Virginia Offshore Wind Developer Update:
Research Lease (OCS-A 0497)

BOEM North Carolina & Virginia
Intergovernmental Renewable Energy Task Force
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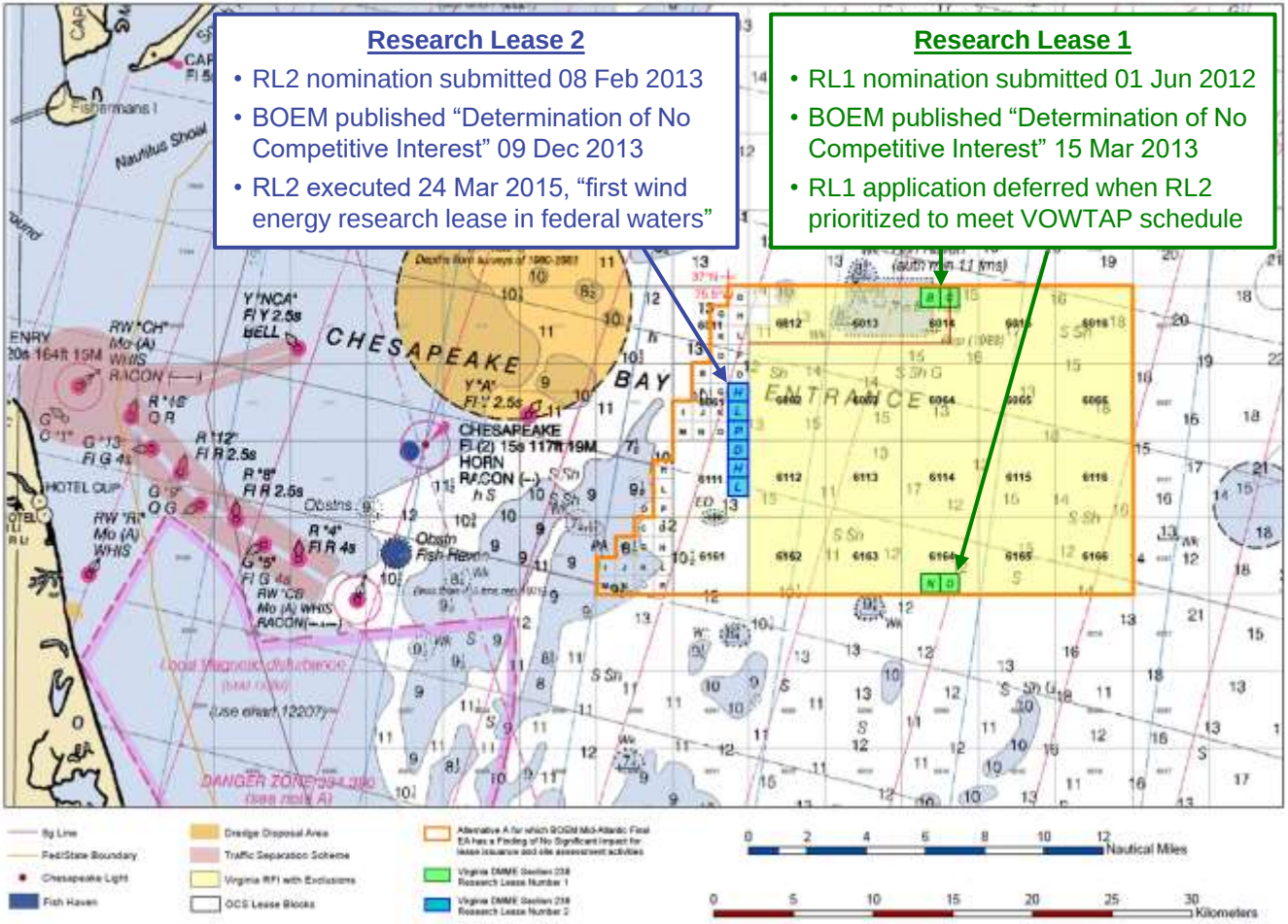
George Hagerman, Senior Project Scientist
Old Dominion University, Center for Coastal Physical Oceanography

DMME
Virginia Department of Mines Minerals and Energy

ODU
Center for Coastal Physical Oceanography

Research Lease Status

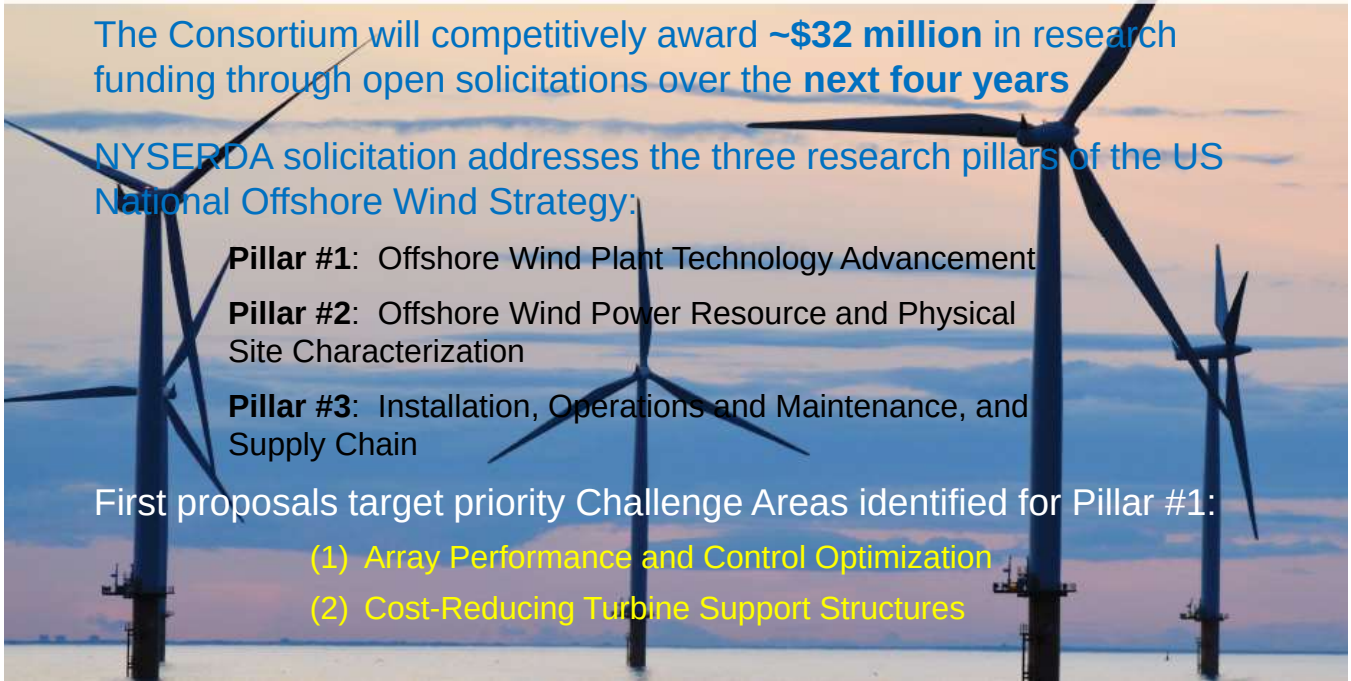


Major Research Funding Opportunity

National Offshore Wind Research and Development Consortium

Notice of Upcoming Technical Challenges

First Research Pillar: Offshore Wind Plant Technology Assessment | Initial Release Version 1.0 | November 2018



The Consortium will competitively award **~$32 million** in research funding through open solicitations over the **next four years**

NYSERDA solicitation addresses the three research pillars of the US National Offshore Wind Strategy:

Pillar #1: Offshore Wind Plant Technology Advancement

Pillar #2: Offshore Wind Power Resource and Physical Site Characterization

Pillar #3: Installation, Operations and Maintenance, and Supply Chain

First proposals target priority Challenge Areas identified for Pillar #1:

(1) Array Performance and Control Optimization

(2) Cost-Reducing Turbine Support Structures

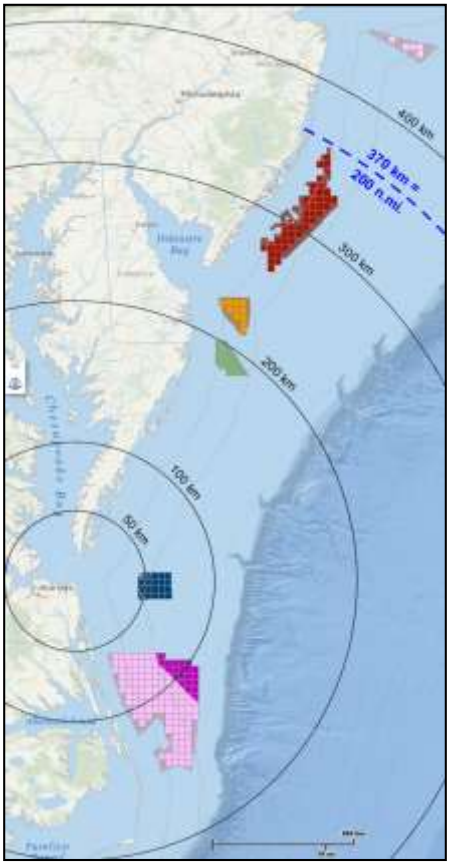
Pillar #1 – Priority Challenge Area 1 (P1-CA1):

Array Performance and Control Optimization

Existing commercial lease project pipeline within a day's sail from Hampton Roads depends on the assumed turbine capacity density:

- Commercial leases off NJ, DE, MD, VA, and Kitty Hawk, NC have a total combined area of 3,056 square kilometers
- The US National Offshore Wind Strategy assumes a potential installed turbine density of 3 megawatts per square kilometer, or 3.0 MW/km^2, which yields a southern Mid-Atlantic **9.17 GW pipeline**
- European resource studies assume 5.4 MW/km^2, which yields a southern Mid-Atlantic **16.5 GW pipeline**
- National Renewable Energy Laboratory (NREL) models find that when optimal turbine positioning is combined with wake steering by active yaw control, baseline of 5.4 MW/km^2 can be increased to 8.8 MW/km^2, which yields a southern Mid-Atlantic **26.9 GW pipeline**

Virginia and North Carolina have unique assets that can physically validate NREL findings

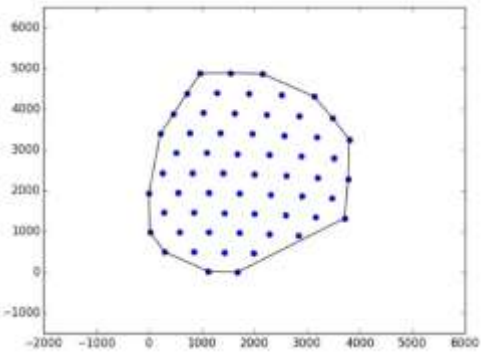


NREL combined optimization for hypothetical project yields 70% more energy per unit area over baseline

	Baseline	YawOpt	PosOpt	Combined
Mean power (MW)	78.86	84.91	78.86	78.84
Area (km^2)	14.53	14.53	12.45	8.96
Power density (W/m^2)	5.43	5.84	6.33	8.80
AEP(GWh) (annual energy production)	1040.3	1094 (+5.2%)	1055.8 (+1.5%)	1095 (+5.3%)

71.6 GWh per km^2

Baseline Layout



Baseline: Turbines positioned in regular grid, all yawed to have zero error for mean wind direction

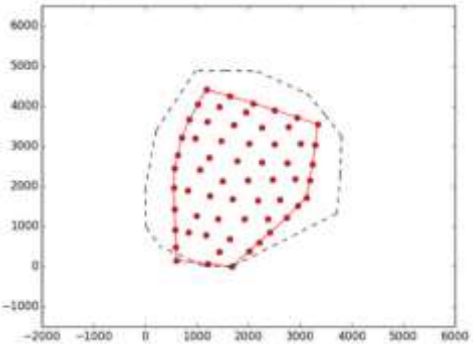
YawOpt: Turbines positioned in regular grid, individually yawed to steer wakes for optimal AEP

PosOpt: Positions optimized, turbines all yawed to have zero error for mean wind direction

Combined: Positions optimized and turbines individually yawed to steer wakes for optimal AEP

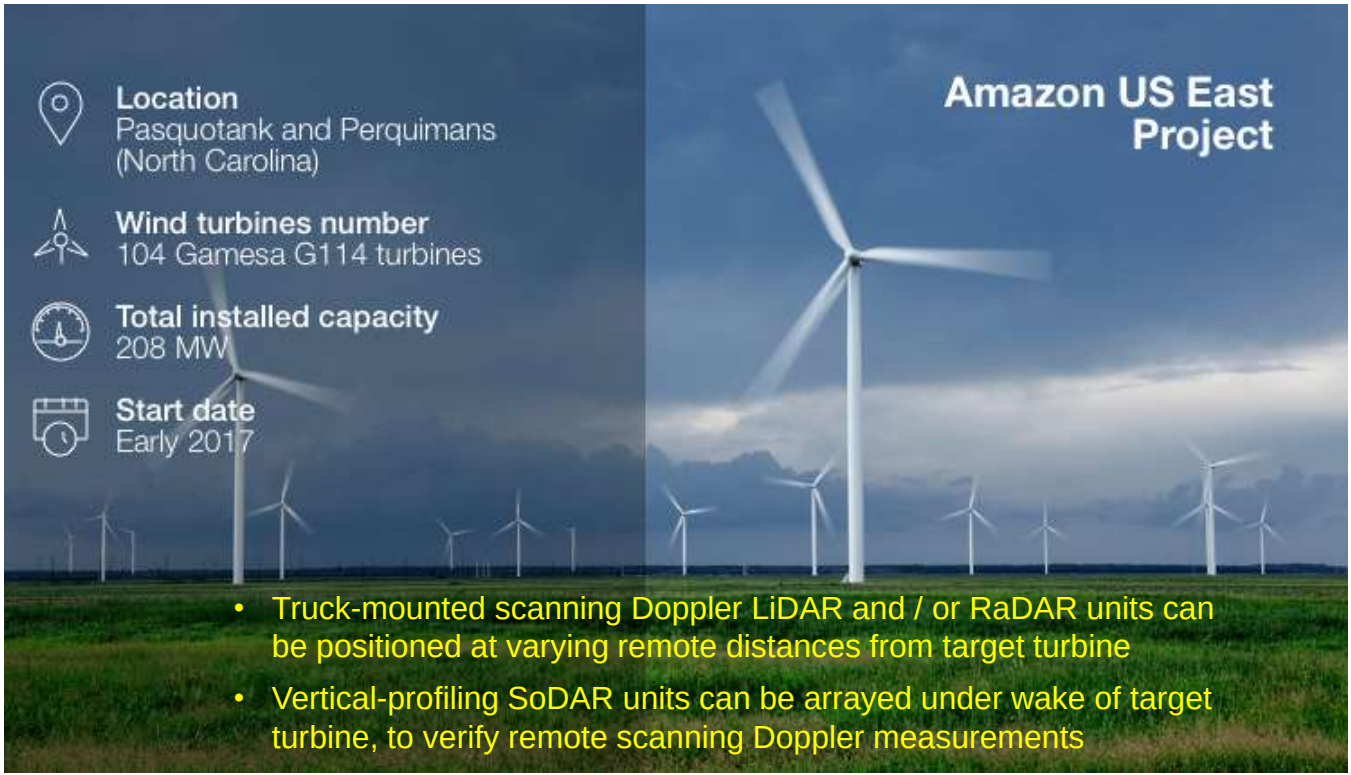
122 GWh per km^2

Combined Layout



Source: Katherine Dykes, National Renewable Energy Laboratory, 11 Oct 2017
See http://onlinelibrary.wiley.com/doi/10.1002/we.1993/abstract for peer-reviewed paper

Amazon US East project being considered as a possible site to verify remote wake measurements



Discussions with Avangrid Renewables have been initiated and are ongoing

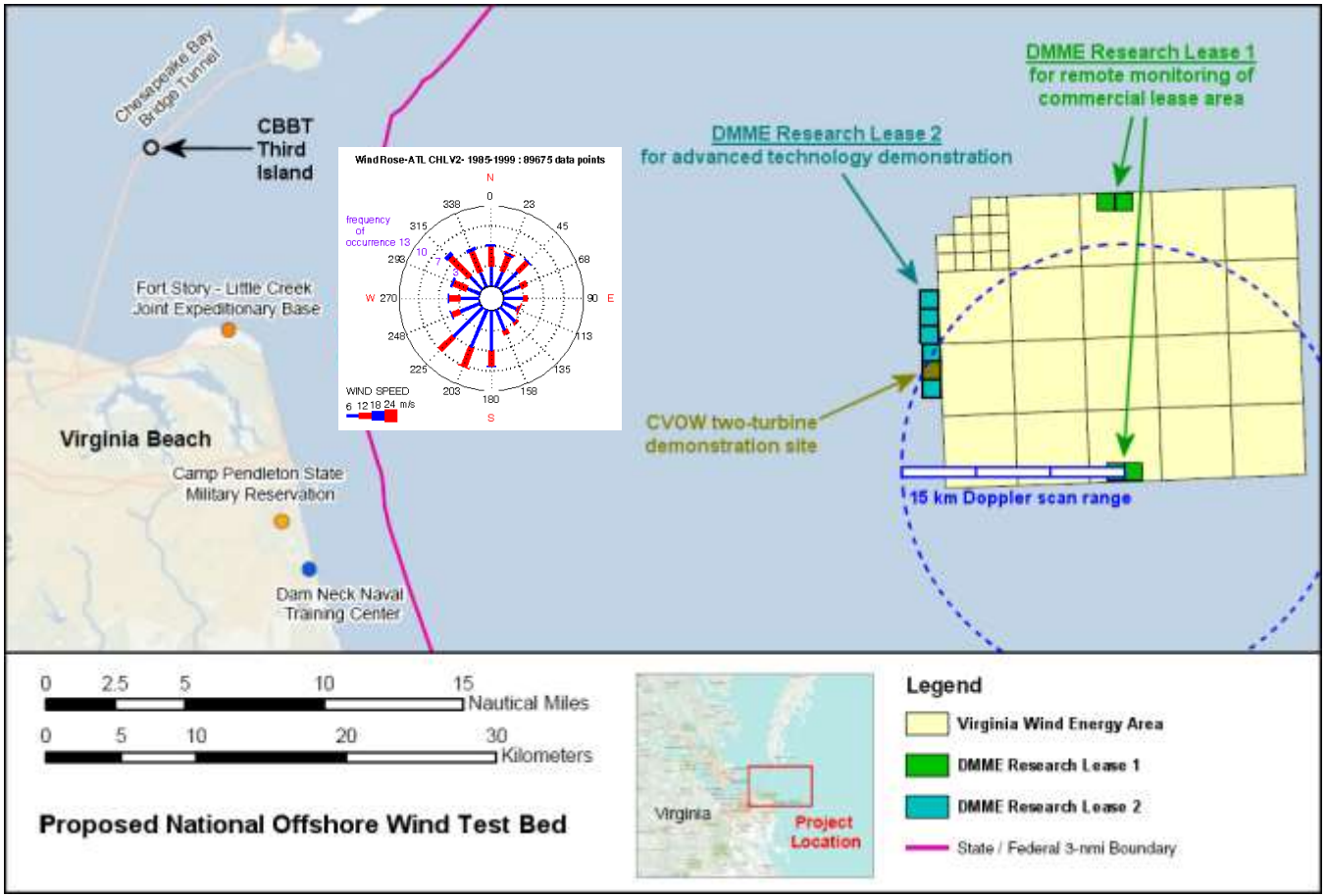
Research instrumentation would be qualified at Chesapeake Bay Bridge Tunnel (CBBT) islands

Station Owner		Station Name	Range (km) *
NOS	Q	Chesapeake Bay Bridge Tunnel	8.4
Weatherflow	R	Lynnhaven Pier/Virginia Beach	13.3
NOS	T	Cape Henry	13.7
Weatherflow	S	Cape Henry	14.2
Weatherflow	K	Thimble Shoals/Chesapeake Bay	14.7
Weatherflow	P	Little Creek/Norfolk	14.8
NOS	C	Kiptopeke State Park	16.5
NOS	O	Willoughby Deguassing Station	22.5
Weatherflow	J	Messick Point Poquoson	23.1

CBBT Third Island (**Marker A**) can verify range of Doppler LiDAR or RaDAR units by testing against existing coastal met masts before finalizing design and operation for fixed platforms in RL1

Instrumentation must meet data availability standards before allowed offshore

Integrating research leases into Ocean Test Bed



Research Pillar #1 – Challenge Area 2 (P1-CA2)

Cost-Reducing Turbine Support Structures

Fixed platforms are required to support Doppler lidar or radar units in RL1, to enable real-time wind mapping of commercial lease area, while simultaneously demonstrating suction-bucket jacket foundations that can be fabricated and assembled in Hampton Roads for entire US East Coast market

- Suction-caisson jackets eliminate pile driving, which greatly expands offshore installation season from summer-only, daytime-only to **year-round, day-and-night**
- Validate jacket transparency to impact of breaking storm waves

First prototype suction-bucket jacket at Borkum Riffgrund I, pioneered by Orsted

Breaking wave at FINO-1 platform in 28m water depth when significant wave height is only 6 m

Suction-bucket jacket ready for European Offshore Wind Deployment Center

Progressive program of research proposals

❑ DOE Office of Energy Efficiency and Renewable Energy

- DOE FOA-2071: Project Development for OSW Technology Demonstrations
  - Characterization of extreme wave profiles, forces, and structural response of CVOW monopile foundations (*subject to Dominion CVOW site access terms & conditions*)

❑ National Offshore Wind R&D Consortium

- NYSERDA P1-CA1: Array Performance and Control Optimization
  - LiDAR measurement of CVOW turbine wakes to physically validate NREL numerical models (*subject to Dominion CVOW site access terms & conditions*)
- NYSERDA P1-CA2: Cost-Reducing Turbine Support Structures
  - LCOE study of suction-bucket jacket foundation needing **least-cost heavy-lift vessel**
- NYSERDA P3-CA1: Heavy Lift Vessel Alternatives
  - LCOE study of "float and flood" suction-bucket jacket foundation embarking tower and turbine, fully assembled at quayside, **eliminating heavy-lift vessel**
- NYSERDA P2-CA2: Development of a Metocean Reference Site
  - Newbuild platforms in RL1 aliquots, demonstrating optimal suction-bucket jacket design
- NYSERDA P3-CA2: Offshore Wind Digitization Through Advanced Analytics
  - Combine validated NREL models and real-time Doppler wind mapping from RL1 platforms to simulate buildout of hypothetical, utility-scale "virtual project" in commercial lease area