National Offshore Wind Research and Development Consortium HEPG

NATIONAL OFFSHORE WIND
RESEARCH & DEVELOPMENT CONSORTIUM

NOWRDC-Funding Research To Address Key Challenges

DOE's Goal: Facilitate a nationally-focused, not-for-profit organization collaborating with industry on prioritized R&D activities to reduce levelized cost of energy (LCOE) of offshore wind in the U.S. and maximize other economic and social benefits

Desired Impacts:

- Innovations directly responsive to the technical and supply chain barriers faced by offshore wind project developers in the U.S.
- Build strong networks connecting technology innovators, investors, and industry
- Increase U.S. content and job opportunities

Administrator: (competitively awarded by DOE in 2018): New York State Energy Research and Development Administration (NYSERDA), solicitation management to be turned over to the Consortium in 2020

Project Value: $41 M ($20.5 DOE funds, matched by NYSERDA) – plus state and member contributions

Duration: 4 years under current funding (+ 3 years to complete all projects); goal is to become self sustaining indefinitely through research partner funding

Members: Developers, Manufacturers, State Agencies, Research Institutions, Utilities

NOWRDC Road Map and Challenge Areas

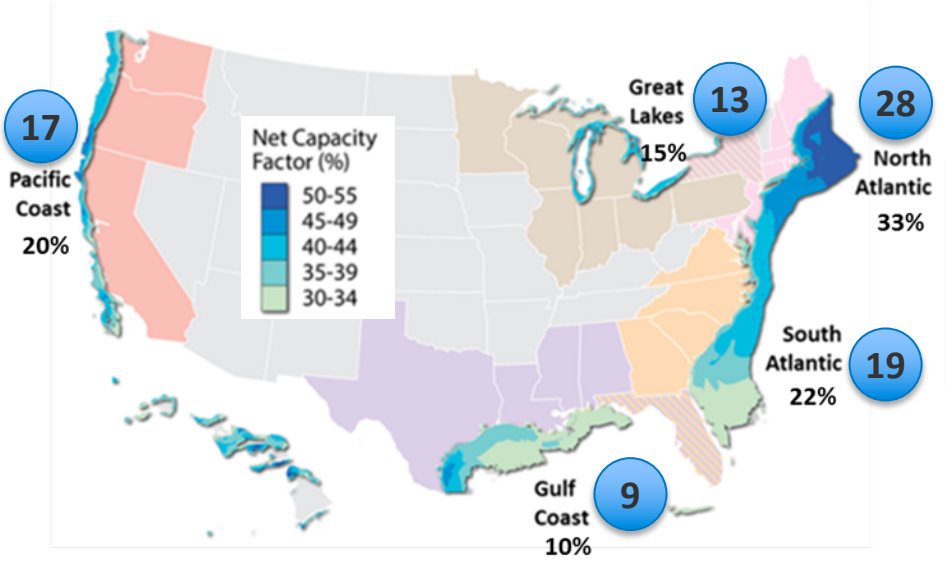
- Prioritized **Research and Development Roadmap 2.0** published in November 2019
- Roadmap topics support three **Research Pillars:**
  1. **Offshore Wind Plant Technology Advancement**
  2. **Offshore Wind Power Resource and Physical Site Characterization**
  3. **Installation, O&M and Supply Chain Solutions**

Global Industry Status

- 176 projects, over 22,592 MW installed (end of 2018)
- Typically fixed bottom support structures in shallow water (<50 m)
- Current Turbine capacity 6.0 - 9.5 MW
- Upwind rotors – 150 m -170 m diameter
- Tower height - 25-m plus rotor radius (min)
- Drivetrain - Direct drive or geared with medium speed generators
- Capacity factors 40 to 55 percent
- Capital cost $4,350/kW in 2018, declining to below $3,000/kW by 2030
- O&M cost higher than land-based
- Leverages and expands opportunities for existing mature marine industries:
  - Offshore oil and gas
  - Submarine cable
  - Marine operations

DOE/DOI Strategy for Offshore Wind

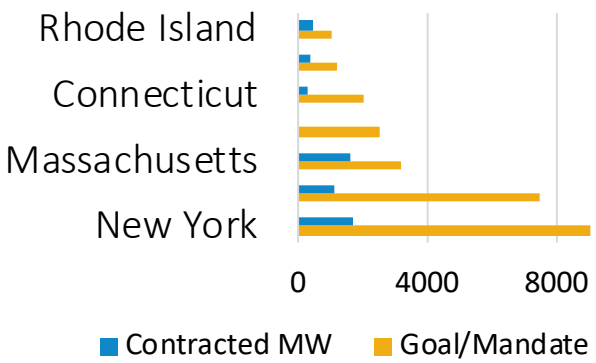
86 GW of Offshore Wind in US by 2050



- **All regions of the US** participate in offshore wind deployment
- **Pacific** can only participate with floating technology. **Northeast, Great Lakes** may need floating wind and fix-bottom wind
- **Great Lakes** will require new technology for floating ice resistance
- **Gulf of Mexico** and South Atlantic will need hurricane resistant designs

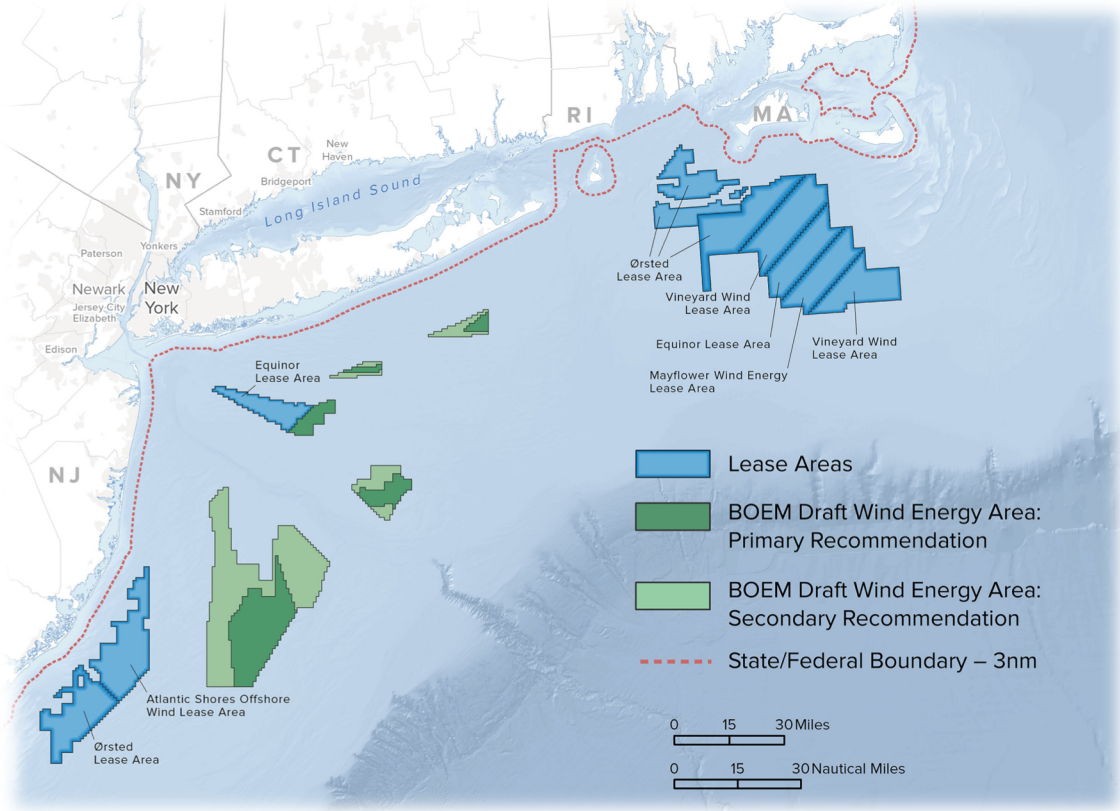
*Offshore Wind Regions from Wind Vision showing percentages of the **86 GW** scenario for each region. (Percentages and bubbles indicate share of the prescribed 86 GW that each region contributes by 2050.)*

Northeast Market Ambitions-26MW



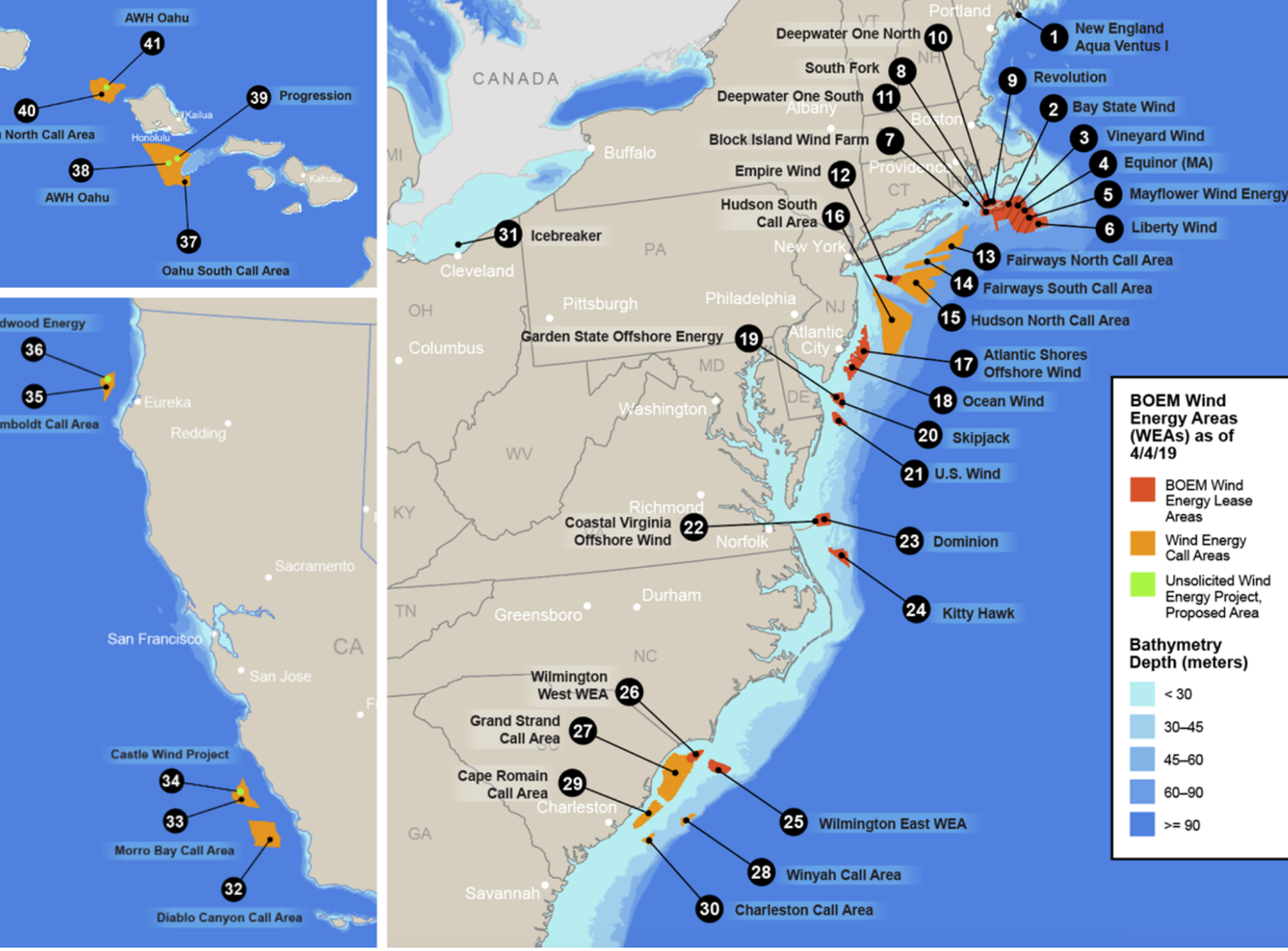
RECENT NEWS

- MA awards 804 MW Mayflower Wind project
- NJ Executive Order increases OSW target to 7.5 GW
- CT awards 804 MW Park City Wind project
- Vineyard project pending BOEM review



U.S. Offshore Wind Industry Regulatory Activity

- Bureau of Ocean Energy Management (BOEM) given authority under EPAct 2005
- 30 CFR 585 released in 2009 provides regulatory framework for federal waters
- Offshore Wind lease sales began in 2011
- BOEM works with state task forces prior to lease area designation
  - Example: BOEM Gulf of Maine Task Force on December 12
- 16 lease areas have been sold in public auctions (about 21 GW)
- ***Call areas (13)*** are nascent ocean tracts under consideration for possible leasing
- A primary role of the Bureau of Safety and Environmental Enforcement (BSEE) is the review and approval of permits for all proposed and planned activities on the Outer Continental Shelf (OCS). Designated operators are required to submit their permits, requests for approvals, and associated data to BSEE prior to start of any operations on the federal OCS. Some of these permits also require revisions to permit approvals if there are any changes to the initial approved permits after operations start.


AWH Oahu
41
40
39 Progression
North Call Area
Kailua
Honolulu
38
AWH Oahu
Kahului
37
Oahu South Call Area
dwood Energy
36
35
mboldt Call Area
Eureka
Redding
Sacramento
San Francisco
CA
San Jose
Castle Wind Project
34
33
Morro Bay Call Area
32
Diablo Canyon Call Area
CANADA
Buffalo
MI
Cleveland
OH
Pittsburgh
Columbus
PA
Philadelphia
NJ
Atlantic City
MD
Washington
DE
WV
KY
VA
TN
Greensboro
Durham
NC
Richmond
Norfolk
Charleston
GA
Savannah
Albany
Boston
Providence
Portland
VT
NH
CT
New York
Deepwater One North 10
South Fork 8
Deepwater One South 11
Block Island Wind Farm 7
Empire Wind 12
Hudson South Call Area 16
31 Icebreaker
Garden State Offshore Energy 19
Coastal Virginia Offshore Wind 22
Wilmington West WEA 26
Grand Strand Call Area 27
Cape Romain Call Area 29
1 New England Aqua Ventus I
9 Revolution
2 Bay State Wind
3 Vineyard Wind
4 Equinor (MA)
5 Mayflower Wind Energy
6 Liberty Wind
13 Fairways North Call Area
14 Fairways South Call Area
15 Hudson North Call Area
17 Atlantic Shores Offshore Wind
18 Ocean Wind
20 Skipjack
21 U.S. Wind
23 Dominion
24 Kitty Hawk
25 Wilmington East WEA
28 Winyah Call Area
30 Charleston Call Area
BOEM Wind Energy Areas (WEAs) as of 4/4/19
BOEM Wind Energy Lease Areas
Wind Energy Call Areas
Unsolicited Wind Energy Project, Proposed Area
Bathymetry Depth (meters)
< 30
30–45
45–60
60–90
>= 90

Challenges in US Offshore Wind Post Leasing

- Recognition of capacity factors by ISO market rules
- Onshore landing/transmission
- Transport of components and O&M
  - Restrictions from the Jones Act
  - Relatively small size of ports and harbors
- Deepwater vs. shallow requires different technology solutions
- Different environmental and weather conditions across US requires different solutions
- Multiple permitting entities for offshore and onshore
- Coordination among states and federal government

The Jones Act

- Heavy lift vessels are generally used for all major offshore wind plant construction activities, including installing wind rotor nacelles and support structure components at the offshore site.
- Weightlifting capacity and boom height tend to drive vessel costs up rapidly and therefore, the ability to install the forecasted larger size turbines may be limited if the lift capacity of available vessels cannot increase accordingly.
- The Merchant Marine Act, 1920 (also known as the Jones Act) requires any vessel that is transporting merchandise between two points in the U.S. to be U.S. built, U.S.-flagged and U.S.-owned. As U.S. offshore wind plants are sited in U.S. waters, any vessel transporting components to or from an offshore wind plant would be required to comply with this law.
- There are a number of U.S. vessels that can support the construction of an offshore wind plant in U.S. waters, there are currently no Jones Act compliant heavy lift vessels with the capacity to install the heavier turbine components (e.g. the nacelle) at the heights required. Additionally, to accommodate larger heavy lift vessels, ports may need to be upgraded (e.g. additional dredging, wider access, stronger quayside, etc.)

Factors Considered by BOEM

- **Physical**
  - Air Quality
  - Water Quality
- **Biological**
  - Marine Mammals
  - Sea Turtles
  - Fish and Essential Fish Habitat (EFH)
  - Coastal Habitats
  - Benthic Resources
  - Avian and Bat Species
- **Socioeconomic**
  - Commercial and Recreational Fishing Activities
  - Aesthetics and Visual Impacts
  - Cultural Resources
  - Military Uses
  - Environmental Justice
  - Land Use and Coastal Infrastructure
  - Tourism and Recreation
  - Demographics and Employment

BOEM Environmental Consultations

- **National Historic Preservation Act (NHPA)**
  - Section 106 requires Federal agencies to take in to account the effects of their undertakings on cultural resources
  - Requires BOEM to identify the appropriate consulting parties, identify cultural resources, assess impacts and mitigate potential adverse effects

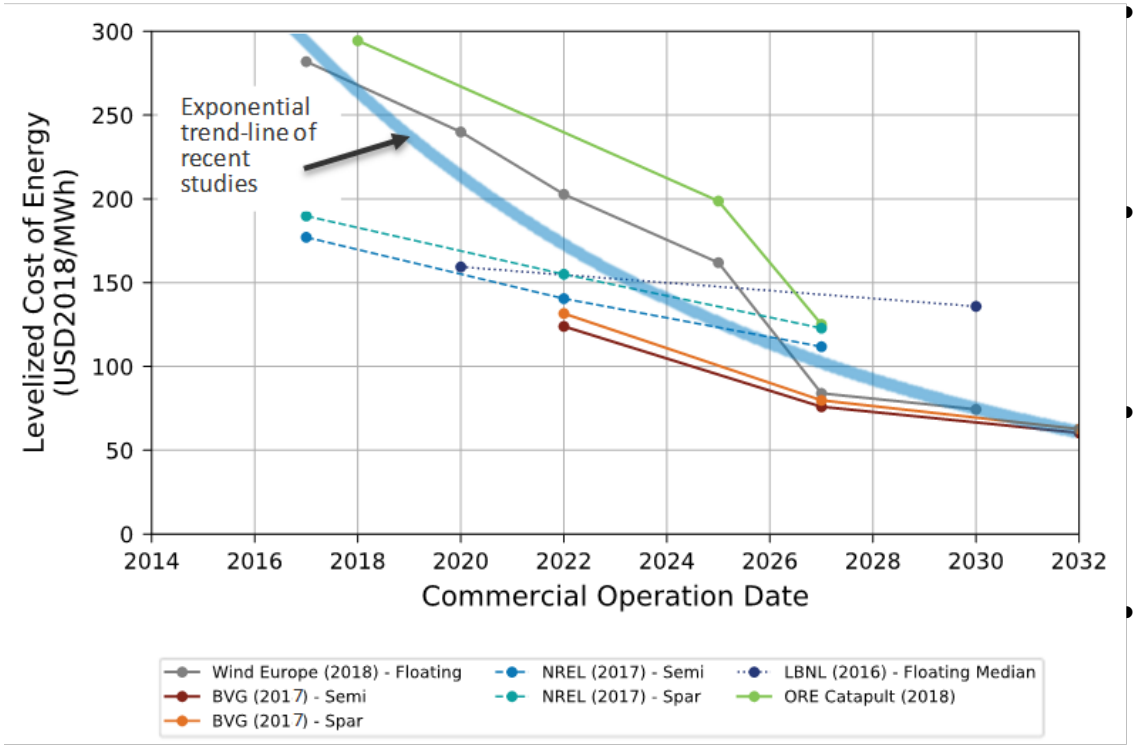
- **Endangered Species Act (ESA)**
  - Section 7 requires consultation when BOEM believes a proposed action may affect ESA-listed species or adversely modify designated critical habitat
  - BOEM will coordinate with the National Marine Fisheries Service (NMFS) and U.S Fish and Wildlife Service (FWS)

BOEM Environmental Consultations

- **Magnuson-Stevens Fishery Conservation and Management Act (Essential Fish Habitat, EFH)**
  - If BOEM funds, permits, or undertakes activities that may adversely affect EFH, BOEM is required to consult with NMFS
- **Marine Mammal Protection Act (MMPA)**
  - All marine mammals are protected under the MMPA, which prohibits (with certain exceptions) the "take" of marine mammals in U.S waters.
  - The Lessee would consult with NMFS regarding any potential take of marine mammals under the proposed action
- **Coastal Zone Management Act (CZMA)**
  - Federal actions that are reasonably likely to affect coastal use or coastal resource must be "consistent to the maximum extent practicable" with relevant enforceable policies of the State's federally approved coastal management program
  - BOEM would coordinate appropriately with the New York Department of State

Current Floating Offshore Costs

Selected Floating Offshore Wind LCOE Trajectories

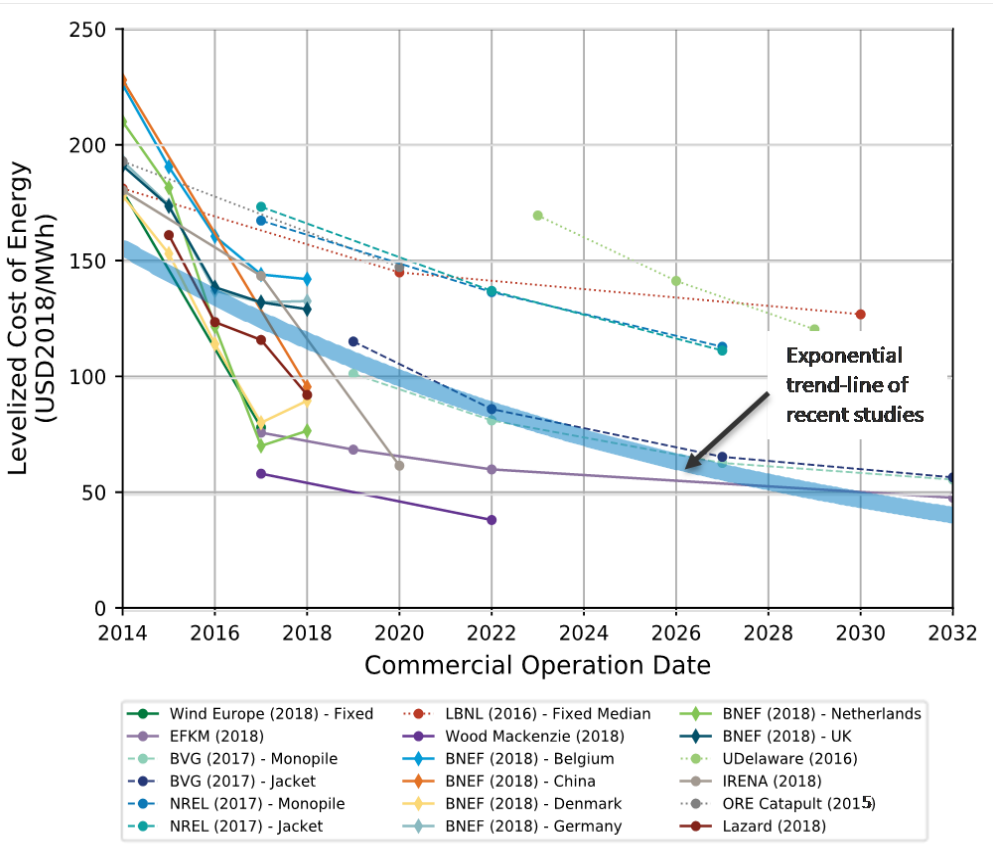


- Floating cost estimates are declining rapidly as new information is obtained
- NREL (2019) study for OR estimated $60/MWh by 2032
- BVG and Wind Europe (2018) estimate costs near $70/MWh by 2030
- New NREL modeling will deliver similar estimates

Musial, W; Beiter, P., Spitsen, p., Nunemaker, J., Gevorgian, V. 2019. “2018 Offshore Wind Technologies Market Report”, U.S. Department of Energy Report, August 2019.
https://www.energy.gov/eere/wind/2018-wind-market-reports#offshore

Fixed-Bottom LCOE Forecasted to Decline to $50/MWh by 2030

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

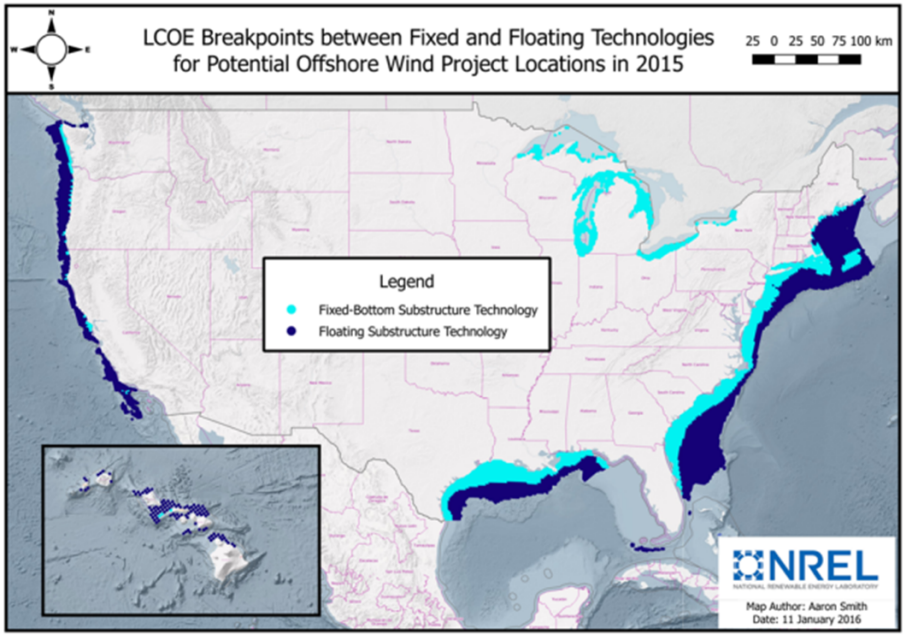


Sources: WindEurope (2018), Danish Ministry of Energy, Utilities and Climate (2018), Valpy et al. (2017), Beiter et al. (2017), Wiser et al. (2016), Barla (2018), BNEF (2018b, 2018c), Kempton et al. (2016), IRENA (2018), ORE Catapult (2015), and Lazard (2018)

Technical Innovations Addressing LCOE and Environmental Challenges

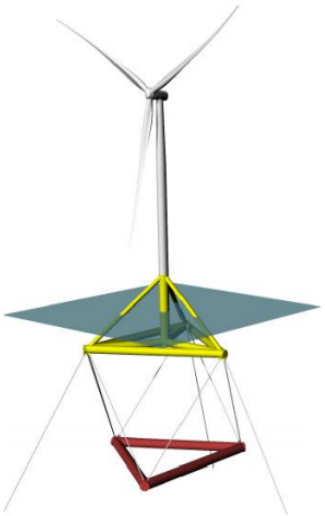
- Advancements in floating and fixed bottom moorings
- Vessel adaptations
- Improved O&M Capabilities
- Increase in Wind Turbine Size
  - Advanced light-weight materials
  - Advanced controls to limit loads and protect vital systems
  - High-fidelity design and analysis tools
  - Material and manufacturing innovations
  - Automated service and logistics
  - Remote diagnostics and robotic repairs
  - Industrialization of the supply chain

Floating Technology Trends – 58% off US Offshore Resource Need to Address Marine Concerns



Examples of Next-Generation Hybrid Floating Substructures

- Lighter and more stable platform designs are under development to facilitate port assembly, commissioning, and stable tow-out.
- 14 Pilot Scale Projects are being built to demonstrate this next generation of technology



Stiesdal Offshore Technologies TetraSpar

SBM Tension Leg Platform

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

Floating Structures

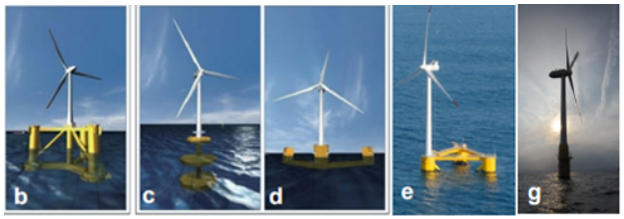


Photo: Equinor
Scotland
30 MW 5 Turbines –
Credit: Walt Musial

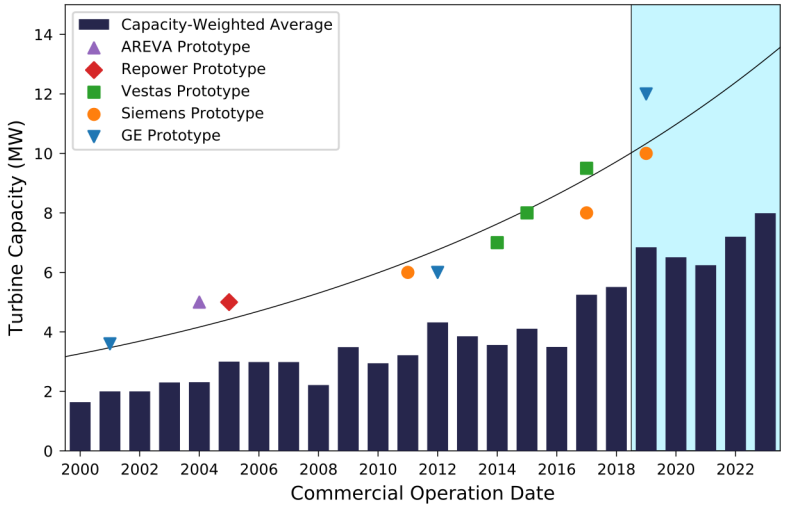
Technical Innovations Enable Continued Turbine Upscaling

- Advanced light-weight materials
- Advanced controls to limit loads and protect vital systems
- High-fidelity design and analysis tools
- Material and manufacturing innovations
- Automated service and logistics
- Remote diagnostics and robotic repairs
- Industrialization of the supply chain

New Turbine Prototypes Foretell Continued Turbine Growth

- **General Electric announced the 12-MW Haliade-X turbine** prototype now being installed in Rotterdam to be on the market in 2021. The turbine is first in class, with a 12-MW direct-drive generator, 220-m rotor, and 140-m hub height.

- **Siemens Gamesa announced the SG10.0-193 DD turbine**—a 10-MW direct-drive turbine with a 193-m rotor—which is planned to be ready for market in 2022.



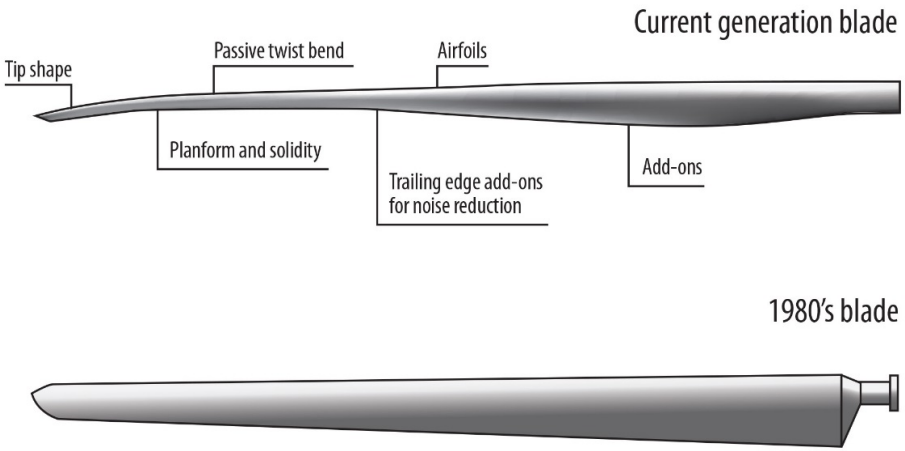
Average Commercial Offshore Turbine Growth With Prototype Development Leading Further Growth
Source: DOE 2018 Market Report

GE 12-MW Wind Turbine Nacelle – Haliade -X

Photo Source: Greentech Media: https://www.greentechmedia.com/articles/read/ge-finishes-first-nacelle-for-12mw-haliade-x-offshore-wind-turbine#gs.xpxkf6

Characterizing the structural, aerodynamic, and hydrodynamics of offshore systems with advanced materials at commodity prices

GE Haliade 12-MW 107-meter Blade Prototype – Longest Blade Ever Built



Source: NREL; based on a graphic from Kenneth Thomsen, formerly Siemens Gamesa Renewable Energy.

https://www.ge.com/reports/extreme-measures-107-meters-worlds-largest-wind-turbine-blade-longer-football-field-heres-looks-like/

Summary

- U.S. states are implementing policies (over 26 GW) in reaction to strong price reductions and lower cost signals from both European and U.S. markets
- LCOE forecasts for offshore wind indicate fixed bottom wind may be near $50/MWh and floating wind may be as low as $60 MWh by 2032 (COD).
- Cost declines may be attributed to a combination of technological and market-based improvements.
- Favorable cost impacts are observed due to upscaling to larger turbines, lower cost of capital, larger project sizes, lower turbine and platform unit costs.
- Significant challenges remain with grid integration, resource characterization, and new technology development for unique environmental conditions (deep water, ice, hurricanes)
- Thanks to Walt Musial/ NREL for photos, technical data, etc.