U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2017 Offshore Wind Technologies Market Update Executive Summary

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.

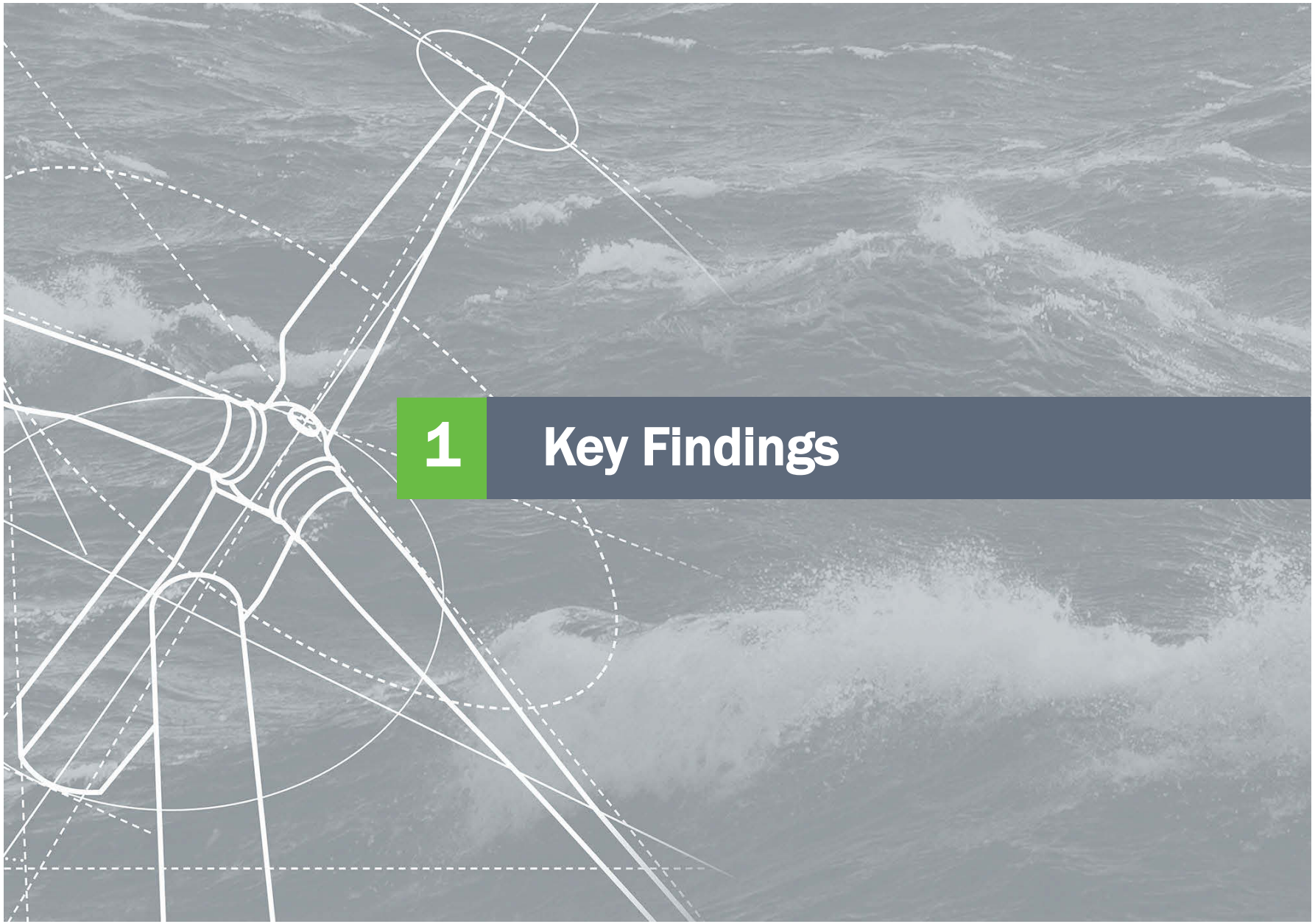
Notes

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. The views expressed in the article do not necessarily represent the views of the U.S. Department of Energy or the U.S. government. The U.S. government retains—and the publisher, by accepting the article for publication, acknowledges—that the U.S. government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. government purposes.

Full text available electronically at: https://www.energy.gov/eere/wind/downloads/2017-offshore-wind-market-update.

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.



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.

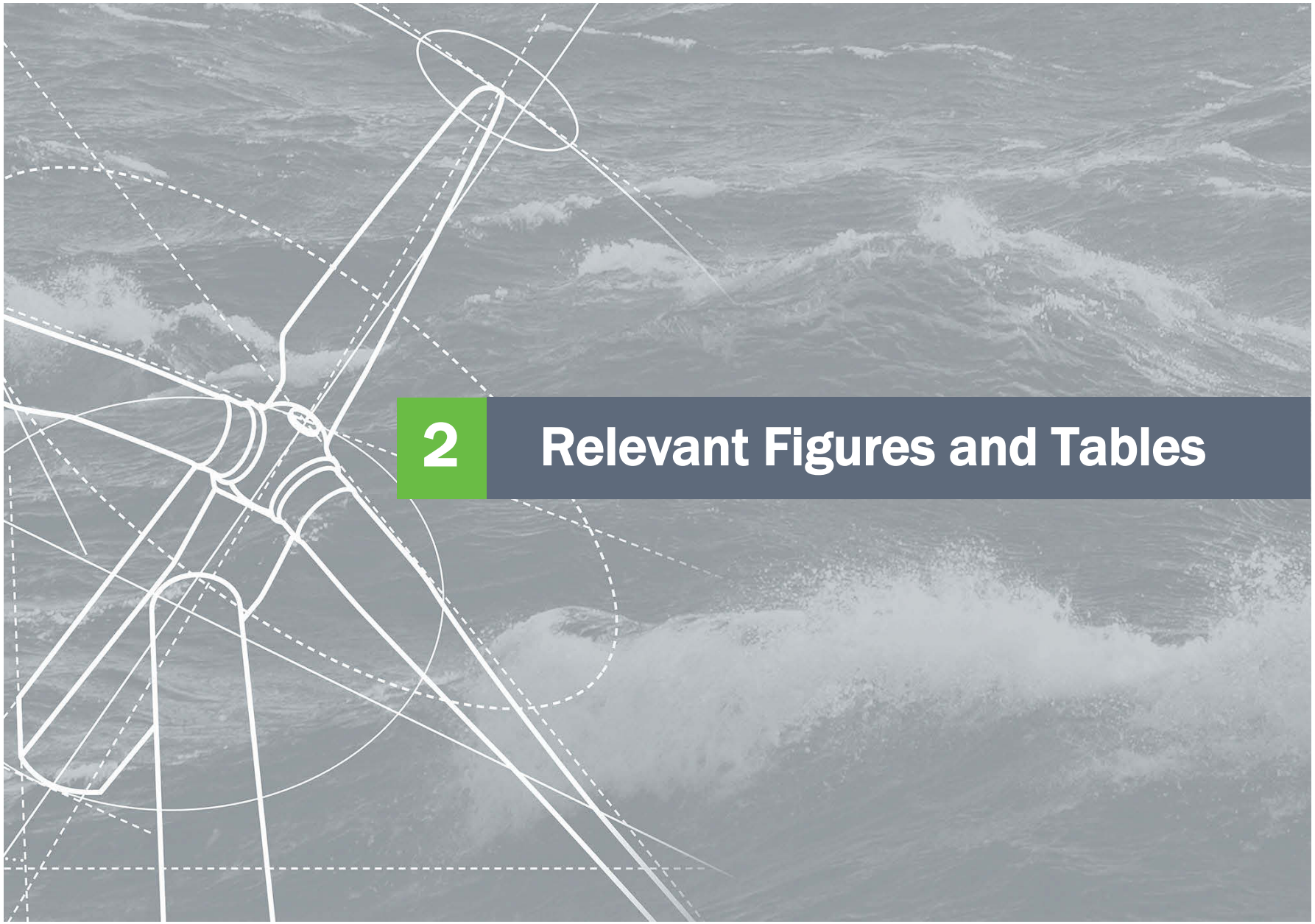
Developers Continue To Test New Fixed-Bottom Substructures To Overcome Geotechnical, Environmental, Domestic Content, and Installation Challenges

- 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 Relevant Figures and Tables

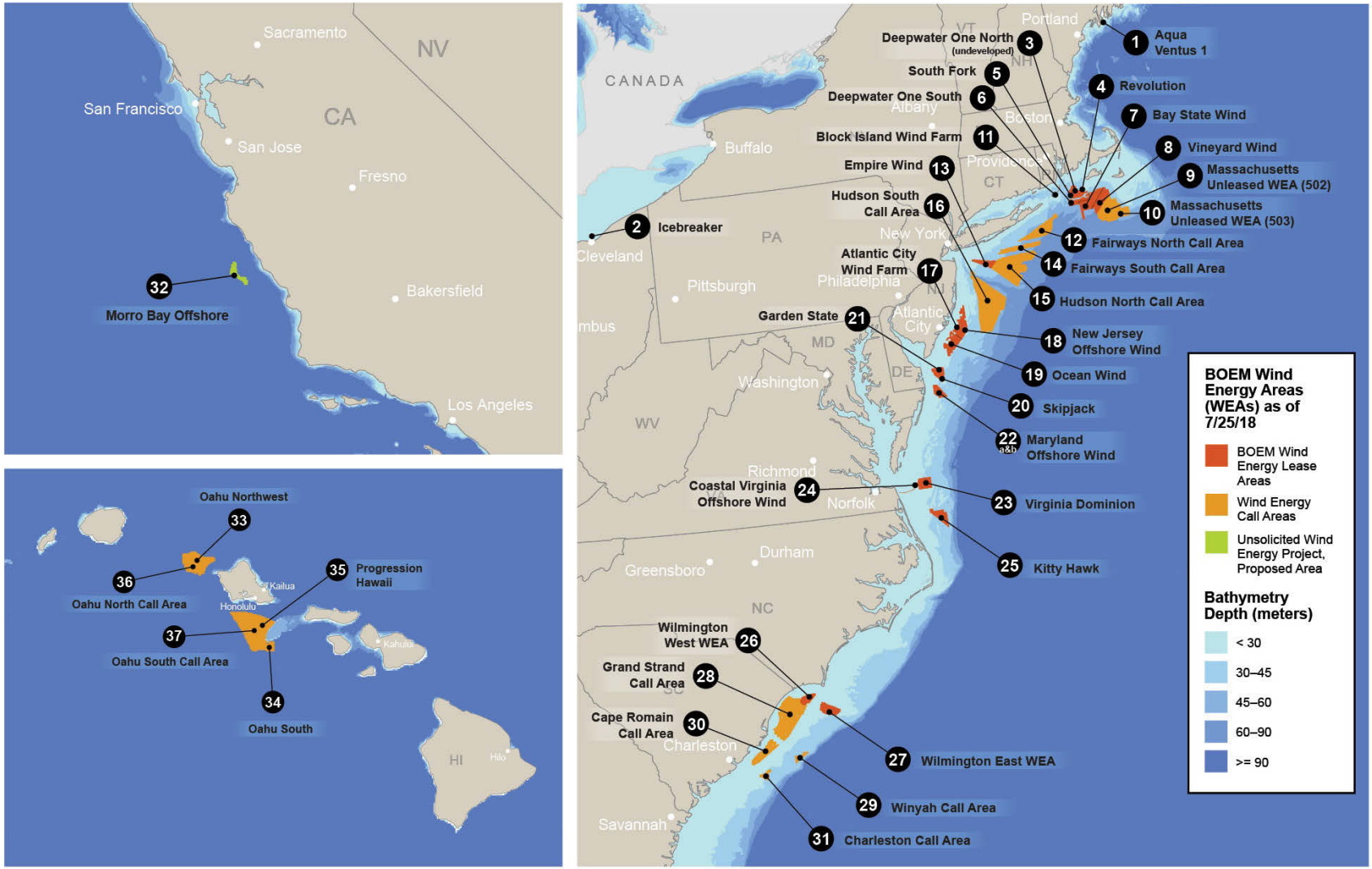
U.S. Project Pipeline Status

			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 14 and 15 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 (km²)	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 km²	$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
	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
	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
	26	Wilmington West WEA	N/A	N/A	NC	Planning	0	1,623	1,623	541	N/A	N/A	14–20	8.3
	27	Wilmington East WEA	N/A	N/A	NC	Planning	0	627	627	209	N/A	N/A	15–29	8.4
	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
	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
	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
	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
	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
	33	Unsolicited Application	Oahu Northwest	Alpha Wind	HI	Planning	400	0	400	133	N/A	N/A	N/A	8.3
	34	Unsolicited Application	Oahu South	Alpha Wind	HI	Planning	400	0	400	133	N/A	N/A	N/A	8.4
	35	Unsolicited Application	Progression Hawaii	Progression	HI	Planning	400	0	400	133	N/A	N/A	N/A	8.4
	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
	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**			