kust [zuid] Wind Farm Sites III and IV) and 2019 (Hollandse Kust [noord]).

[10] Zero-subsidy auction results indicate that the auction award for site development and operation provides the award winner with a subsidy of $0/MWh on top of the prevailing wholesale electricity price during the contract term. Projects awarded with zero-subsidy bids receive the wholesale electricity price for their generation and are fully exposed to the merchant price risk of the competitive wholesale power market (for a more detailed discussion, see e.g., Beiter et al. forthcoming).

[11] The German zero-subsidy results awarded in April 2017 (1,490 MW awarded) are expected to commence commercial operation in 2024–2025.

Highlights (continued)

- The expected cost reductions driving recent record-low winning auction bids for future European projects are reported to include a combination of increased turbine and project size; continued optimization of technology and installation processes; improved market, regulatory, and auction design structures; increased competition within the supply chain; favorable macroeconomic trends; and strategic market behavior (Musial et al. 2017; Green Giraffe 2018).
- Although many cost reductions are generally expected to be transferrable to a U.S. context,[12] the full magnitude of these cost reductions may not be exhibited in the first tranche of full-scale commercial U.S. projects, in part because of both physical differences (e.g., water depth, distance from shore, wind resource, geotechnical, marine life) and the risks associated with deploying in a new market (Beiter et al. forthcoming).

[12] For instance, some European developers (Dutch and German) are not responsible for the costs of transmission infrastructure as these are the financial obligation of the grid operator. It is currently expected that in the United States the developer may have to pay for a larger share of the transmission infrastructure than in some European jurisdictions.

Highlights (continued)

Capital Expenditures

Capital expenditures (CapEx) are the single largest contributor to the life cycle costs of offshore wind plants and include all expenditures incurred prior to the COD.

- After an increase in CapEx up until 2015, CapEx values have stabilized and are estimated to decline over the next few years.
- Hornsea One (1,218 MW) in the United Kingdom, the largest offshore wind farm currently under development (Hill 2018), has a reported CapEx of $4 billion ($3,280/kilowatt [kW]).

Operational Expenditures

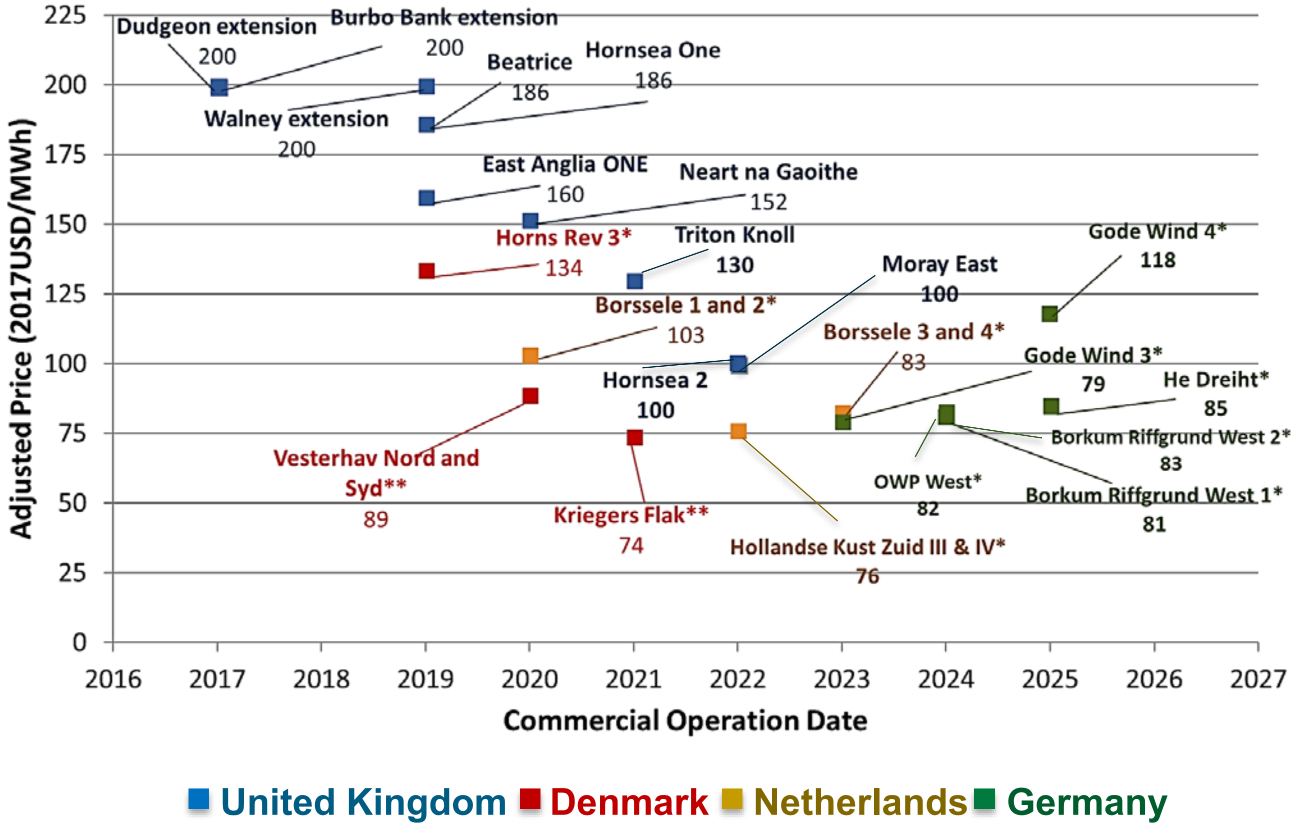
Operational expenditures (OpEx) cover all costs incurred after the COD—but before decommissioning—that are required to operate the project and maintain turbine availability to generate power.

- Industrywide OpEx estimates for offshore wind projects are subject to considerable uncertainty because of limited publicly available empirical data.[13] Major O&M cost drivers include the distance from the project to maintenance facilities and the prevailing metocean climate at a project site (Stehly et al. 2017).

[13] Although wind project owners commonly report CapEx, they rarely report OpEx. Uncertainty from the lack of available data is further amplified because it is standard practice in the offshore wind industry for turbine OEMs to offer 5-year warranties, so the full range of operating costs may not be apparent.

Auction Pricing Trends

- The observed price decline for project bids in recent auctions continues with the latest rounds in Germany, the Netherlands, and the United Kingdom during 2017–2018. Data shown here reflect estimated levelized revenue based on winning bids and expected wholesale power market revenues.



Adjusted Strike Prices from European Offshore Wind Auctions

Notes: *Grid and development costs added; **Grid costs added and contract length adjusted
Sources: NREL Spatial Cost Model; BNEF 2017 (German wholesale price projections); PBL Netherlands Environmental Assessment Agency (2018) (Dutch wholesale price projections)

Auction Pricing Trends (continued)

Germany

Auction	First Offshore Wind Auction (§ 26 WindSeeG)				Second Offshore Wind Auction (§ 26 WindSeeG)	
Award type	One-way contract for difference (CfD)[15]				One-way CfD[15]	
Award date	04/01/2017				04/27/2018	
Project name	Borkum Riffgrund West 2	Gode Wind 3	He Dreiht	OWP West	Borkum Riffgrund West 1	Gode Wind 4
Capacity (MW)	240	110	900	240	420	132
Winning bidder	Ørsted	Ørsted	EnBW	Ørsted	Ørsted	Ørsted
COD	2024	2023	2025	2024	2024	2025
Distance from shore (km)	67	39	85	58	53	42
Water depth (m)	29–31	30–34	39	29–33	29–31	30–34
Duration (years)	20				20	
Government development support	Predevelopment by German Maritime and Hydrography Agency				Predevelopment by German Maritime and Hydrography Agency	
Government grid connection support	Transmission system operator (TenneT)				Transmission system operator (TenneT)	
Government support for negative wholesale prices	No support for periods of >6 consecutive hours				No support for periods of >6 consecutive hours	
Lease duration	25 (with 5-year extension option)				25 (with 5-year extension option)	
Inflation-indexed	No				No	
Nonexecution penalty ($/kW)	~112				~112	
Auction price (2016$/MWh)	0	65	0	0	0	118
Adjusted auction price (2016$/MWh)[14]	~81	~78	~83	~80	~79	~115

[14] Adjusted auction price was estimated by calculating levelized revenue of energy as described in Beiter et al. (forthcoming) and by adding grid and development costs for direct comparison with projects across various jurisdictions.
[15] A one-way CfD award provides a guaranteed price floor at which generation is compensated during the length of the contract term; if the wholesale price falls above the guaranteed price floor, the generator receives the wholesale price (upside not capped).
Source: Green Giraffe (2018)

Auction Pricing Trends (continued)

United Kingdom

Auction	Contract for Difference Round 2 Auction		
Award type	Two-sided CfD[16]		
Award date	September 11, 2017		
Project name	Triton Knoll	Hornsea 2	Moray East
Capacity (MW)	860	1,386	950
Winning bidder	Innogy/Statkraft	Ørsted	EDPR/Engie
COD	2021/2022	2022/2023	2022/2023
Distance from shore (km)	33	100	30
Water depth (m)	13–30	25–67	39–50
Duration (years)	15		
Government development support	No		
Government support for negative wholesale prices	No		
Lease duration (years)	25		
Inflation-indexed	Yes		
Auction price (2017$/MWh)	127	98	98
Adjusted auction price (2016$/MWh)[17]	127	98	98

[16] A two-way CfD award provides a guaranteed price floor at which generation is compensated during the length of the contract term; if the wholesale price falls above the guaranteed price floor, the generator is compensated at the guaranteed price floor level (upside capped).

[17] Adjusted auction price was estimated by calculating levelized revenue of energy, as described in Beiter et al. (forthcoming).

Source: Smart (2017)

Auction Pricing Trends (continued)

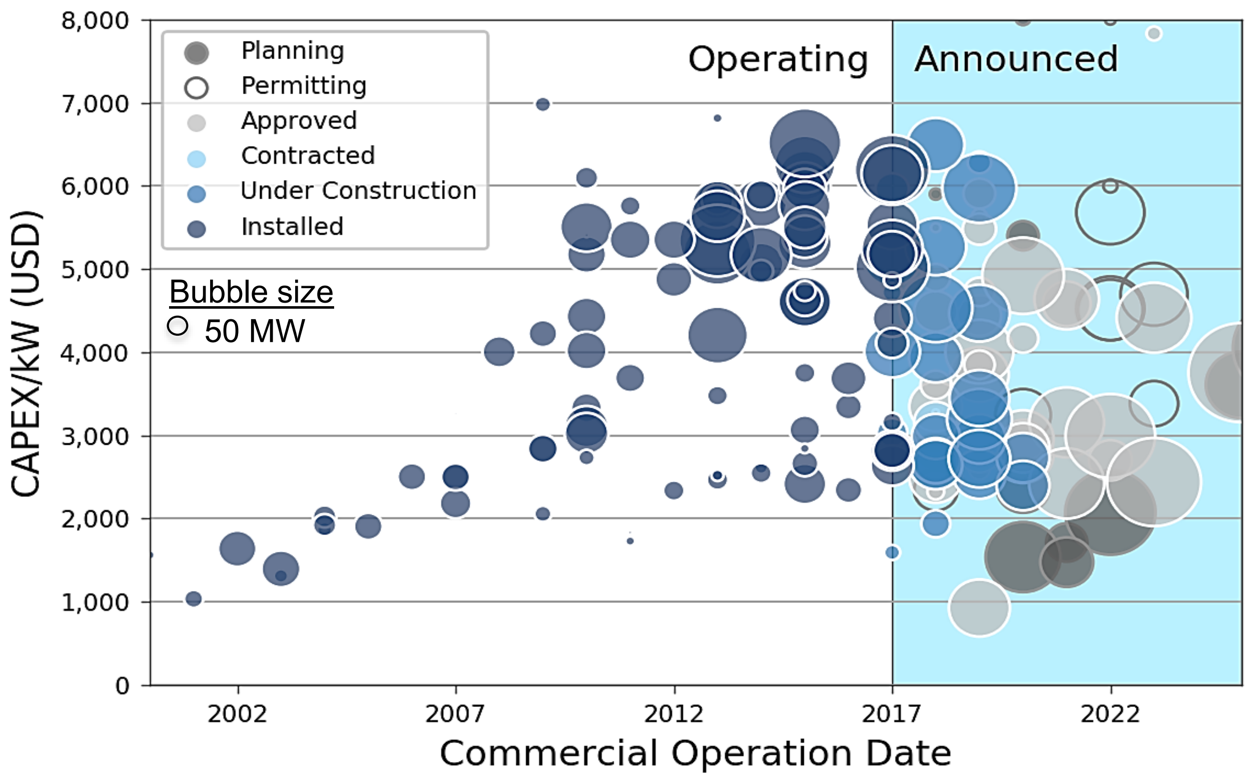
Netherlands

	2018 Auction
Award type	Criteria-based[18] (zero-subsidy)
Award date	March 19, 2018
Project name	Hollandse Kust Zuid III and IV
Capacity (MW)	700
Winning bidder	Nuon/Vattenfall
COD	2022
Distance from shore (km)	22
Water depth (m)	17–22
Duration (years)	15
Government development support	Soil studies and Environmental Impact Assessment
Government grid connection support	Transmission system operator (TenneT)
Government support for negative wholesale prices	No support for periods of >6 consecutive hours
Inflation-indexed	N/A
Nonexecution penalty ($/kW)	$29/kW in first year
Auction price (2017$/MWh)	0
Adjusted auction price (2016$/MWh)[19]	~74

[18] The Netherlands held a prebidding stage in December 2017, which prescribed the 2018 auction to be zero-subsidy and that projects were to be judged solely on their performance against a set of predefined selection criteria (offshoreWIND.biz 2017).
[19] An adjusted auction price was estimated by calculating levelized revenue of energy, as described in Beiter et al. (forthcoming) and by adding grid and development costs for direct comparison with projects across various jurisdictions.

Capital Expenditures

- Although CapEx increased between 2000 and 2015,[20] this trend is expected to be reversed based on announced costs for future projects, which suggest a considerable decline between 2015 (observed) and 2025 (announced). The lowest CapEx of <$2,700/kW for projects installed in 2017 was reported for the Jiangsu Luneng Dongtai (200 MW) in China.

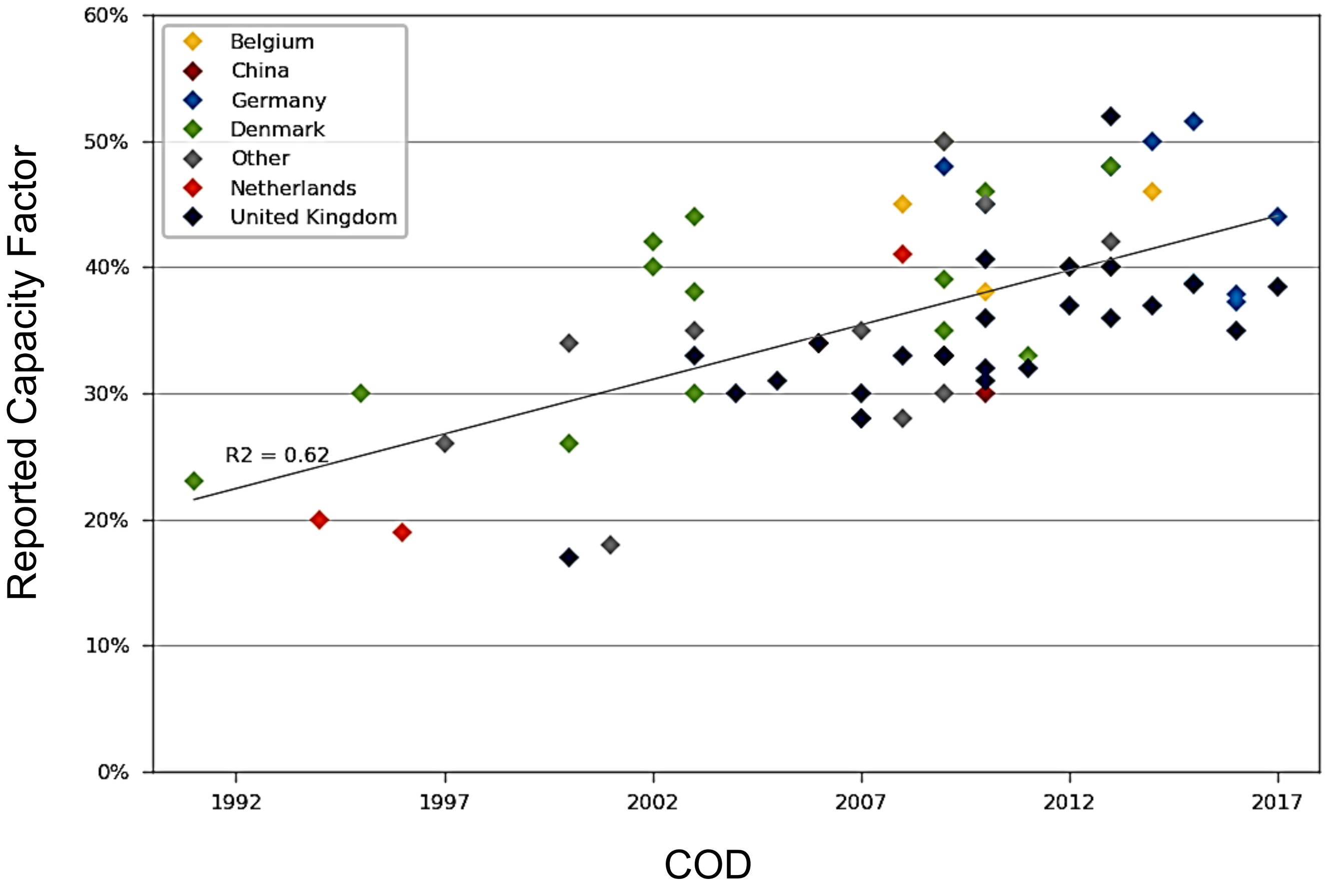


Capital Expenditures of Global Offshore Wind Projects by Commercial Operation Date and Project Capacity

[20] See Musial et al. (2017) for a discussion on drivers of changes in CapEx between 2000 and 2025.
Note: The size of the bubbles indicates project capacity (MW). Data are only shown for projects with reported CapEx and COD.

Performance

- Capacity factors have improved over time but exhibit considerable variance in any given year because of differences in technology and site conditions.



Global Offshore Wind Reported Capacity Factors by Commercial Operation Date

Source for 2017 data: Knight and Campbell (2018)

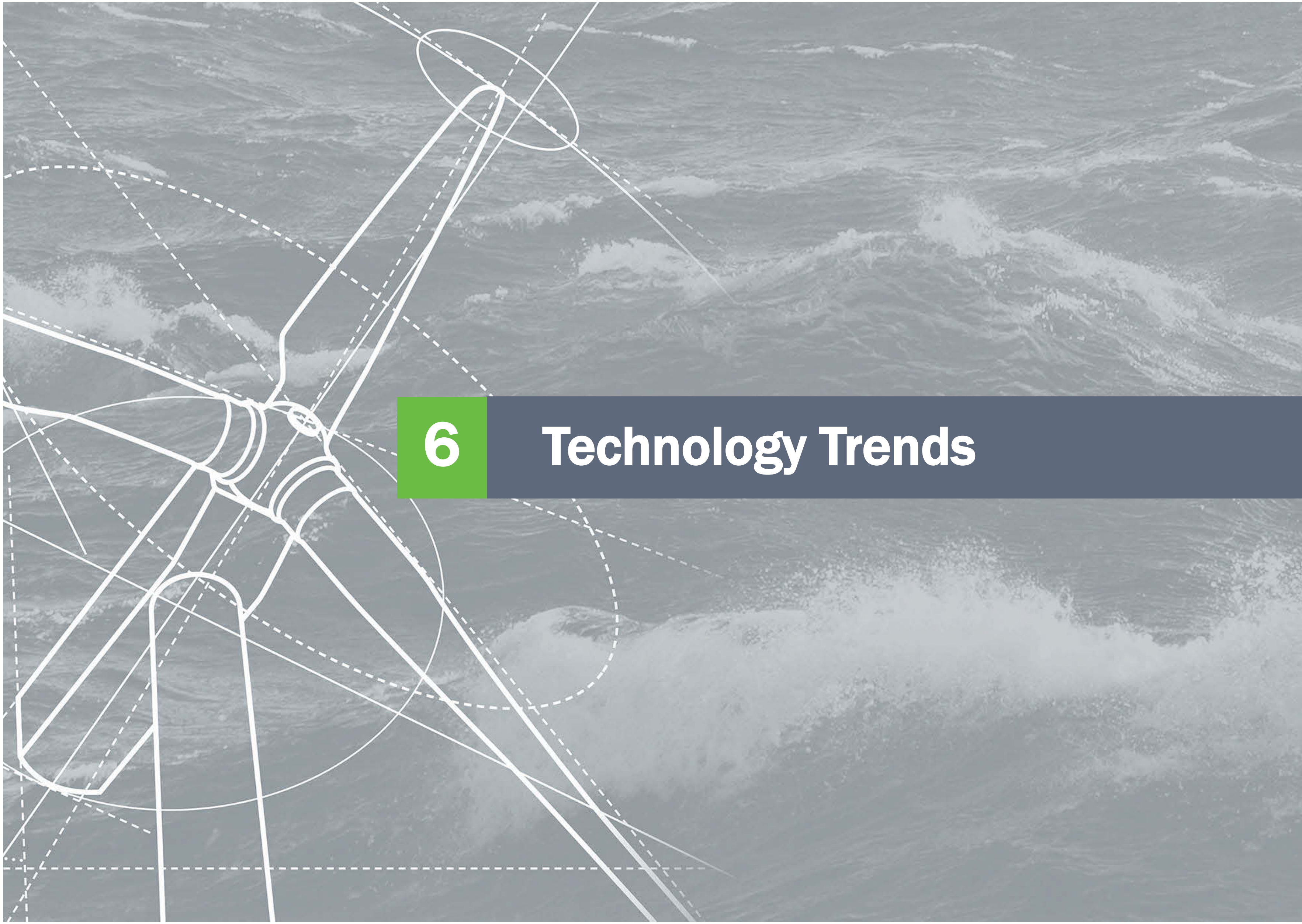
Financing

- Typical debt-to-equity ratios among Northern European projects have increased between 2006 and 2017, which coincides with project derisking and growing investor confidence during this time period. A higher debt-to-equity ratio generally lowers project financing costs.

Year	Debt-to-Equity Ratio
2006–2007	60:40
2009–2011	65:35
2012–2013	70:30
2014–2015	70:30
2016–2017	75:25

Source: Reprinted from Green Giraffe (2016, 2018).

Note: Year 2008 not available from source.



6 Technology Trends

Highlights

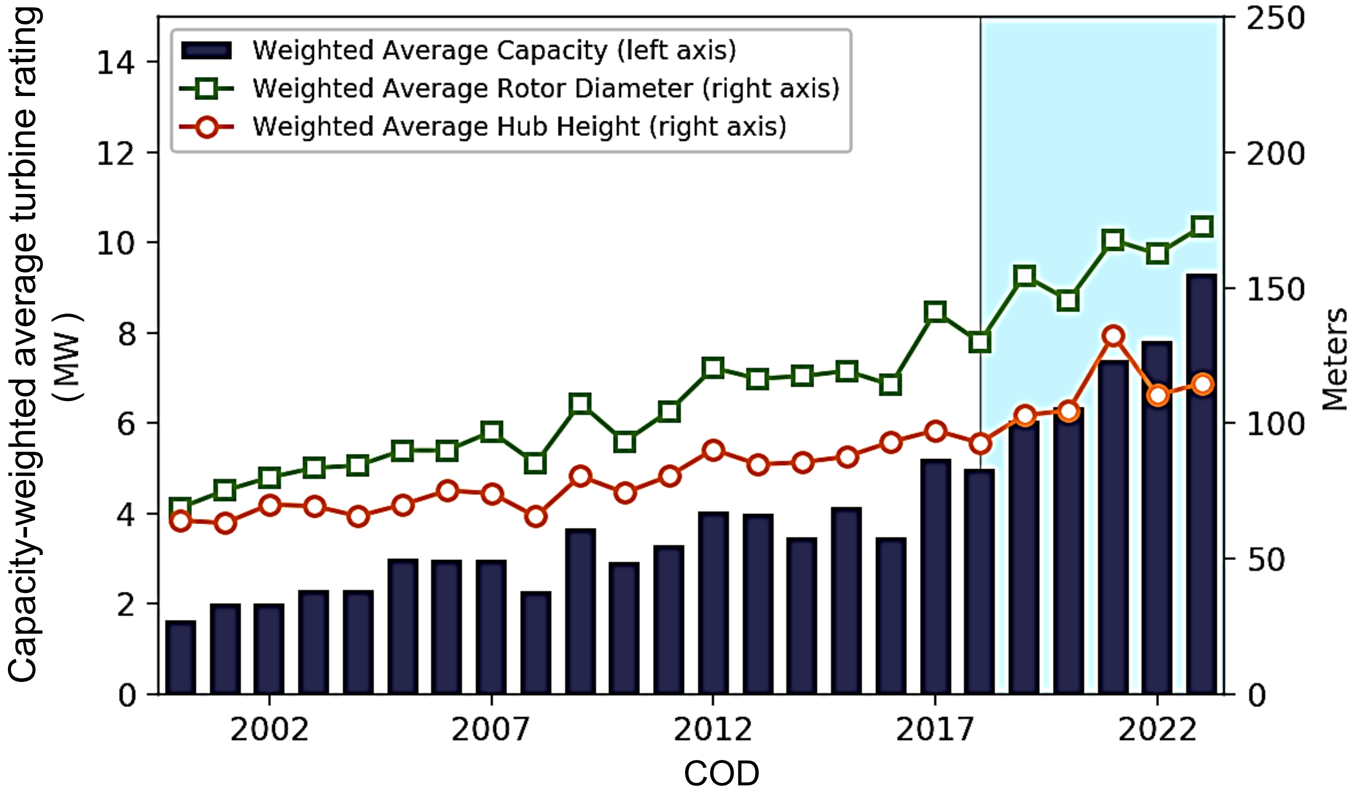
- Major turbine OEMs continue to pursue larger offshore wind turbines; the most prominent example available today is GE's recently announced 12-MW Haliade-X turbine, but Siemens/Gamesa and Senvion have each announced 10-MW+ turbine ambitions while MHI Vestas has increased the nameplate capacity of its V164 platform to 9.5 MW.
- Turbine sizes in the 12–15 MW range are anticipated to be a key enabler of cost reductions that are driving the recent record-low auction results observed over the past 12–18 months.
- As turbines grow in size, the supply chain and turbine installation and servicing capabilities have been forced to keep pace, with an array of novel strategies and new solutions; a maturing U.S. market is pushing adaptation of these services to ensure Jones Act compliance with stated interest from multiple vessel suppliers.
- Monopile substructures dominate the global offshore wind market today. However, developers have announced they intend to deploy an increasingly varying array of substructure technologies to reduce costs as well as deal with deeper water depths and difficult geotechnical conditions.
- Floating technology solutions took continued significant steps to large-scale commercialization with Equinor commissioning its Hywind project, the world's first commercial floating offshore wind farm, in October 2017 off of Peterhead, Scotland. The project comprises five 6-MW Siemens Gamesa turbines on spar foundations and in waters that are more than 100 m deep.

Highlights (continued)

- Advancement of storage technology is driving an increased interest in coupled offshore wind and storage projects; as part of the proposals submitted for the Massachusetts solicitations, Deepwater Wind proposed a potential partnership with Tesla for a 40-MW/144-MWh battery, and Bay State Wind proposed a partnership with NEC for a 55-MW/110-MWh battery system (Bay State Wind 2018b).
- The auction for the Dutch Borssele Wind Farm Site V (19 MW) revealed novel innovations on two 9.5-MW turbines specifically in the planned "slip joint" technology, which connects the monopile and transition piece, as well as in plans to use "eco-designs" for scour protection. These innovations were proposed by the winning bidders, Two Towers consortium, composed of Van Oord, Green Giraffe BV, Investri Offshore BV, and MHI Vestas. The project is expected to be operational in 2021 (Van Oord 2018).
- Industry interest in a transition to 66-kilovolt (kV) intra-array collector systems continued during 2017; the transition from 33-kV to 66-kV cables, transformers, and switchgears has been recognized as a necessary step for the offshore wind industry for reliability enhancements and cost of energy reduction and was supported by new investments from Siemens, ABB, JDR, and the Prysmian Group, among others.
- In Spain, a consortium led by Esteyco is preparing to test a self-installing turbine prototype called the Elican project; the approach is anticipated to eliminate the need for specialized installation vessels.
- Semi-taut angled mooring lines are being pioneered by companies such as SBM and GICON to provide the ability to reduce the length and size of moorings for floating platforms with larger turbines.

Turbine Technology

- The capacity-weighted average turbine rating installed in 2017 was 5.3 MW, with an average rotor diameter of 141 m and a 98-m hub height. Based on our sample, by the mid-2020s average turbine rating is anticipated to approach 10 MW, with the potential to exceed 11 MW later in the decade as informed by initial data for projects with an expected COD in the period of 2023–2025.



Global Turbines Capacities, Rotor Diameters, and Hub Heights by Installation Year

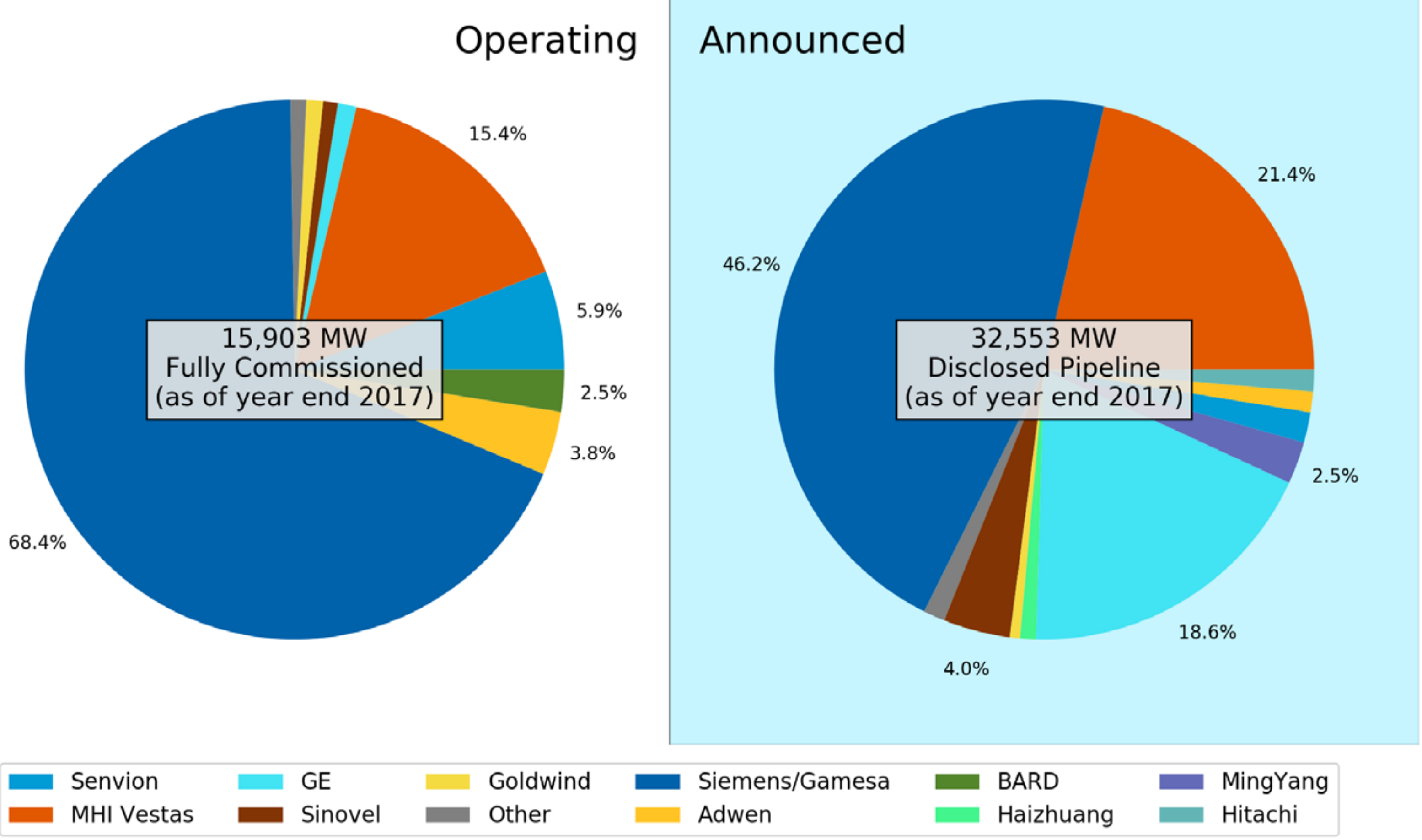
Note: The total number of observations for years 2022–2023 (COD) is relatively small (n<10 in a given year), introducing some uncertainty with regards to future average turbine rating, which may vary by jurisdiction.

Turbine Technology (continued)

- On March 1, 2018, GE Renewable Energy unveiled a 12-MW Haliade-X offshore wind turbine that has been announced with the following specifications (GE [2018a, 2018b]; Recharge Wind [2018a]):
  - Rated power of 12 MW
  - Rotor diameter of 220 m; 107-m blade
  - Total height of 260 m from transition piece to blade tip
  - Power production of 65 gigawatt-hours a year (capacity factor of 63%) for typical German North Sea sites (GE 2018b)
  - Announced CapEx savings of $26 million per turbine per 100 MW when compared with previous Haliade model, which had a rated power of 6 MW and a rotor diameter of 150 m
  - Investment includes $57 million in the Saint-Nazaire, France, facilities to adapt them to Haliade-X nacelle assembly and $93 million in the Cherbourg, France, facilities for tooling, blade molds, assembly line, and blade development
  - GE Renewable Energy aims to supply its first nacelle for demonstration in 2019 and ship the first units in 2021.
- Senvion is developing a 10-MW+ turbine and announced that a prototype will be ready in late 2019 or early 2020 (offshoreWIND.biz 2018).
- Siemens Gamesa has announced that it is planning to release a 10-MW+ turbine (Recharge Wind 2018b).

Turbine Technology (continued)

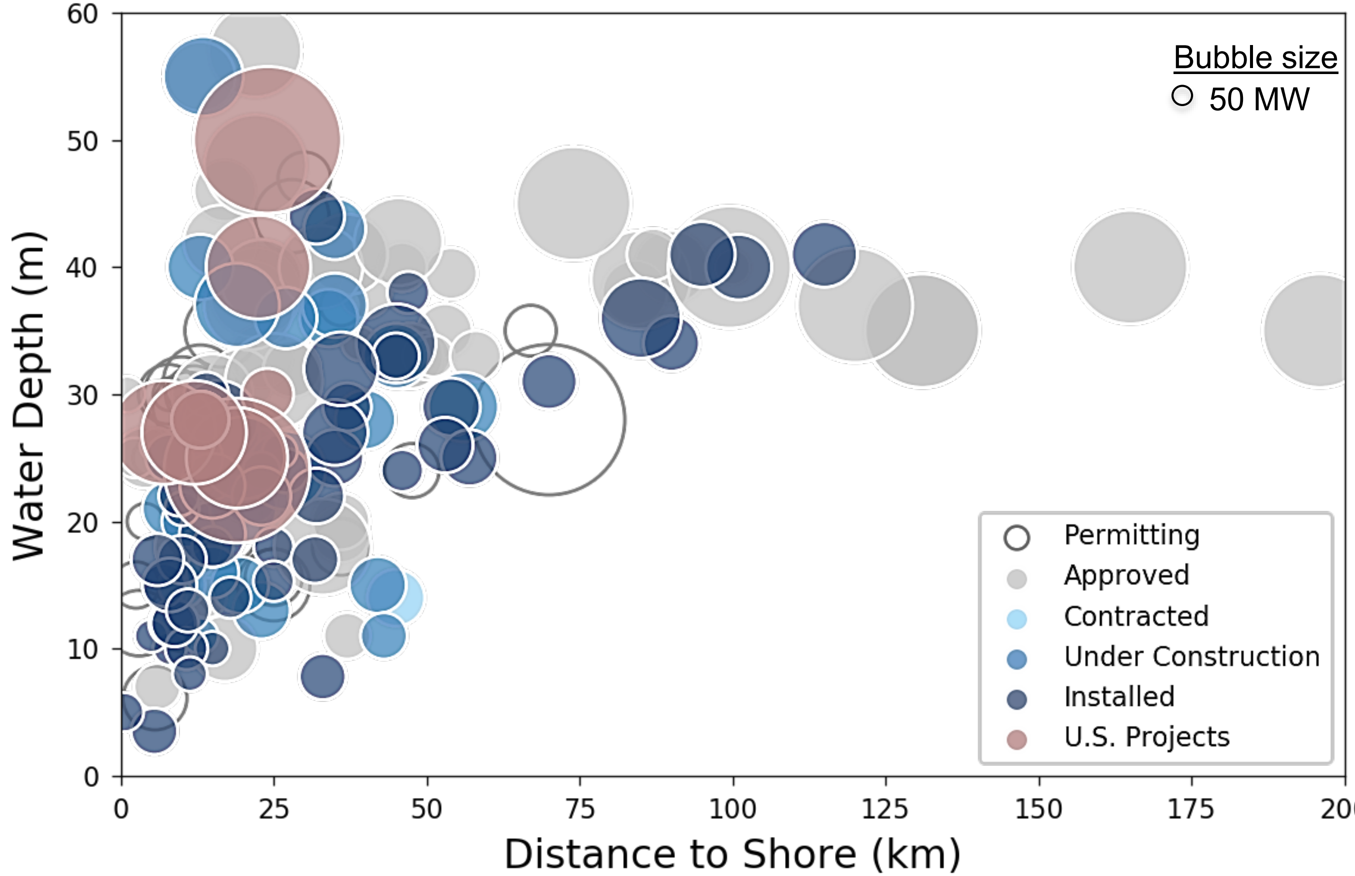
- Focusing on the operating fleet, Siemens/Gamesa holds a dominant position with a market share of more than 68% of installed turbine capacity, and MHI Vestas maintains a significant minority share at 15%. Looking ahead, Siemens/Gamesa, MHI Vestas, and GE are expected to capture more than 85% of the known pipeline.



Global Offshore Wind Turbine Market Share by OEM

Site Characteristics

- The majority of installed projects around the world are located in water depths of <40 m and <50 km from shore. While most developers still prefer to build projects in shallow water close to shore to minimize cost, some developers have been able to build bankable projects that are in deeper waters further from shore.

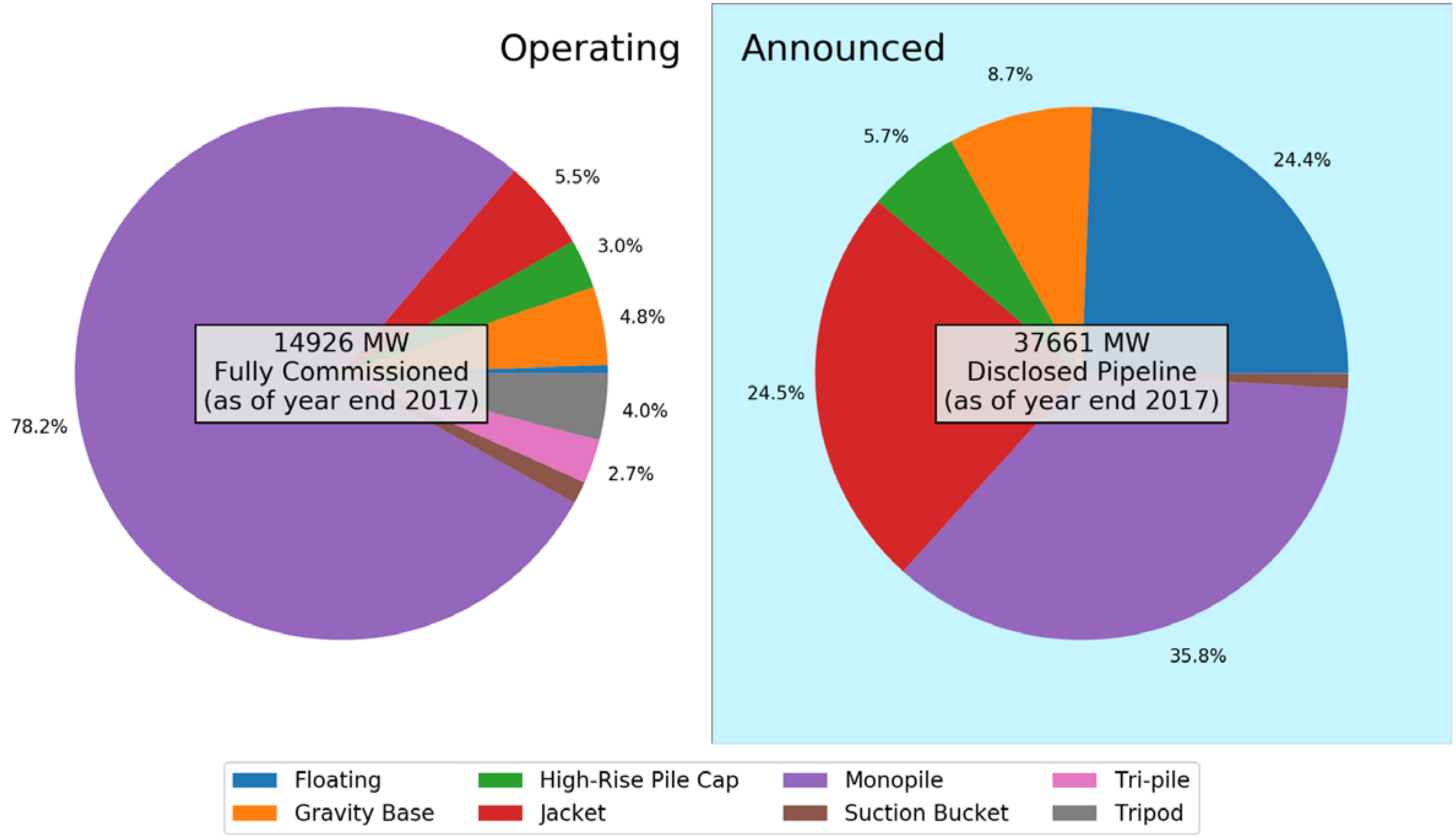


Global Offshore Wind Projects as a Function of Water Depth and Distance to Shore

Note: Data are only shown for projects with reported distance to shore (up to 200 km) and water depth (up to 60 m).

Substructure Technology

- Nearly 80% of globally installed substructures are monopiles. As the industry has begun to expand beyond Northern Europe and into locations with more diverse site characteristics, the announced project pipeline indicates increasing penetration for floating substructures as well as increasing diversity among fixed-bottom substructures.



Global Offshore Wind Substructure Market Share by Type

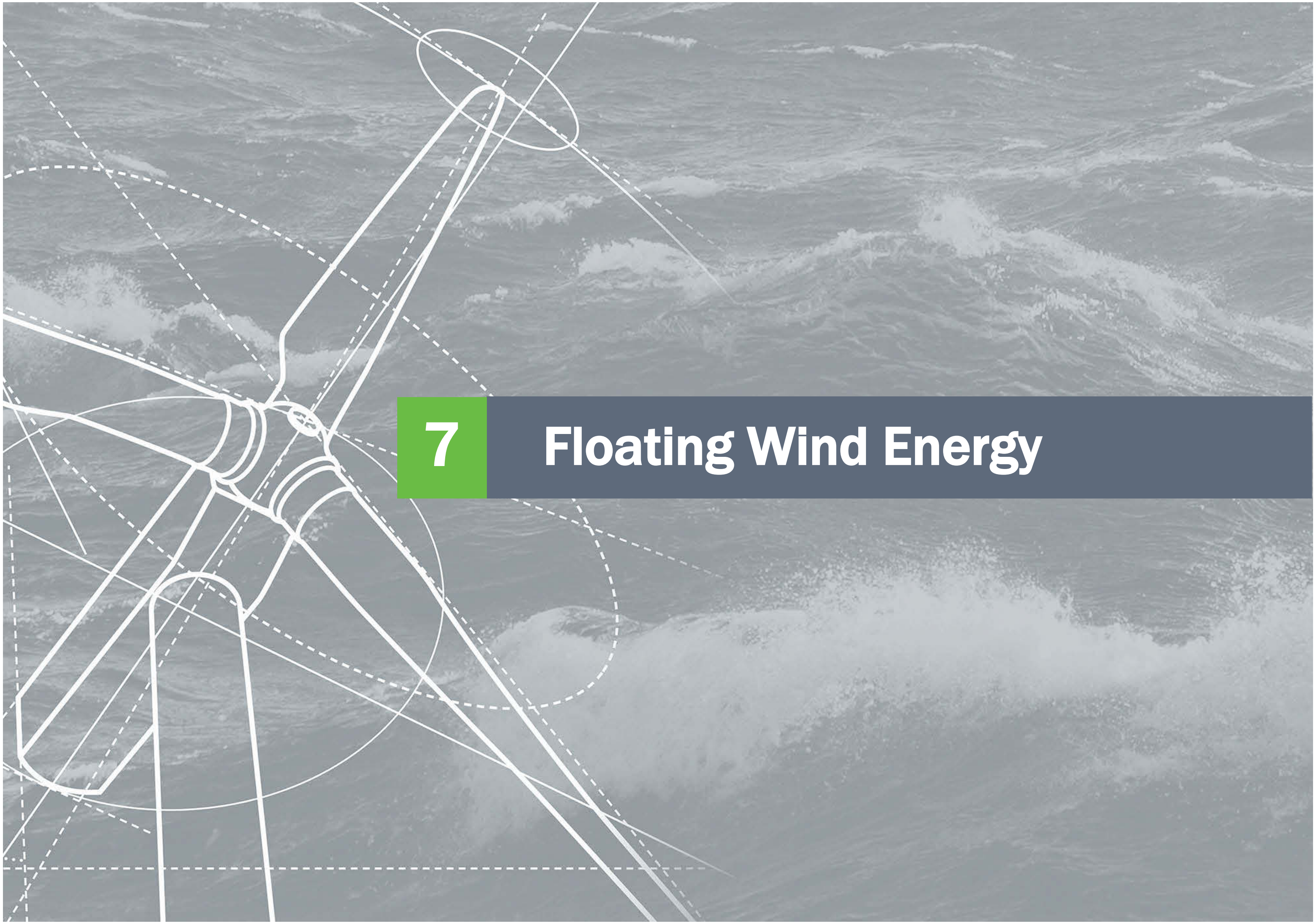
Vessel and Marine Logistics

- Larger turbines are expected to stretch the capabilities of current offshore installation vessels, especially for offshore projects placed in deeper waters.
- Development of new offshore wind turbine vessel concepts, including wind turbine shuttle vessels, has continued; this trend allows for more assembly work at port and more efficient offshore transportation and installation at sea (Huisman 2018).
- As the U.S. market matures, pressure is increasing for companies to build Jones-Act-compliant turbine installation vessels capable of installing 12-MW turbines; Zentech/Renewable Resources International, AllCoast/AK Suda, and Aelous Energy Group have announced plans to deploy U.S.-flagged turbine installation vessels for projects with CODs around 2022 but have not yet initiated construction of these vessels.
- There is a persistent push to improve the U.S. port infrastructure and manufacturing capabilities supporting offshore wind components, installation, and maintenance.

Source: Reprinted from Zentech (2017)

Electrical Infrastructure Advancements

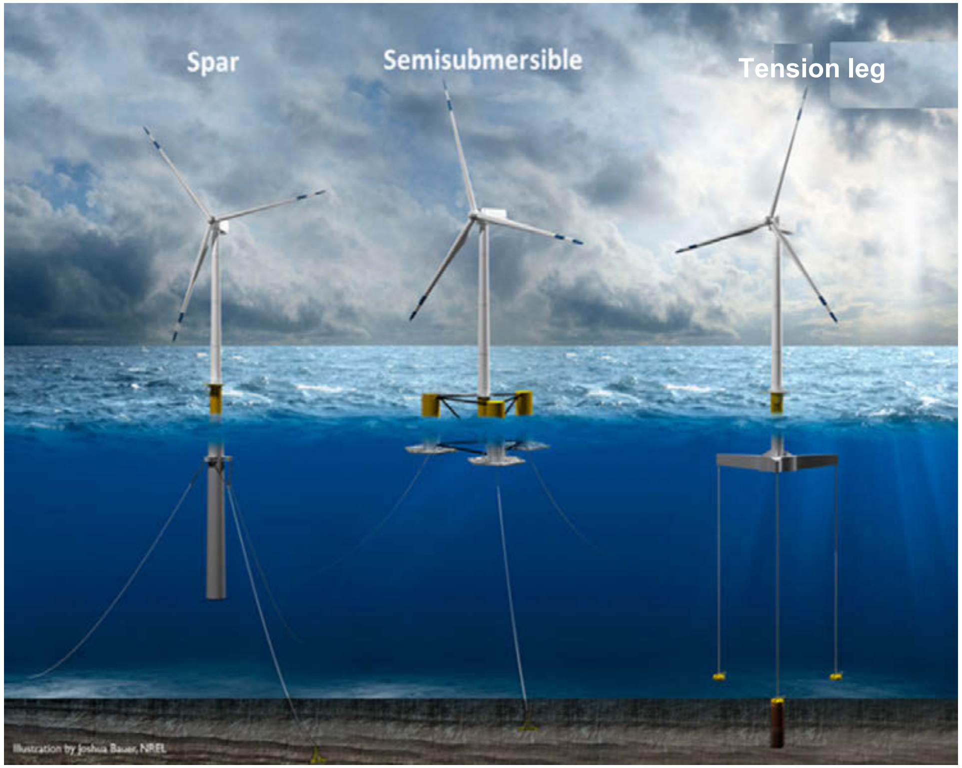
- According to Siemens, there are potential savings of up to 15% in the cost of the offshore collector systems when using 66-kV cables relative to 33-kV cables. Although project-specific results depend on distance between turbines, soil conditions, and overall project capacity, this potential cost savings is expected across a substantial majority of future offshore wind power plants, and the industry continues to work diligently to realize the opportunity.
- In 2017, ABB announced its latest innovation in transformer technology, with the 66-kV WindStar transformer, which can fit into the tower of an offshore wind turbine (ABB 2018). The first ABB WindSTAR transformer was supplied to MHI Vestas; an additional five ABB transformers will be used at the Blyth Offshore Demonstrator, a 42.5-MW five-turbine plant that will be the first demonstration of 66-kV cables in the United Kingdom (ABB 2017). ABB also provided eleven 66-kV transformers to be used in wind turbine generators at the European Offshore Wind Deployment Centre.
- JDR was awarded a contract by VBMS (of the United Kingdom) to supply a 66-kV intra-array cable for ScottishPower Renewables East Anglia One offshore wind power plant—the world's first commercial application of 66-kV technology (JDR 2017a). This project includes 155 km of 66-kV intra-array cables (JDR 2017a). JDR was also awarded a contract for the first 66-kV dynamic cables application for a 25-MW floating wind plant off the coast of Viana de Castelo in Portugal (JDR 2017b).
- Prysmian Group announced the capability to manufacture both 33-kV and 66-kV cables at its production facility in Wrexham, United Kingdom (Prysmian Group 2017). Prysmian confirmed the successful completion of type testing for 66-kV cables as part of the Carbon Trust's Offshore Wind Accelerator Programme.
- Siemens continued development of a full 66-kV solution for its direct-drive 6-, 7-, and 8-MW wind turbine generators. The high-voltage solution includes a 66-kV transformer, switchgear, and cable in-between, and will be used alongside JDR's intra-array cables at the East Anglia One offshore wind farm.



7 Floating Wind Energy

Floating Project Pipeline

- Floating wind is a subset of offshore wind energy evolving out of commercial fixed-bottom offshore wind technologies, but is at a precommercial stage.
- Fifty-eight percent of the U.S. technical resource area is in waters where floating wind will work best.
- Floating substructures are buoyant platforms that are moored to the seafloor and less constrained by water depth.
- Currently, several floating offshore wind energy platform archetypes are being developed for precommercial projects.



Three floating offshore wind energy platform archetypes derived from oil and gas experience guide the development of the next generation of optimized floating wind energy systems. *Illustration by Joshua Bauer, NREL*

Floating Project Pipeline

United States

- BOEM, state officials, and developers continue to plan for the deployment of commercial floating offshore wind energy projects off the Pacific Coast. RCEA signed a public-private partnership with an industry consortium led by Principle Power LLC to submit an unsolicited lease proposal to BOEM in summer 2018 for a project off the coast of Humboldt Bay, California (RCEA 2018).
- Offshore wind industry developers are working with DOD, BOEM, and the state of California to resolve potential conflicts with military operations, training, and radar over a wide portion of the OCS off central California where offshore wind development is being considered. There are similar potential conflicts off Hawaii.
- On June 12, 2018, the Maine Public Utilities Commission voted to review the terms of the power contract for the 12-MW Maine Aqua Ventus two-turbine demonstration project off Monhegan Island (4COffshore 2018). Aqua Ventus is one of the two active DOE Offshore Wind Advanced Technology Demonstration Projects. If built, it would be the first floating wind project in the United States using megawatt-scale wind turbines.

Floating Project Pipeline

Global

- The pipeline of planned projects remains relatively constant from 2016 to the present, with 2,711 MW total proposed globally as the industry prepares for the deployment of the precommercial pilot phase, which consists of about 11 projects.
- Floating technology took significant steps toward commercialization in October 2017 with Equinor commissioning their 30-MW Equinor/Masdar Hywind-II project, the world's first commercial floating offshore wind farm off Peterhead, Scotland. The project comprises five 6-MW Siemens Gamesa turbines on spar platforms in waters more than 100 m deep. The project achieved a capacity factor of 65% in its first 3 months of operation (November–January) (Equinor 2018).
- As part of the European Commission's ReaLCoE project, Senvion, Principle Power, and 12 other entities partnered to develop floating wind systems capable of supporting offshore wind turbines that are 10 MW or larger by 2021 (Davidson and Weston 2018).
- Ideol's Floatgen 2-MW demonstration project was assembled in port, towed to sea, moored to the seafloor at Le Croisic (France), and connected to the grid in May 2018.

Floating Wind Commercialization

Sources: (from left to right): Windfair 2015 (first three); Principle Power, Inc., Statoil, NREL

Photo: Equinor Scotland 5 Turbines, 30 MW Øyvind Gravås / Woldcam - Statoil ASA

Source: Equinor

Source: Principle Power, Inc.

Proof-of-Concept Phase 2009–2016

6 full-scale prototypes totaling about 20 MW
2- to 7-MW turbines

Precommercial Phase 2017–2023

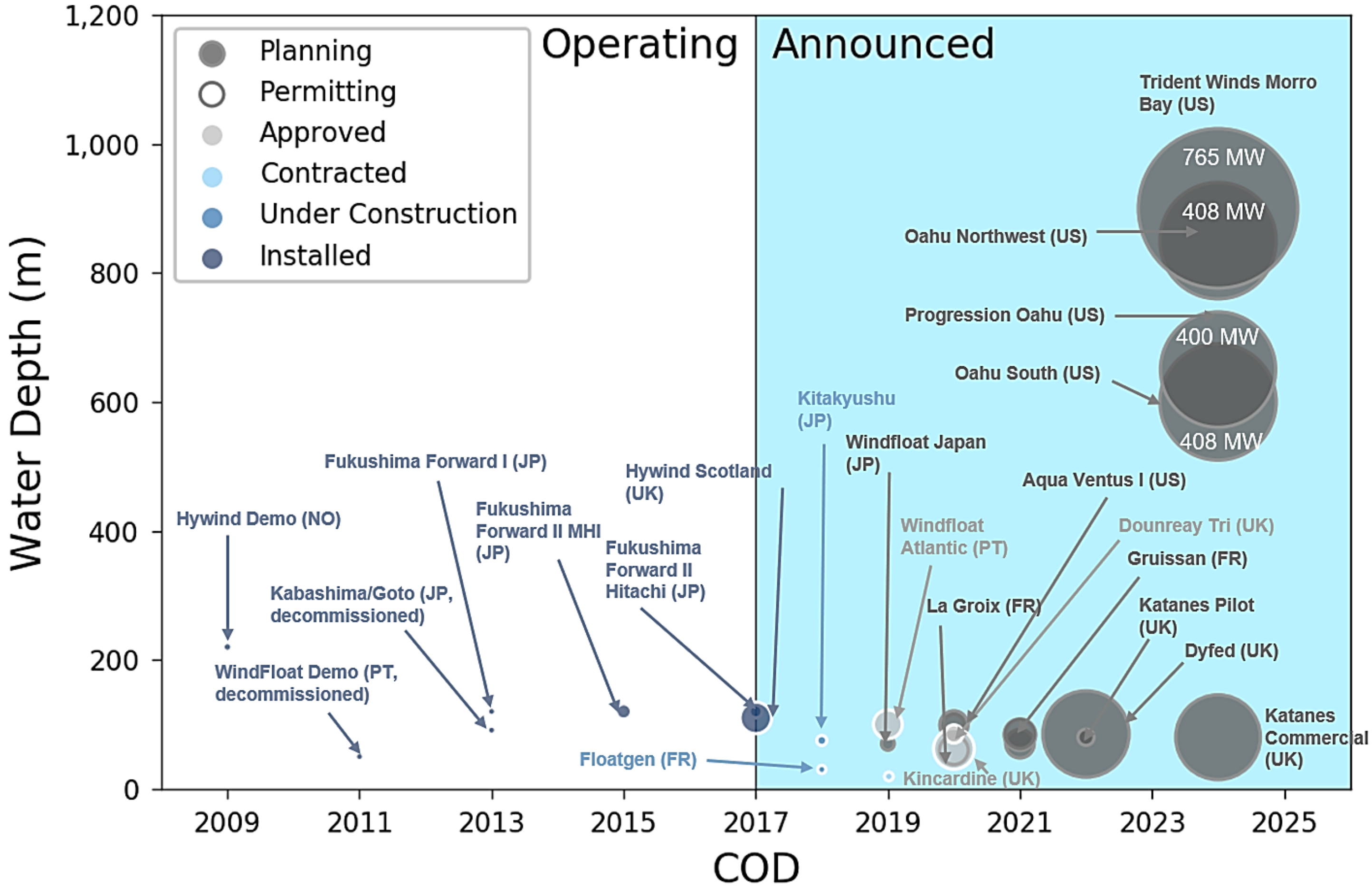
Multiturbine commercial arrays
12- to 50-MW projects
11 projects totaling 229 MW

Commercial Floating Arrays 2024 and beyond

400 MW+ arrays proposed
Alpha Wind (Hawaii)
Principle Power (Hawaii/California)
Progression (Hawaii)
Equinor (TBD)
Trident Wind (California)
Dyfed/Kantanes (United Kingdom)

Global Pipeline for Floating Projects

- The first floating offshore wind farm commenced commercial operation in 2017, indicating a transition from proof-of-concept, single-turbine deployments to multiturbine, precommercial pilot projects. Fifty-five megawatts of floating projects are installed or currently under construction.



Developer-Announced Global Floating Offshore Wind Pipeline

Note: Projects that are included in the graph but not labeled include GICON SOF Pilot (Germany), Faraman (France), FLOCAN5 (Spain), and Leucate (France).

Global Pipeline for Floating Projects

	Project	COD	Lead Organization	Status	Country	Turbine Capacity (MW)	Project Capacity (MW)	Water Depth (m)	Foundation Type
Americas	Aqua Ventus I	2020	U Maine	Permitting	United States	6	12	100	Semisubmersible
	Oahu Northwest Lease Request	2024	Alpha Offshore Wind	Planning	United States	6–8	408	850	Semisubmersible
	Oahu South Lease Request	2024	Alpha Offshore Wind	Planning	United States	6–8	408	600	Semisubmersible
	Progression	2024	Progression Energy	Planning	United States	8+	400	650	Semisubmersible
	Morro Bay Offshore Wind	2024	Trident Energy	Planning	United States	8+	765	900	Semisubmersible
Asia	Kabashima/Goto	2013	MOE	Installed (Decommissioned in 2015)	Japan	2	2	91	Spar
	Fukushima Forward I	2013	METI	Installed	Japan	2	2	120	Semisubmersible
	Fukushima Forwad II - MHI	2015	METI	Installed	Japan	7	7	120	Semisubmersible
	Fukushima Forward II - Hitachi	2017	METI	Installed	Japan	5	5	120	Spar
	Kitakyushu NEDO Next Generation Demo	2018	NEDO	Under Construction	Japan	3	3	75	Barge
	WindFloat Japan	2019	Principle Power, NEDO	Planning	Japan	5	5	70	Semisubmersible

Installed Project | Under Development Project

Global Pipeline for Floating Projects

	Project	COD	Lead Organization	Status	Country	Turbine Capacity (MW)	Project Capacity (MW)	Water Depth (m)	Foundation Type
Europe	Floatgen	2018	Gamesa/Ideol	Under Construction	France	2	2	30	Barge
	Les éoliennes flottantes de Groix & Belle-Île (La Groix)	2020	Eolfi	Permitting	France	6.15	24.6	60	Semisubmersible
	Provence Grand Large (Faraman)	2020	EDF	Planning	France	8	24	99	Tension-leg platform
	EolMed (Gruissan)	2021	Quadren/Ideol/Bouygues	Planning	France	6.15	24.6	70	Barge
	Les éoliennes flottantes du Golfe du Lion (Leucate)	2021	Engie/EDPR/CDC	Planning	France	6	24	70.5	Semisubmersible
	Hywind Scotland	2017	Statoil	Installed	United Kingdom	6	30	100	Spar
	Dounreay Trì	2020	Highland and Islands Enterprise	Approved	United Kingdom	6–8	10	85	Two-turbine semisubmersible
	Kincardine	2020	Pilot Offshore Renewables	Approved	United Kingdom	6	50	62	Semisubmersible spar hybrid
	Dyfed Floating Energy	2022	Floating Power Plant	Planning	United Kingdom	5–8	224	85	Semisubmersible
	Katanes Floating Pilot	2022	Floating Power Plant	Planning	United Kingdom	7–8	8	80	Semisubmersible
	Katanes Floating Commercial	2024	Floating Power Plant	Planning	United Kingdom	8–8	216	80	Semisubmersible
	WindFloat I	2011	Principle Power	Installed (Decommissioned in 2016)	Portugal	2	2	50	Semisubmersible
	WindFloat Atlantic	2019	Principle Power	Approved	Portugal	8.33	25	100	Semisubmersible
	Hywind 1 Demo	2009	Statoil	Installed	Norway	2.3	2.3	220	Spar
	GICON Pilot	2019	Gicon	Financial Close	Germany	2.3	2.3	20	Tension-leg platform
	FLOCAN5	2021	Canary Islands Government	Permitting	Spain	5–8	25	85	Semi-spar

Installed Project | Under Development Project

8 Additional Resources

Additional Resources

Data

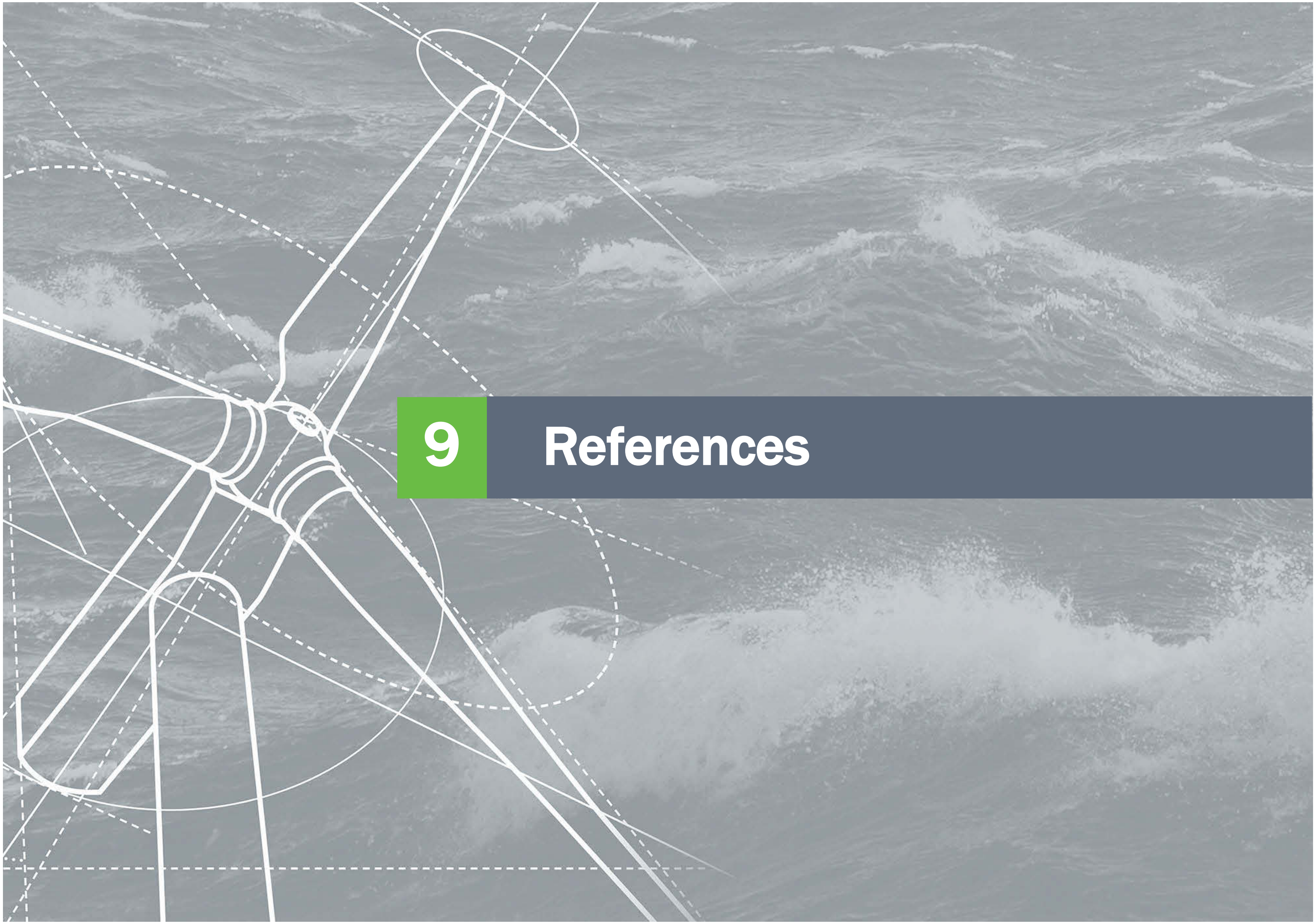
- 4COffshore: http://www.4coffshore.com/windfarms/request.aspx?id=owfdb
- Renewables Consulting Group: Global Renewable Infrastructure Projects database: https://thinkrcg.com/data-services/
- BOEM, Renewable Energy: https://www.boem.gov/renewable-energy/

Research

- NYSERDA Master Plan: https://www.nyserda.ny.gov/All-Programs/Programs/Offshore-Wind/New-York-Offshore-Wind-Master-Plan
- Lawrence Berkeley National Laboratory Technical Report: *Estimating the Value of Offshore Wind Along the United States' Eastern Coast*

Additional Organizations

- Business Network for Offshore Wind: https://www.offshorewindus.org/
- The Massachusetts Clean Energy Center: http://www.masscec.com/
- NYSERDA: https://www.nyserda.ny.gov/
- American Wind Energy Association: http://www.awea.org/



9 References

References

Data Sources

- 4COffshore. 2018. Offshore Wind Farms Intelligence. http://www.4coffshore.com/windfarms/request.aspx?id=owfdb.
- Bloomberg New Energy Finance. 2018. Renewable Energy Project Database. https://about.bnef.com/.
- MAKE Consulting. 2018. Global Offshore Wind Power Project Database. http://www.consultmake.com/research/databases.
- WindEurope. 2018. Wind in power 2017. https://windeurope.org/about-wind/statistics/european/wind-in-power-2017/.

References

- ABB. 2017. “ABB doubles voltage level of special wind turbine transformer” Press Release. June 23, 2017. Accessed May 2018. “http://www.abb.com/cawp/seitp202/2ee2f5603a6b434fc1258148002d4795.aspx.
- ABB. 2018. “WindSTAR transformers.” Accessed May 2018. https://new.abb.com/products/transformers/special-application/windstar-transformers.
- Bay State Wind. 2018a. Twitter. May 24, 2018. Accessed May 2018. https://baystatewind.com/.
- Bay State Wind. 2018b. “Bay State Wind Partners with NEC Energy Solutions.” March 16, 2018. Accessed May 2018. http://baystatewind.com/News/2018/03/Bay-State-Wind-Partners-with-NEC-Energy-Solutions.
- Bay State Wind. 2018c. “Bay State Wind, Unions and Educators to Collaborate on Worker Training.” May 7, 2018. Accessed May 2018. https://baystatewind.com/News/2018/05/Bay-State-Wind-Labor-Release.
- Bay State Wind. 2018d. “Bay State Wind plans more than $2 million in environmental research grants.” April 10, 2018. Accessed May 2018. https://baystatewind.com/News/2018/04/Bay-State-Wind-plans-more-than-2-million-in-environmental-research-grants.
- Beiter, P., P. Spitsen, W. Musial, E. Lantz. Forthcoming. “Assessing Initial U.S. Offshore Wind Project Costs.” Manuscript submitted to journal. Accessed May 2018.
- Bureau of Ocean Energy Management. 2018a. “Renewable Energy Path Forward on the Atlantic.” Accessed September 2018. https://www.boem.gov/Renewable-Energy-Path-Forward/.
- Bureau of Ocean Energy Management. 2018b. “New York Bight.” https://www.boem.gov/NY-Bight/.
- Bureau of Ocean Energy Management. 2018c. “Proposed Commercial Wind Leases OCS-A 0502 & OCS-A 0503.” Accessed May 2018. https://www.boem.gov/Massachusetts-Proposed-Commercial-Wind-Leases/.
- Bureau of Ocean Energy Management. 2018d. “Commercial Wind Leasing Offshore Massachusetts.” Accessed May 2018. https://www.boem.gov/commercial-wind-leasing-offshore-massachusetts/.
- Bureau of Ocean Energy Management. 2018e. “Maryland Activities.” Accessed May 2018. https://www.boem.gov/state-activities-maryland/.

References (continued)

- California Energy Commission. 2018. "California Signs Memorandum of Understanding with Denmark on Offshore Wind." May 1, 2018. Accessed May 2018. http://calenergycommission.blogspot.com/2018/05/california-signs-memorandum-of.html.
- Clemson University. 2017. "Clemson to test world's most powerful wind turbine." October 24, 2017. Accessed May 2018. http://newsstand.clemson.edu/mediarelations/u-s-leads-the-world-in-offshore-wind-turbine-testing/.
- Commonwealth of Virginia Department of Mines, Minerals and Energy. 2018. *Request for Proposals: Developing a Plan to Position Virginia as the East Coast Offshore Wind Supply Chain and Service Industry Location of Choice*. May 21, 2018. Accessed May 2018. https://www.dmme.virginia.gov/de/LinkDocuments/OffshoreWind/2018_Offshore_Wind_Supply_Chain_RFP.pdf.
- Connecticut Department of Energy & Environmental Protection. 2018. *Notice of Request for Proposals from Private Developers for Clean Energy*. January 31, 2018. Accessed May 2018. http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/0fa7e92df14f12248525822600682775/$FILE/2018.01.31_FINAL%20RFP.pdf.
- Davidson and Weston 2018. "Principle Power joins Senvion's 10MW project." *Windpower Offshore*. May 4, 2018. Accessed May 2018. https://www.windpoweroffshore.com/article/1463807/principle-power-joins-senvions-10mw-project.
- Demetre, K. 2018. "Vineyard Wind announces $2M fund to develop offshore wind labor pool in Massachusetts." Stratton Report. Accessed May 2018. http://strattonreport.com/news/vineyard-wind-offshore-wind-labor-pool/?mc_cid=c9e26127cc&mc_eid=756004ce63.
- Dvorak, P. 2018. "Principle Power and Senvion plan to flat a 10-MW turbine." Windpower Engineering & Development. June 13, 2018. Accessed June 2018. https://www.windpowerengineering.com/design/floating-turbines/principle-power-and-senvion-plan-to-float-a-10-mw-turbine/.
- Equinor. 2018. "World class performance by world's first floating wind farm." February 15, 2018. Accessed May 2018. https://www.statoil.com/en/news/15feb2018-world-class-performance.html.
- Federal Register. 2018a. Bureau of Ocean Energy Management. March 30, 2018. Accessed May 2018. https://www.boem.gov/83-FR-13777/.
- Federal Register. 2018b. Bureau of Ocean Energy Management. April 11, 2018. Accessed May 2018. https://www.boem.gov/83-FR-15602/.
- General Court of the Commonwealth of Massachusetts. "An Act to Promote Energy Diversity." Bill H.4568. August 8, 2016. Accessed May 2018. https://malegislature.gov/Bills/189/House/H4568.
- GE Renewable Energy. 2018a. "GE announces Haliade-X, the world's most powerful offshore wind turbine." March 1, 2018. Accessed May 2018. https://www.genewsroom.com/press-releases/ge-announces-haliade-x-worlds-most-powerful-offshore-wind-turbine-284260.
- GE Renewable Energy. 2018b. "Haliade-X Offshore Wind Turbine Platform." Accessed May 2018. https://www.ge.com/renewableenergy/wind-energy/turbines/haliade-x-offshore-turbine.
- Green Giraffe. 2016. "Offshore wind finance – 2016 update." Accessed March 2018. https://green-giraffe.eu/sites/green-giraffe.eu/files/161206_energytalk_v5_-_sent_orga.pdf.

References (continued)

- Green Giraffe. 2018. "Auction design and finance in offshore wind." Accessed May 2018. https://green-giraffe.eu/presentations/auction-design-and-finance-offshore-wind.
- Harrington, M. 2017. "Wind farm's long-term cost will be high for power projects." *Newsday*. Accessed May 2018. http://www.newsday.com/long-island/wind-farm-s-long-term-cost-will-be-high-for-power-projects-1.13142127.
- Hill, J. 2018. "Ørsted Begins Construction Of World Largest Offshore Wind Farm, The 1.2 Gigawatt Hornsea Project One." *CleanTechnica*. January 29, 2018. Accessed May 2018. https://cleantechnica.com/2018/01/29/orsted-begins-construction-world-largest-offshore-wind-farm-1-2-gw-hornsea-project-one/.
- House Bill 226: Maryland Offshore Wind Energy Act of 2013. General Assembly of Maryland. Accessed May 2018. http://mgaleg.maryland.gov/2013RS/bills/hb/hb0226E.pdf.
- Huisman. 2018. "Wind Turbine Shuttle." Accessed May 2018. https://www.huismanequipment.com/en/products/renewables/offshore_wind/wind_turbine_shuttle.
- Jacobsen, S. 2018. "Offshore wind power firms see Taiwan as a battleground to expand in Asia." Reuters. Accessed April 2018. https://www.reuters.com/article/us-taiwan-windpower/offshore-wind-power-firms-see-taiwan-as-a-battleground-to-expand-in-asia-idUSKBN1I11IV.
- JDR. 2017a. "JDR to Supply 66KV Intra-Array Cables for East Anglia One." Accessed May 2018 http://www.jdrcables.com/jdr-supply-66kv-intra-array-cables-east-anglia-one/.
- JDR. 2017b. "JDR selected as preferred cable supplier for WINDFLOAT Atlantic project." Accessed May 2018. http://www.jdrcables.com/jdr-selected-preferred-cable-supplier-windfloat-atlantic-project/.
- Knight, S., and S. Campbell. 2018. "Comparing offshore output for 2017." *Windpower Monthly.* March 22, 2018. Accessed May 2018. https://www.windpowermonthly.com/article/1460225/comparing-offshore-output- 2017.
- Massachusetts Clean Energy. 2017. "83C Documents." Accessed May 2018. https://macleanenergy.com/83c/83c-documents/.
- Massachusetts Clean Energy. 2018. "83D Update on Negotiation Status." Accessed May 2018. https://macleanenergy.com/2018/04/25/83d-update-on-negotiation-status/.
- Musial, W., Z. Parker, J. Fields, G. Scott, and C. Draxl. 2013. *Assessment of Offshore Wind Energy Leasing Areas for the BOEM Massachusetts Wind Energy Area* (Technical Report). NREL/TP-5000-60942. NREL, Golden, CO (US). http://www.nrel.gov/docs/fy14osti/60942.pdf.
- Musial, W., P. Beiter, P. Schwabe, T. Tian, T. Stehly, P. Spitsen. 2017. *2016 Offshore Wind Technologies Market Report*. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Accessed May 2018. https://energy.gov/sites/prod/files/2017/08/f35/2016%20Offshore%20Wind%20Technologies%20Market%20Report.pdf.
- New Jersey State Legislature. 2018a. "A3723." May 23, 2018. Accessed May 2018. http://www.njleg.state.nj.us/bills/BillView.asp?BillNumber=A3723.
- New Jersey State Legislature. 2018b. "S1217." May 30, 2018. Accessed May 2018. http://www.njleg.state.nj.us/bills/BillView.asp?BillNumber=S1217.

References (continued)

- New York State. 2017. “Governor Cuomo presents 25th Proposal of 2017 State of the State: Nation’s Largest Offshore Wind Energy Project Off Long Island Coast and Unprecedented Commitment to Develop up to 2.4 Gigawatts of Offshore Wind Power by 2030,” New York State Governor Andrew M. Cuomo. Accessed May 2018. https://www.governor.ny.gov/news/governor-cuomo-presents-25th-proposal-2017-state-state-nations-largest-offshore-wind-energy.
- New York State. 2018. “Governor Cuomo Unveils 20th Proposal of 2018 State of the State: New York’s Clean Energy Jobs and Climate Agenda,” New York State Governor Andrew M. Cuomo. Accessed May 2018. https://www.governor.ny.gov/news/governor-cuomo-unveils-20th-proposal-2018-state-state-new-yorks-clean-energy-jobs-and-climate.
- NYSERDA. 2018. “New York State Offshore Wind Master Plan.” Accessed May 2018. https://www.nyserda.ny.gov/All-Programs/Programs/Offshore-Wind/New-York-Offshore-Wind-Master-Plan.
- New York State Department of Public Service. 2018. “Dockett 18-00265/18-E-0071” http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=18-e-0071&submit=Search.
- Nikolewski, R. 2018. “Offshore Wind Farms Coming to California – but Navy Says No to Large Sections of the Coast.” The San Diego Tribune. May 6, 2018. Accessed May 2018. http://www.sandiegouniontribune.com/business/energy-green/sd-fi-offshore-wind-20180506-story.html.
- NYSERDA. 2018. “NYSERDA Announces $5 Million Available for Assessment of Wind Resources to Support Responsible and Cost-Effective Offshore Wind Energy Development.” May 1, 2018. Accessed May 2018. https://www.nyserda.ny.gov/About/Newsroom/2018-Announcements/2018-05-01-NYSERDA-Announces-5-Million-for-Assessment-of-Wind-Resources.
- Office of the Governor. 2018. “Rhode Island and Massachusetts Announce Largest Procurement of Offshore Wind in Nation’s History.” RI.gov. May 23, 2018. Accessed May 2018. https://www.ri.gov/press/view/33287.
- offshoreWIND.biz. 2017. “Dutch Govt to Launch First Subsidy-Free Tender on 15 December.” October 18, 2017. Accessed May 2018. https://www.offshorewind.biz/2017/10/18/dutch-govt-to-launch-first-subsidy-free-tender-on-15-december/.
- offshoreWIND.biz. 2018. “Senvion 10MW+ Wind Turbine Prototype Ready By Late 2019, Early 2020.” December 5, 2017. Accessed May 2018. https://www.offshorewind.biz/2017/12/05/senvion-10mw-offshore-wind-turbine-prototype-ready-by-late-2019-early-2020-expertise-hub-video/.
- PBL Netherlands Environmental Assessment Agency. 2018. “National Energy Outlook 2017.” Accessed May 2018. http://www.pbl.nl/en/publications/national-energy-outlook-2017.
- Prysmian Group. 2017.“Prysmian to add offshore cable capabilities to UK factory in Wrexham.” April 20, 2017. Accessed May 2018. https://www.prysmiangroup.com/en/PR_Prysmian%20Group%20_Wrexham_20_04_2017_news.html.
- Recharge Wind. 2018a. “GE unveils market-changing 12MW offshore wind turbine.” March 1, 2018. Updated May 24, 2018. Accessed May 2018. http://www.rechargenews.com/wind/1443296/ge-unveils-market-changing-12mw-offshore-wind-turbine.
- Recharge Wind. 2018b. “Siemens Gamesa still undecided on size of 10MW-plus turbine.” April 10, 2018. Accessed May 2018. http://www.rechargenews.com/wind/1469330/siemens-gamesa-still-undecided-on-size-of-10mw-plus-turbine.
- Redwood Coast of Energy Authority (RCEA). 2017. *Notice of Recommendation for Preferred Respondent*. March 21, 2017. Accessed May 2018. https://redwoodenergy.org/wp-content/uploads/2018/04/5.1-RCEA-RFQ-18-001-Notice-of-Recommendation.pdf.
- ______2018. *Request for Qualifications for Humboldt County Offshore Wind Energy Development Partners*. Accessed May 2018. https://redwoodenergy.org/wp-content/uploads/2017/08/RCEA-Offshore-Wind-RFQ-18-001-1.pdf.

References (continued)

- Smart, G. 2017. *Moving Toward a Subsidy-Free Future for Offshore Wind. Understanding the April 2017 Germany Auction*. Catapult Offshore Renewable Energy. Accessed May 2018. https://ore.catapult.org.uk/app/uploads/2017/12/SP0013-Moving-Toward-a-Subsidy-Free-Future-for-Offshore-Wind-1.pdf.
- State of New Jersey. 2018. "Governor Murphy Signs Executive Order to Promote Offshore Wind Energy." Press release. Accessed May 2018. http://nj.gov/governor/news/news/562018/approved/20180131a_eo.shtml.
- Stehly, T., D. Heimiller, G. Scott. 2017. *2016 Cost of Wind Energy Review*. Accessed May 2018. https://www.nrel.gov/docs/fy18osti/70363.pdf.
- U.S. Department of the Interior. 2018. "Planning, Analysis & Competitiveness Subcommittee Recommendations." Royalty Policy Committee. Accessed May 2018. https://www.doi.gov/sites/doi.gov/files/uploads/rpc_-_recommendations_5.29.2018.pdf.
- U.S. Department of the Navy. 2018. "California Offshore Planning Areas: Informational & Operational Overview." Presentation for California Energy Commission. February 15, 2018. Accessed May 2018. http://www.energy.ca.gov/renewables/offshore_energy/documents/.
- Van Oord. 2018. "Consortium excited with winning tender for Borssele V." Press release. Accessed May 2018. https://www.vanoord.com/news/2018-consortium-excited-winning-tender-borssele-v-0.
- Vineyard Wind. 2018. "Plugging into a new industry." April 1, 2018. Accessed May 2018. https://www.vineyardwind.com/in-the-news/2018/4/1/plugging-into-a-new-industry.
- Walton, R. 2018. "FERC advances transmission line to serve Massachusetts' offshore wind industry." Utility Dive. Accessed May 2018. https://www.utilitydive.com/news/ferc-advances-transmission-line-to-serve-massachusetts-offshore-wind-indus/517125/.
- Zentech. 2017. *Zee Rig 3. Jones Act Compliant Wind Turbine Installation Vessel*. Accessed May 2018. http://zentech-usa.com/wp-content/uploads/2014/09/Zee-Rig-3-Wind-Farm-Brochure-1-Page_06Aug17_r.pdf.

This update is being disseminated by the U.S. Department of Energy (DOE). As such, this document was prepared in compliance with Section 515 of the Treasury and General Government Appropriations Act for fiscal year 2001 (public law 106-554) and information quality guidelines issued by DOE. Though this update does not constitute “influential” information, as that term is defined in DOE’s information quality guidelines or the Office of Management and Budget’s Information Quality Bulletin for Peer Review, the study was reviewed both internally and externally prior to publication. For purposes of external review, the study benefited from the advice and comments of nine energy industry stakeholders, U.S. Government employees, and national laboratory staff.

Available electronically at SciTech Connect http:/www.osti.gov/scitech
Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from:
U.S. Department of Energy Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
OSTI http://www.osti.gov
Phone: 865.576.8401
Fax: 865.576.5728
Email: reports@osti.gov
Available for sale to the public, in paper, from:
U.S. Department of Commerce
National Technical Information Service
5301 Shawnee Road Alexandria, VA 22312
NTIS http://www.ntis.gov
Phone: 800.553.6847 or 703.605.6000
Fax: 703.605.6900
Email: orders@ntis.gov