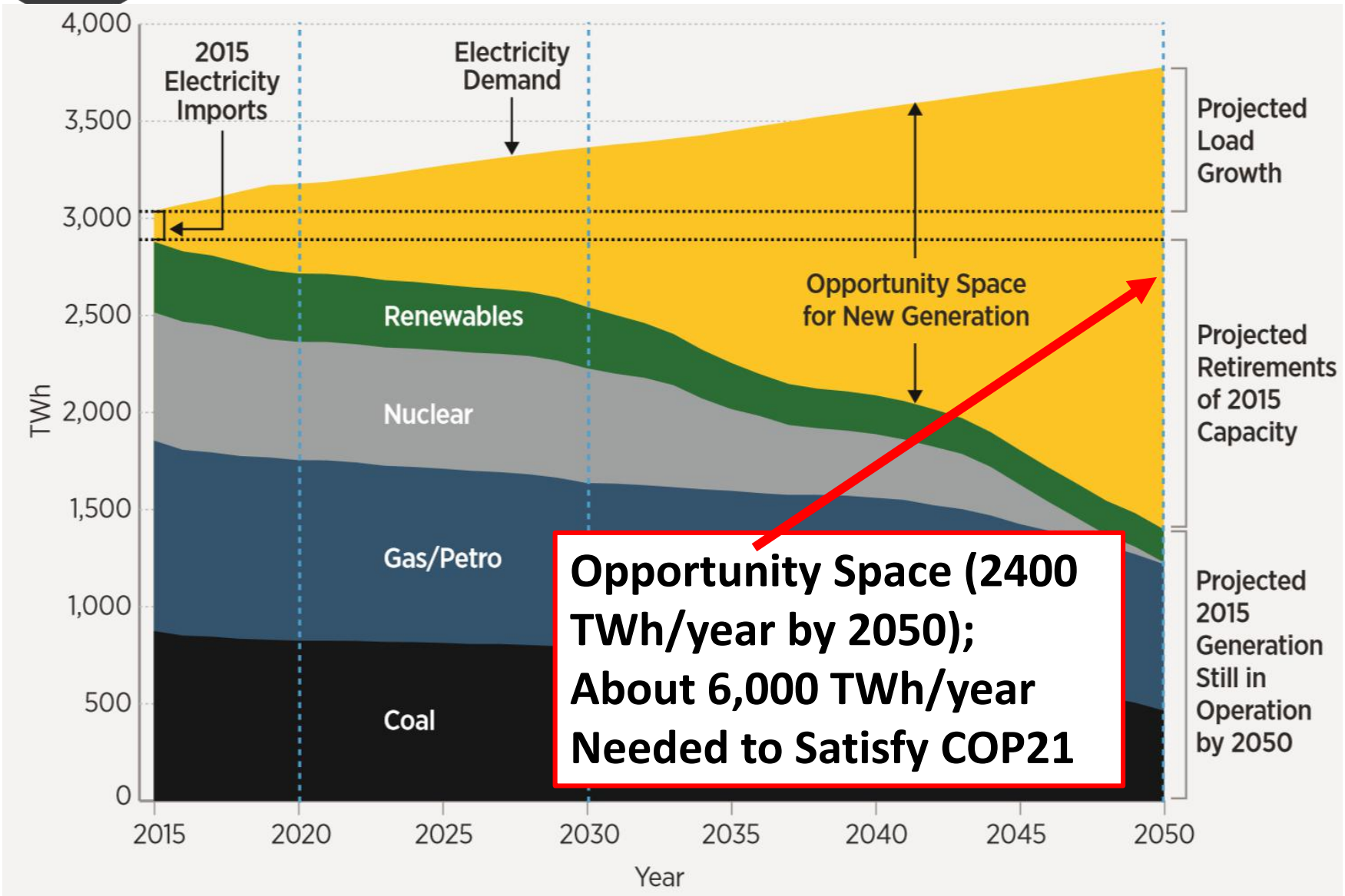
Impact of Foundation Selection on Wind Turbine Design and Operations

Block Island Wind Farm

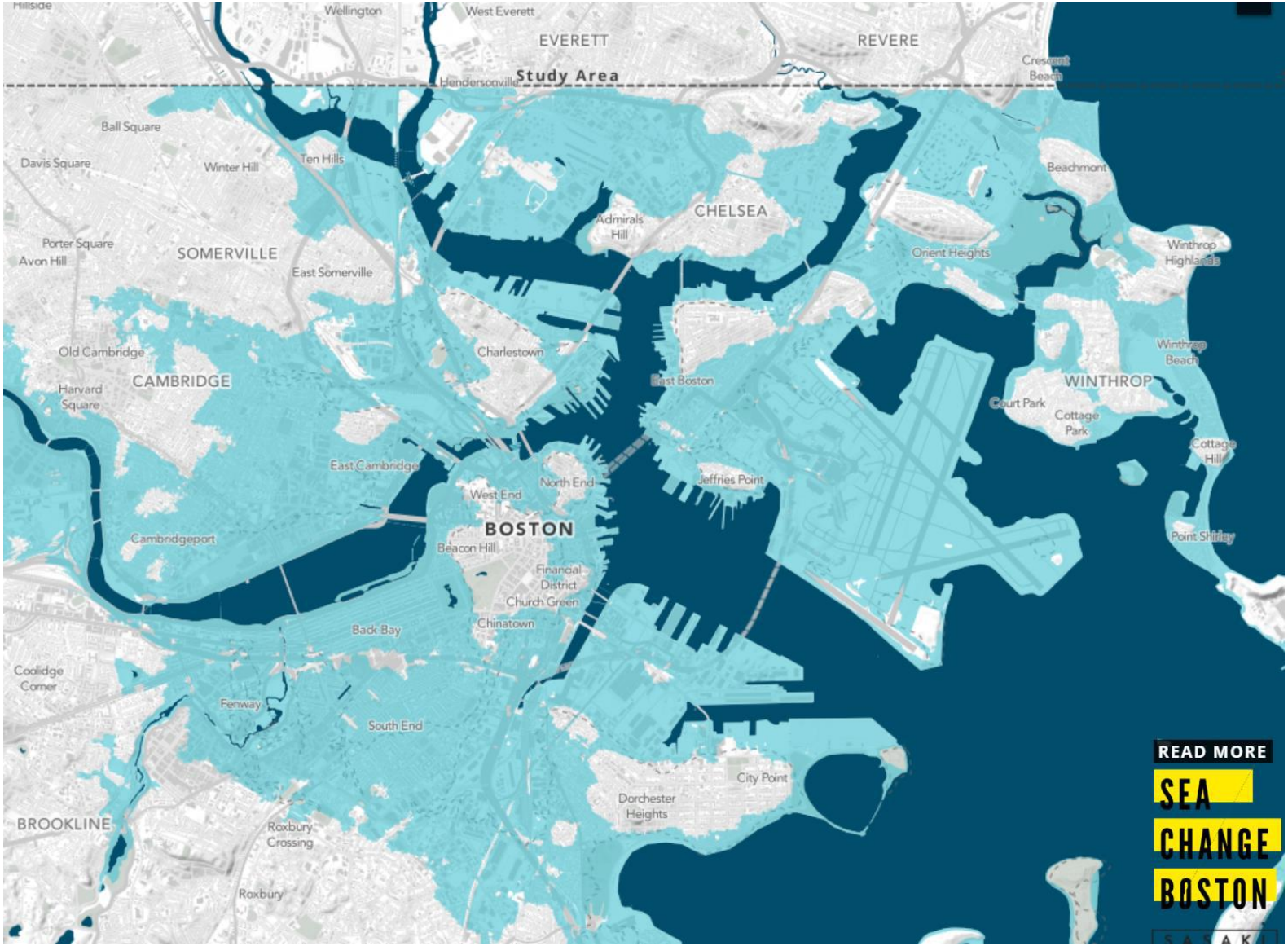
A Short Story on U.S. Offshore Wind & Foundations

- Electricity Needs and Offshore Wind Resource
- Leases and Commitments
- U.S. Department of Energy Investments
- Foundations for First Projects
- U.S. National Offshore Wind Strategy
- POWER-US Activities
- “Our Thinking”

U.S. Electricity Need Due to Plant Retirements



Boston in Year 2100 with Storm Surge

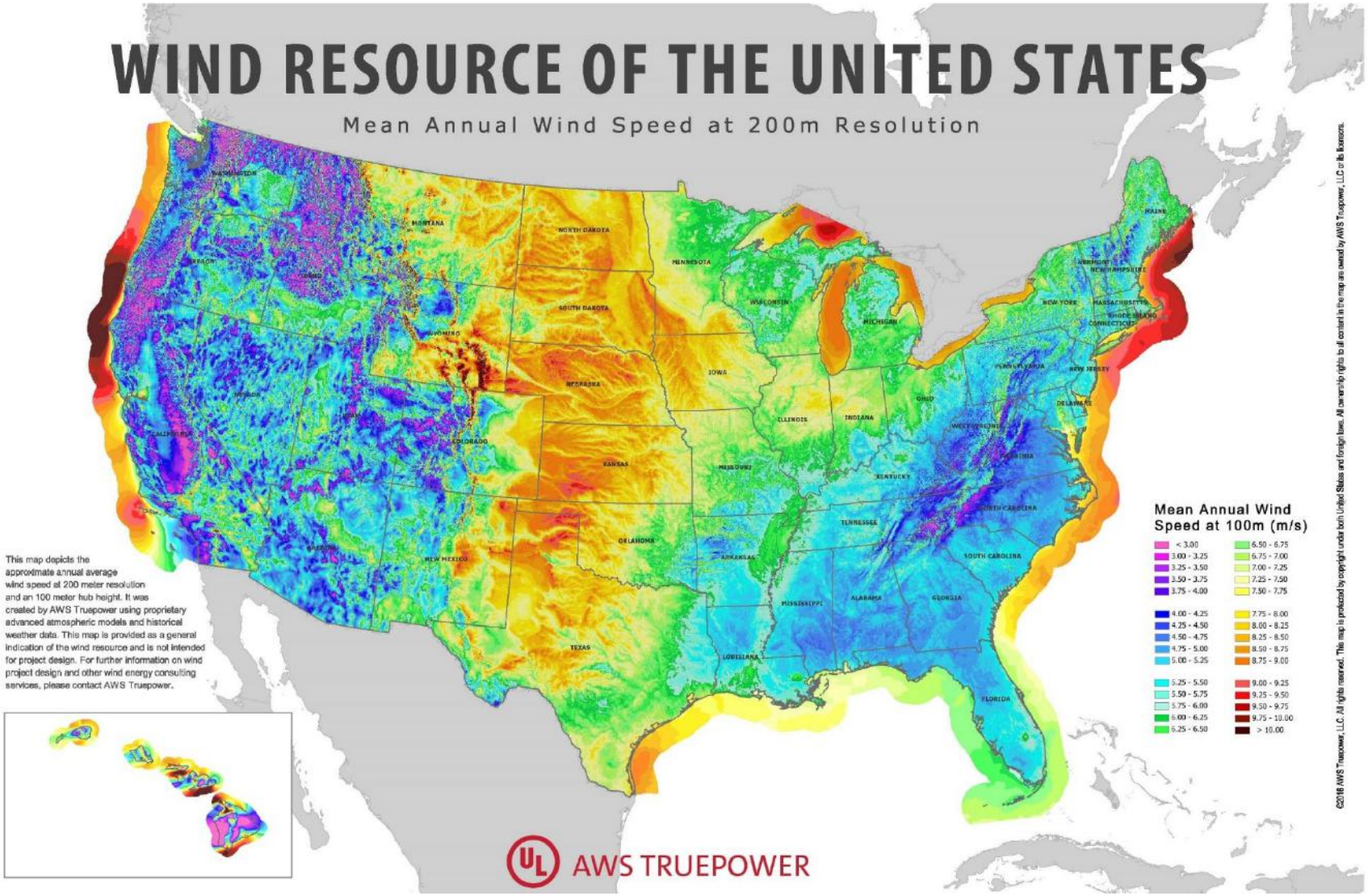


Clean Energy is a State Matter & Coasts are Green

U.S. Climate Alliance of State Governors
As of February 22, 2018, the 17 members of the Alliance made up 40.66% of the U.S. population and 46.46% of U.S. GDP. The location of these committed states are quite relevant to offshore wind.

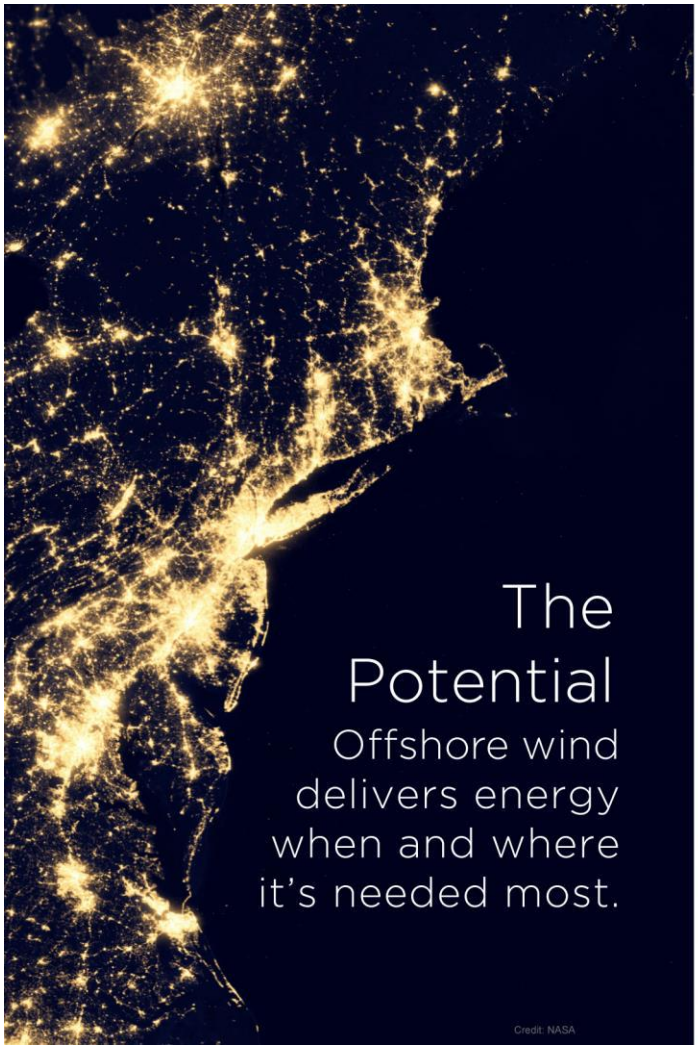
Clean Energy has become a grass-roots movement

Offshore Wind Resource > Several Times the Need

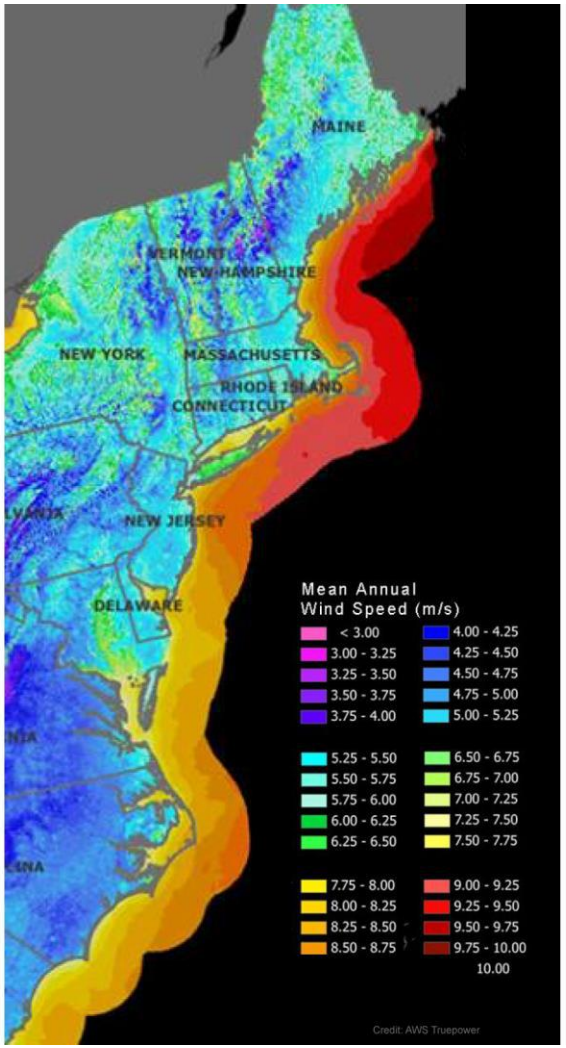


U.S. Mid to North Atlantic is a Sweet Spot for OW

Need



Resource



Feasibility

Lease Areas, Contracts, & "Commitments"

Block Island in R.I. 2016 – First U.S. Wind Farm (30 MW)

Maryland 2017 – 368 MW PPA (US Wind & DeepWater Wind)

New York 2017 – 90 MW PPA (DeepWater Wind)
2400 MW "Commitment"

Massachusetts 2018 – 800 MW PPA (Vineyard Wind)
Mandate for 2400 MW of additional OWE
Bill to increase Mandate to up to 5000 MW

Rhode Island 2018 – 400 MW PPA (DeepWater Wind)

Connecticut 2018 – 200 MW PPA (DeepWater Wind)

New Jersey 2018 – 3500 MW "Commitment"

Virginia 2018 – Exploring 5000 MW

Ørsted

U.S. Dept. of Energy Investments in OW Research

Office of Science Laboratories

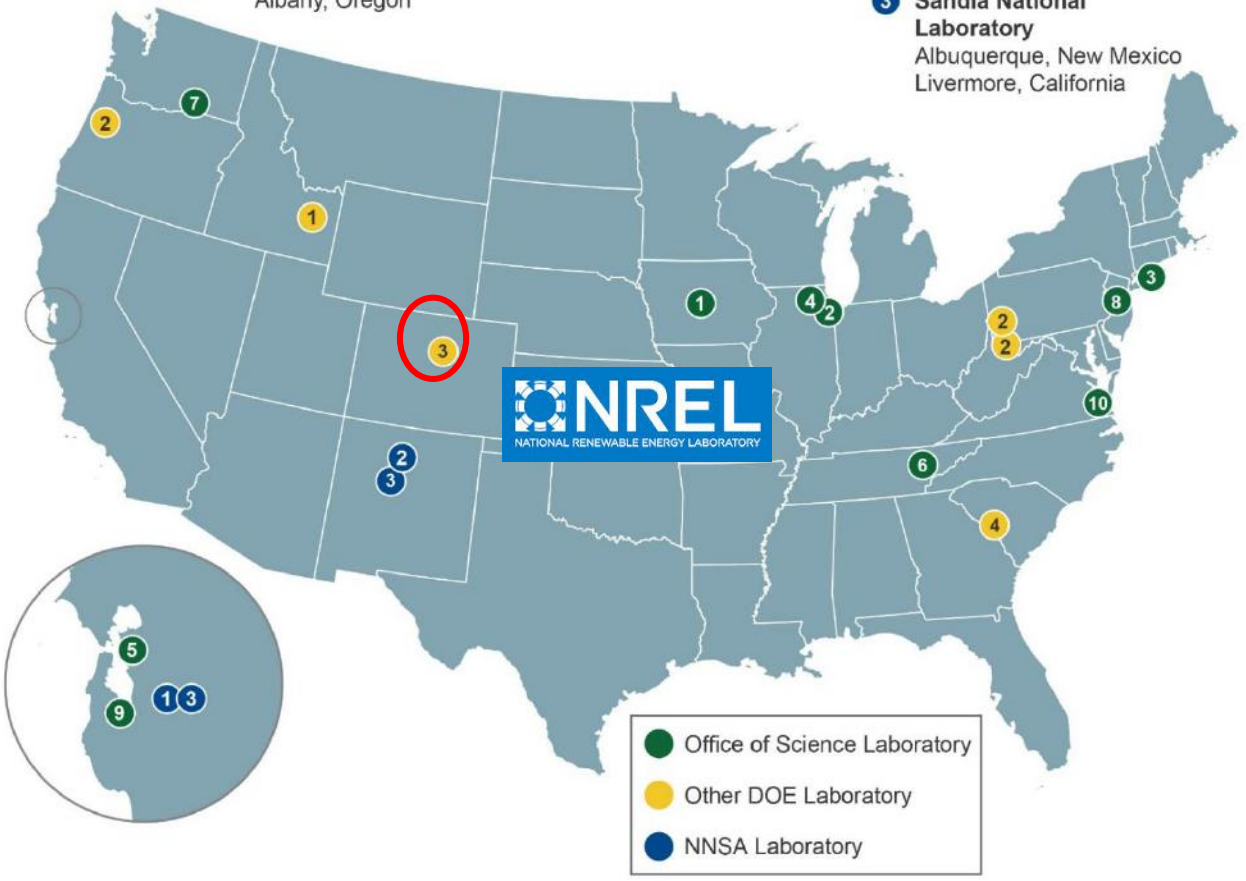
1. **Ames Laboratory**
   Ames, Iowa
2. **Argonne National Laboratory**
   Argonne, Illinois
3. **Brookhaven National Laboratory**
   Upton, New York
4. **Fermi National Accelerator Laboratory**
   Batavia, Illinois
5. **Lawrence Berkeley National Laboratory**
   Berkeley, California
6. **Oak Ridge National Laboratory**
   Oak Ridge, Tennessee
7. **Pacific Northwest National Laboratory**
   Richland, Washington
8. **Princeton Plasma Physics Laboratory**
   Princeton, New Jersey
9. **SLAC National Accelerator Laboratory**
   Menlo Park, California
10. **Thomas Jefferson National Accelerator Facility**
    Newport News, Virginia

Other DOE Laboratories

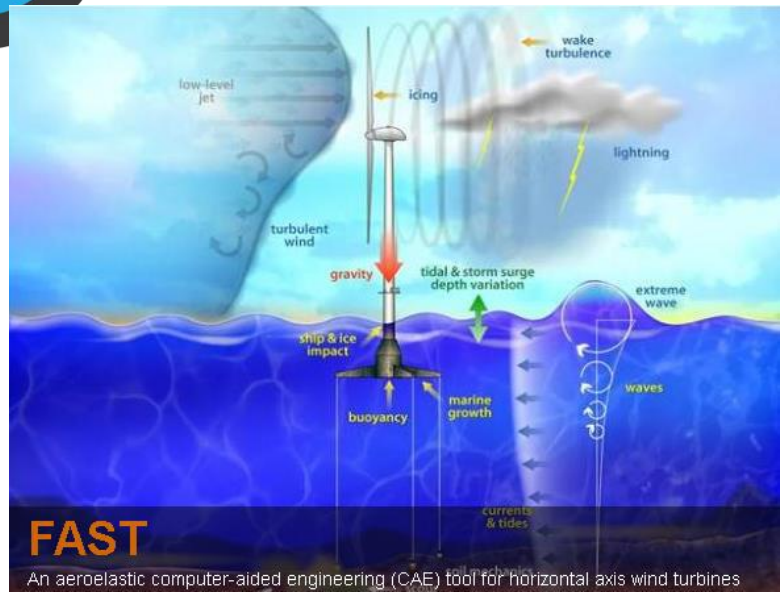
1. **Idaho National Laboratory**
   Idaho Falls, Idaho
2. **National Energy Technology Laboratory**
   Morgantown, West Virginia
   Pittsburgh, Pennsylvania
   Albany, Oregon
3. **National Renewable Energy Laboratory**
   Golden, Colorado
4. **Savannah River National Laboratory**
   Aiken, South Carolina

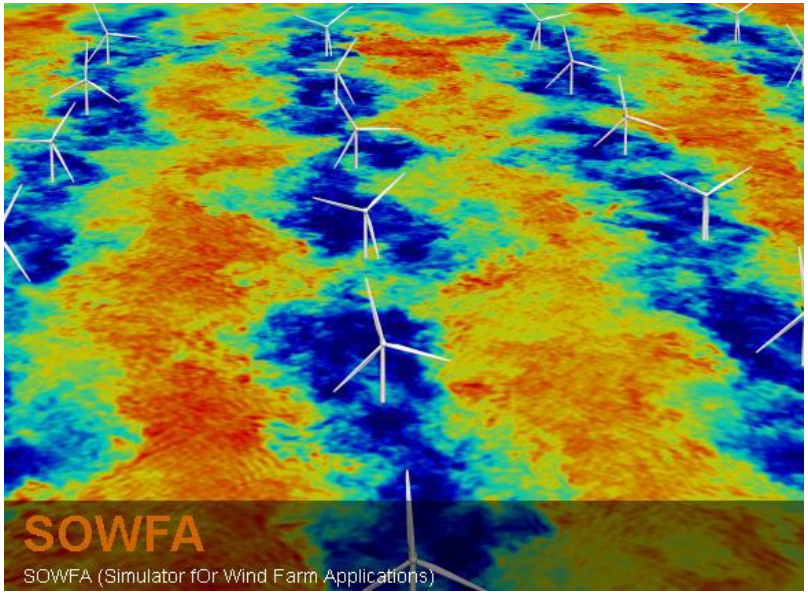
NNSA Laboratories

1. **Lawrence Livermore National Laboratory**
   Livermore, California
2. **Los Alamos National Laboratory**
   Los Alamos, New Mexico
3. **Sandia National Laboratory**
   Albuquerque, New Mexico
   Livermore, California

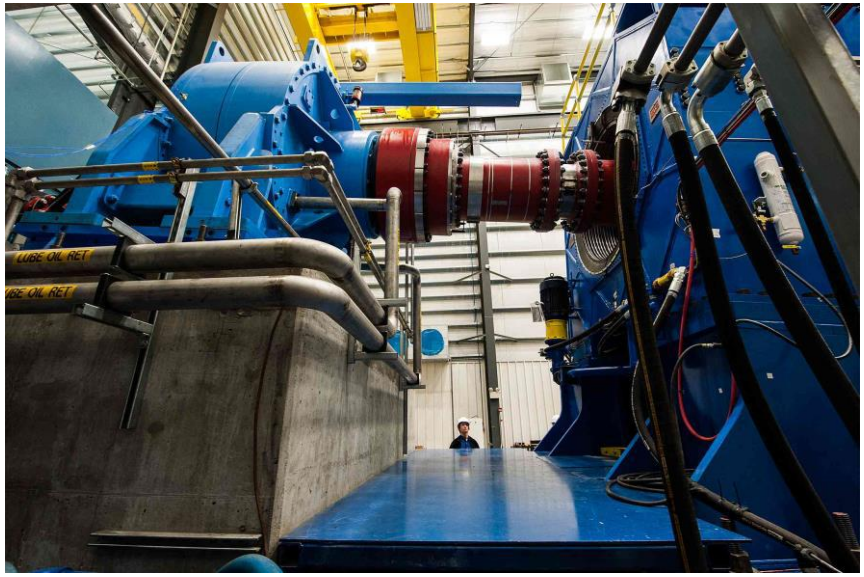


National Renewable Energy Laboratory

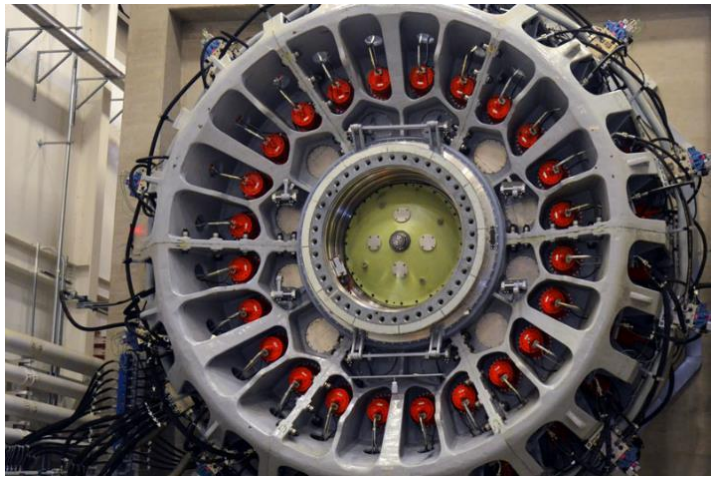




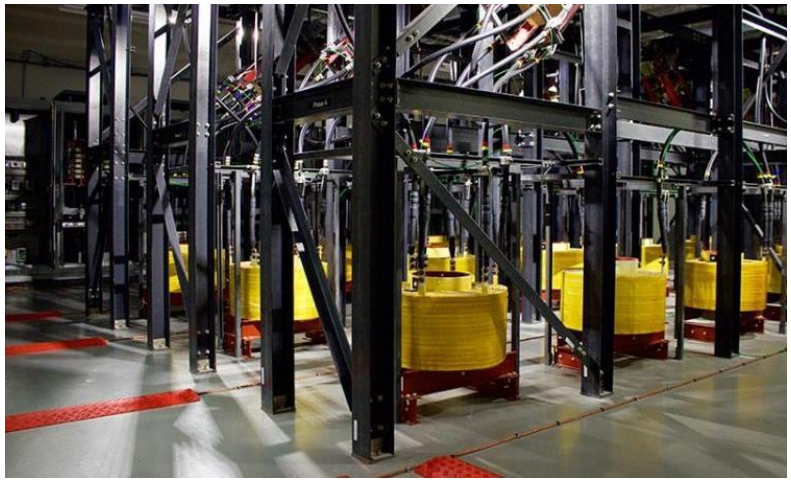
National Renewable Energy Laboratory



Clemson Drivetrain and eGRID Laboratories



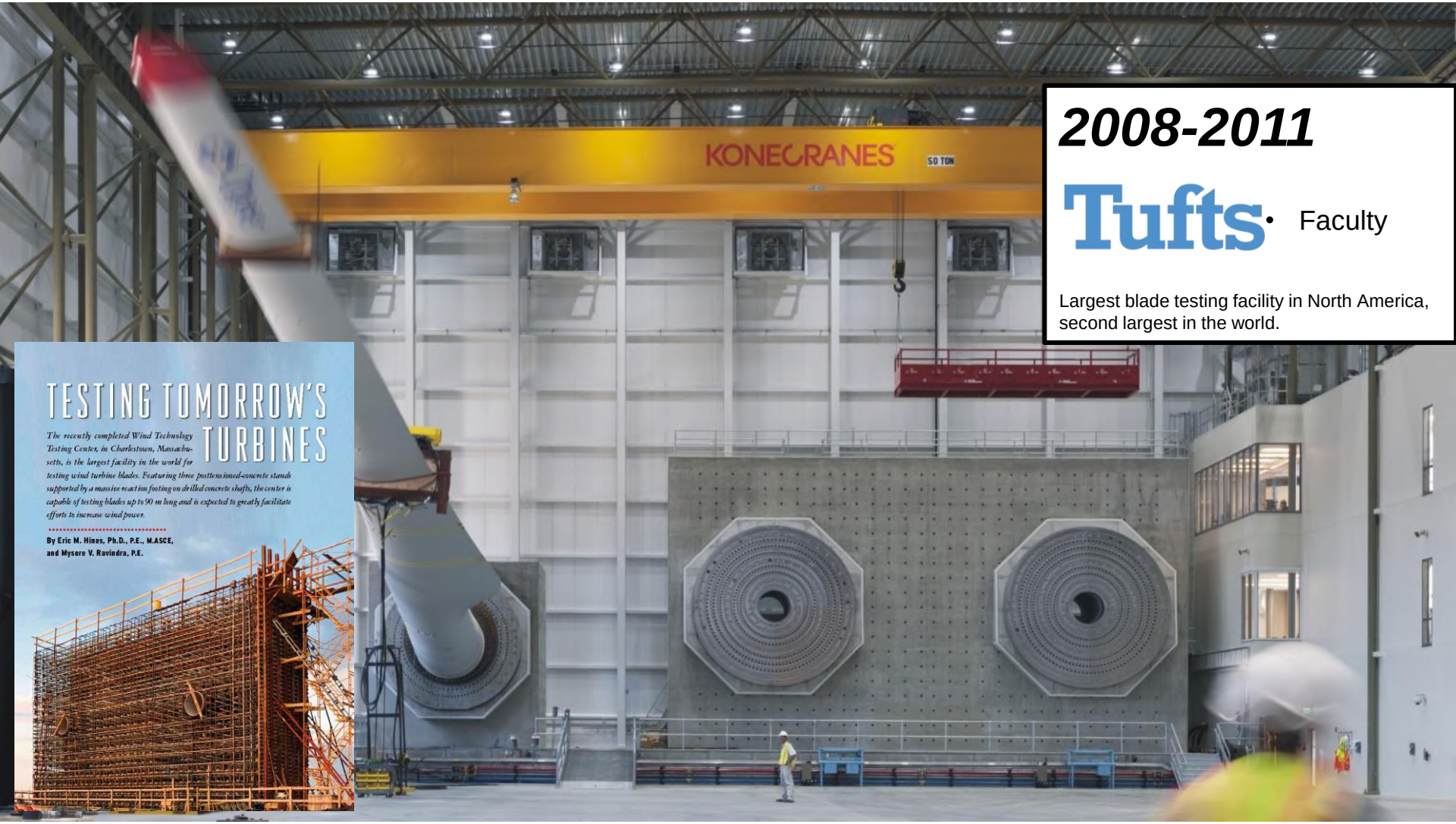
7.5 & 15 MW
Drivetrain
Testing



Duke eGRID
Simulator

CLEMSON
UNIVERSITY

Wind Technology Testing Laboratory - Boston

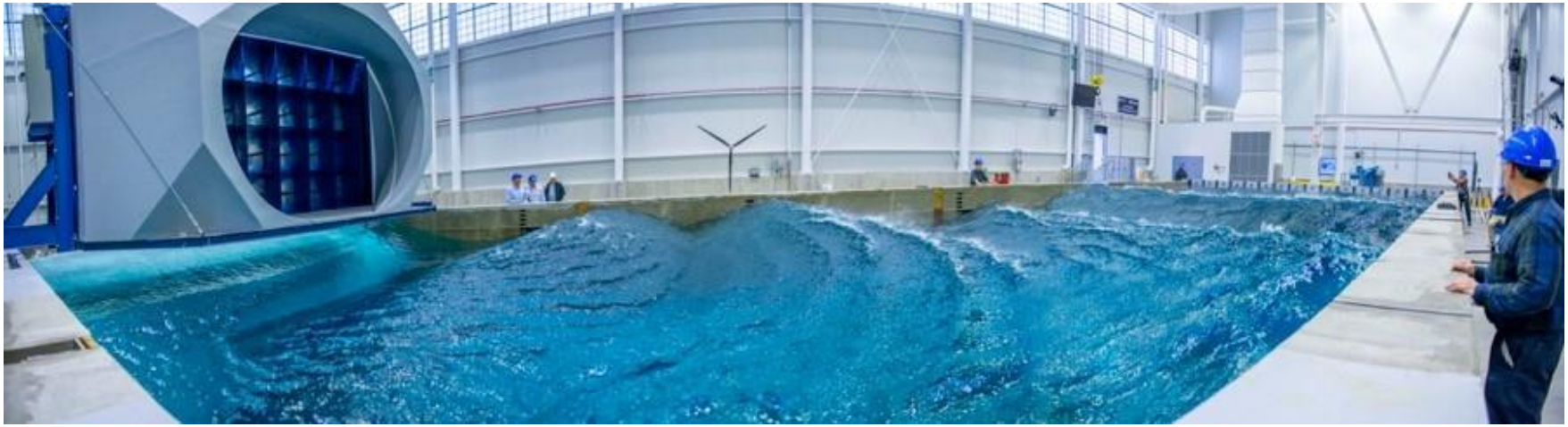


2008-2011

Tufts · Faculty

Largest blade testing facility in North America, second largest in the world.

University of Maine



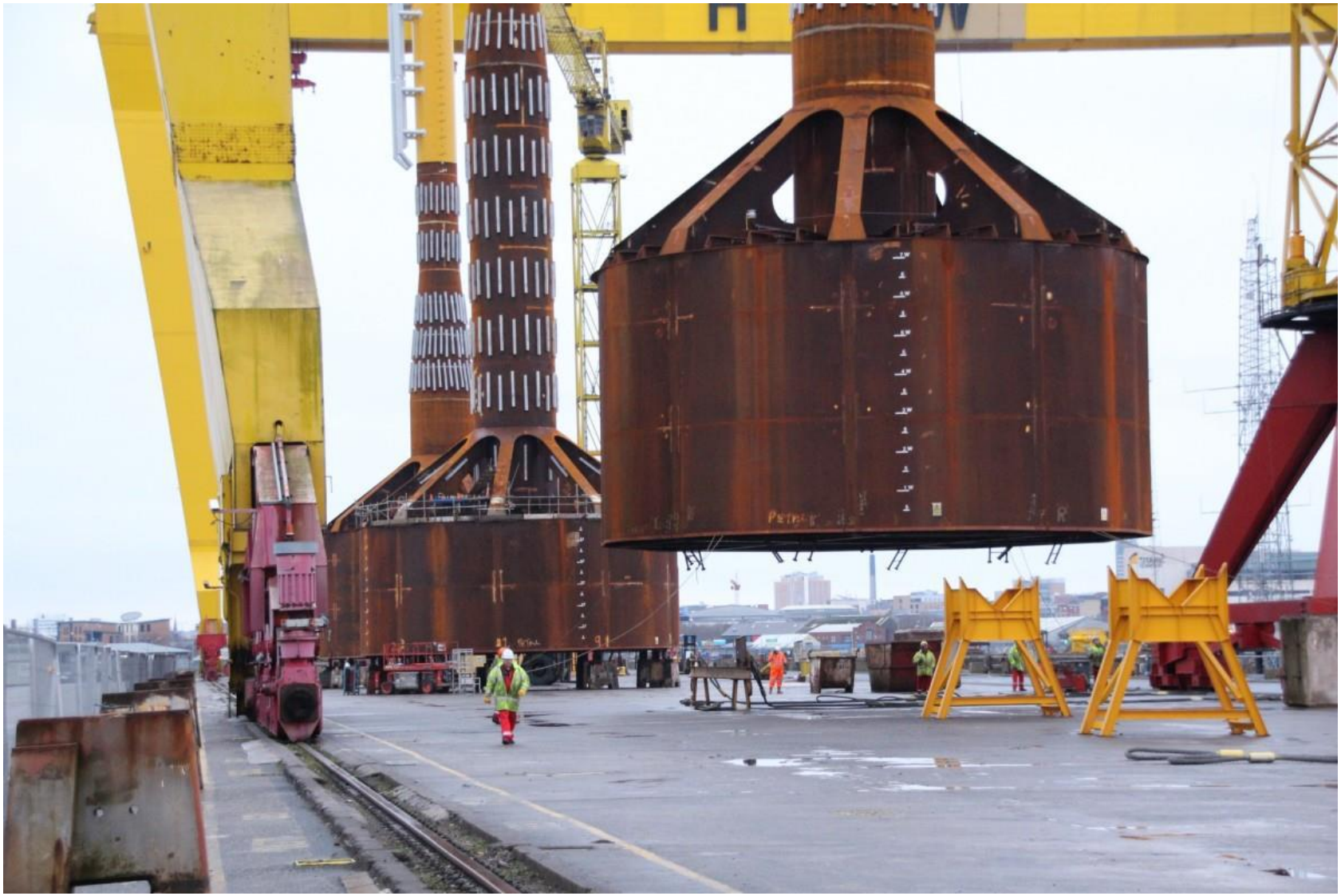
Wave-Wind Facility;
LiDAR; Floating Demo

1865 THE UNIVERSITY OF MAINE

Concrete Floating Demonstration Project

Parameter	VolturnUS 1:8	VolturnUS Full-Scale
Draft	2.9 m	20m
Hub Height	12.2 m	100m
Rotor Diameter	9.6 m	152m
Rated Power	20 kW	6MW
Peak Thrust Load	1.37kN	700kN
Hull Material	Concrete	Concrete
Tower Material	Composite	Composite
Water Depth	15-27m	100m
Number of Mooring Lines	3 x catenary chain	3 x catenary chain
Anchors	Drag Anchor	Drag Anchor

Lake Erie Mono Suction Bucket Leedco



Wind Float Principal Power

Vineyard Wind (CIP-Avangrid-Iberdrola) 800 MW

UNITED STATES

Vineyard Wind secures levelised cost of $65/MWh

2 August 2018 by Craig Richard

UNITED STATES: The 800MW Vineyard Wind project off the coast of Massachusetts will generate electricity for $65/MWh over the 20-year lifetime of the project, according to a letter recommending its approval.

Copenhagen Infrastructure Partners has been involved in a number of European offshore wind projects including Veja Mate

A 400MW first phase of the project, with an expected commissioning date of 2022, will come in at $74/MWh, a letter from the state's Department of Energy Resources (DRE) to its Department of Public Utilties revealed.

First Big U.S. Offshore Wind Farm Offers $1.4 Billion to Customers

Jim Efstathiou Jr.

Published on August 01 2018, 1:41 PM
Last Updated on August 06 2018, 1:29 AM

(Bloomberg) -- [illegible] about $1.4 billion over 20 years from the first commercial-scale offshore wind farm in the U.S.

Avangrid Inc. [illegible] Partners, joint developers of the 800-megawatt project south of Martha's Vineyard, expect to provide power and renewable energy credits [illegible] to a letter Wednesday from the state Department [illegible]

That's a levelized price in 2017 dollars over the term of the contracts, and makes the Vineyard Wind project about 18 percent cheaper than other alternatives, according to the letter. It's also lower than the wind industry expected and shows that offshore wind can be a competitive source of clean energy as costs continue to come down.

"That's pretty shocking for us," said Tom Harries, a wind analyst at Bloomberg NEF. "I think the wider industry expected much higher prices. The repercussions of this are it will probably awaken a lot of other coastal states to the value of offshore wind."

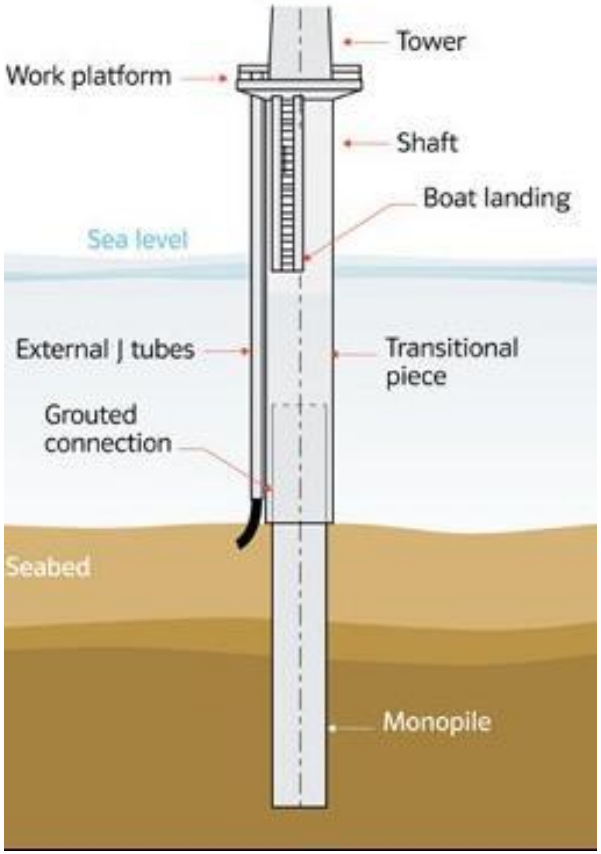
Getting Cheaper
Average cost of offshore wind in Europe

As prices continue to fall, offshore wind is expected to grow by 16 percent annually through 2030, driven by installations in the U.K., Germany, Netherlands and China, according to BNEF. The U.S. is a latecomer to the market, and early projects may cost

Updated: Application filed for Californian floating project

Siemens Gamesa receives first US offshore order

No Large Monopile Fabricators in U.S.

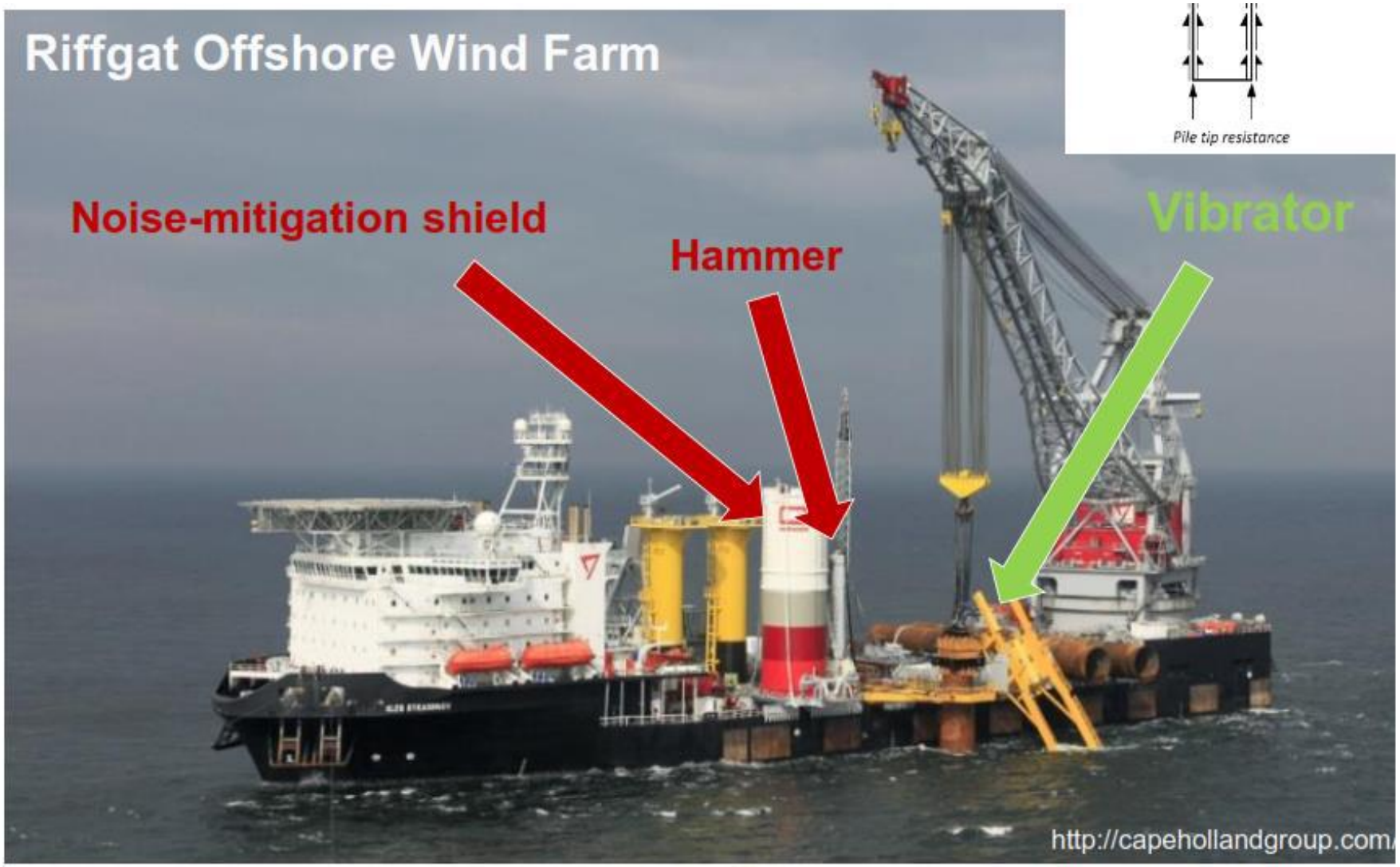


Jackets Need to be Shipped from Gulf Coast

Lack of Decent Ports in Much of East Coast

Foundation Solutions for First Projects

Monopiles and Jacket Installation Impacts



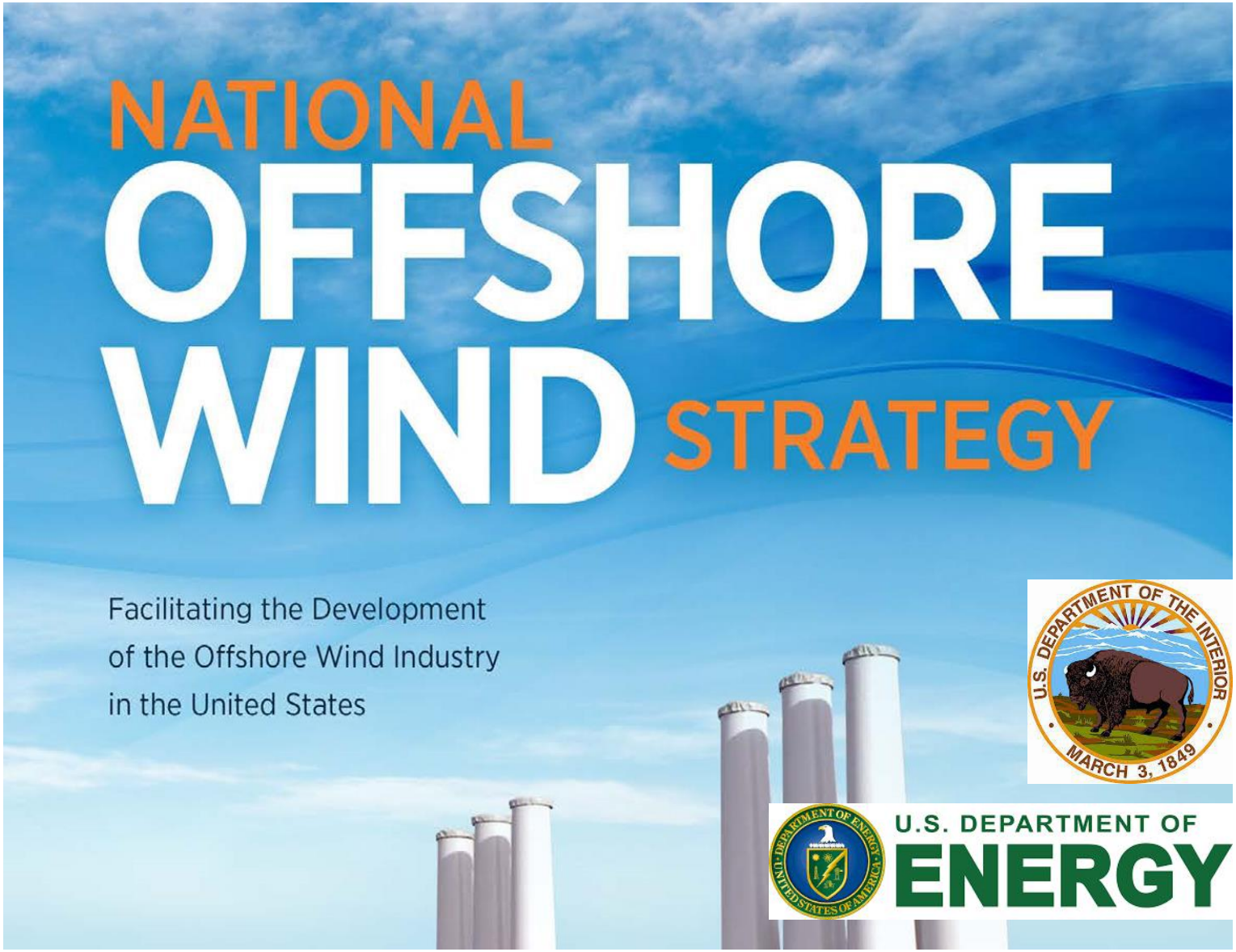
Impact Mitigation Strategies

5) DanTysk – Foundations Installation ➡ Noise mitigation

Concrete Gravity Base can be Locally Manufactured

Turbine and Blades Mounted on Hywind Spar

DOE-DOI National Offshore Wind Strategy

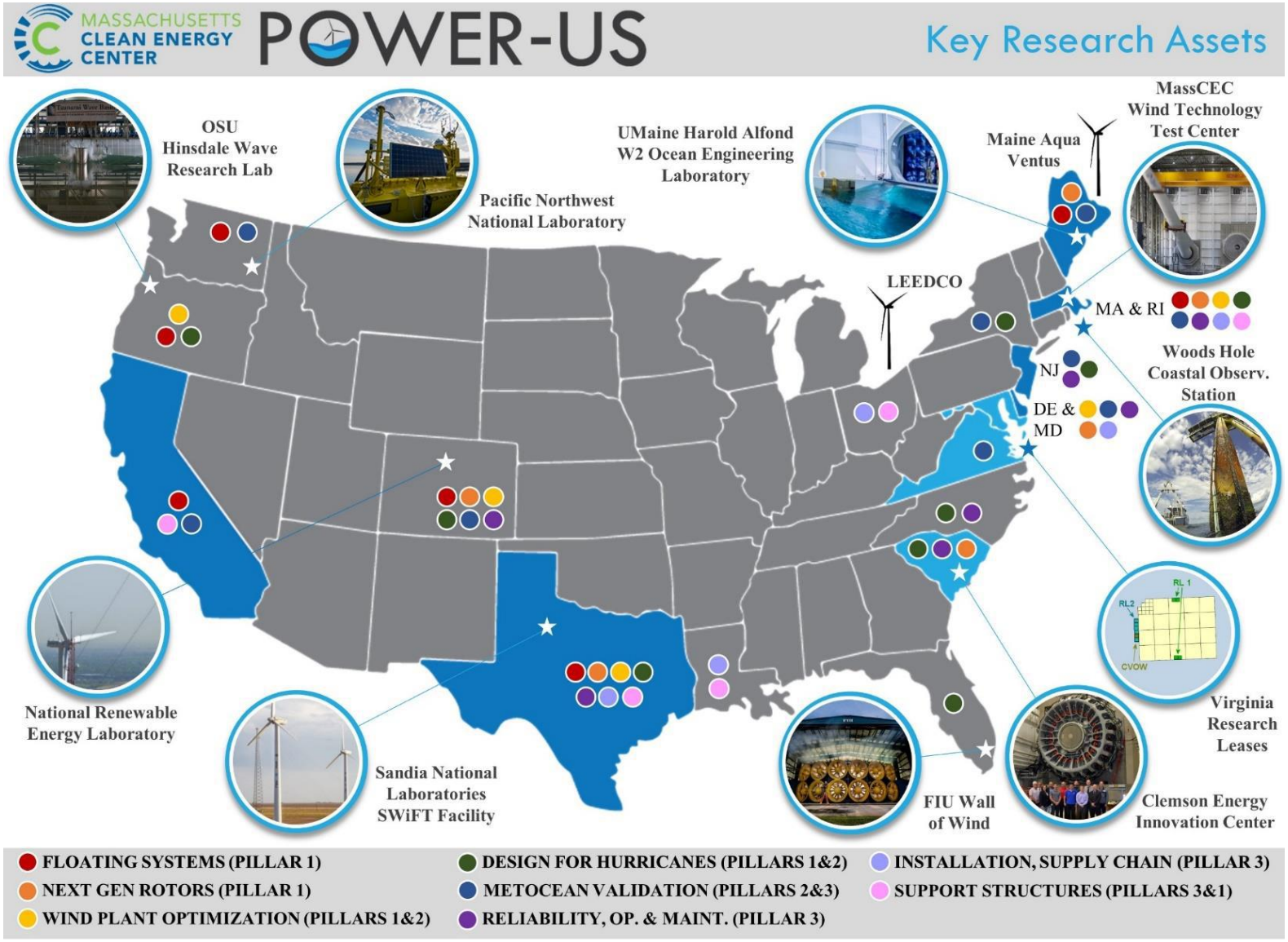


POWER-US October 2017 Meeting at NREL

POWER-US

PARTNERSHIP FOR OFFSHORE WIND ENERGY RESEARCH

Groups Represented in POWER-US



*States colored in dark blue are prospective Charter Members. Discussions are ongoing with states colored in light blue.

Network Modelled After NSF Earthquake Network

Oregon State University
http://nees.orst.edu/

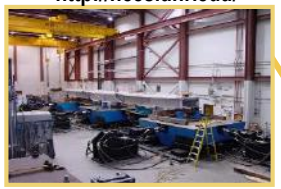
University of California, Santa Barbara
http://nees.ucsb.edu/

University of Minnesota
http://nees.umn.edu

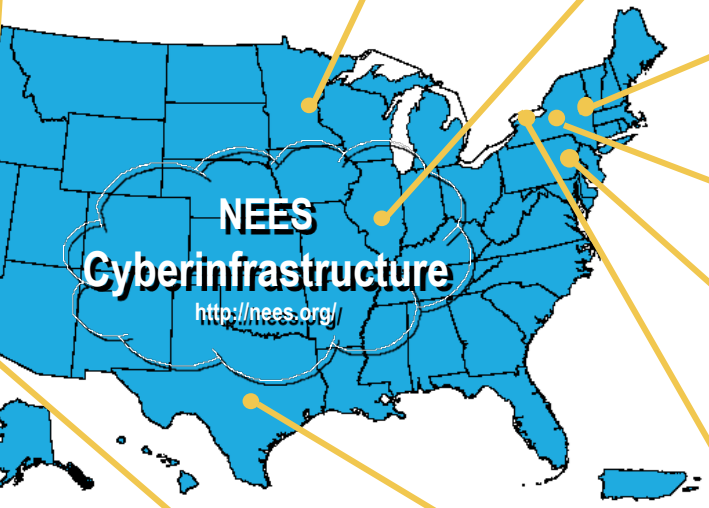
University of Illinois at
Urbana-Champaign
http://nees.illinois.edu/

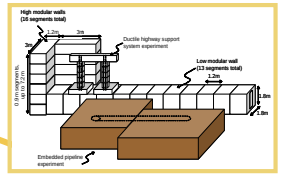
Rensselaer Polytechnic Institute
http://nees.rpi.edu/

University of Nevada, Reno
http://nees.unr.edu/



University of California, Davis
http://nees.ucdavis.edu/

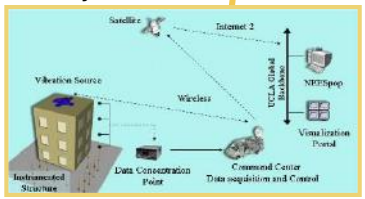




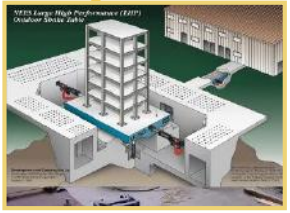
Cornell University
http://nees.cornell.edu/

University of California, Berkeley
http://nees.berkeley.edu

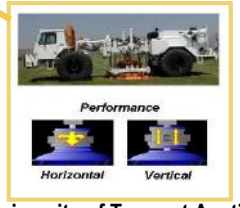
Lehigh University
http://www.nees.lehigh.edu/



University of California, Los Angeles
http://nees.ucla.edu/



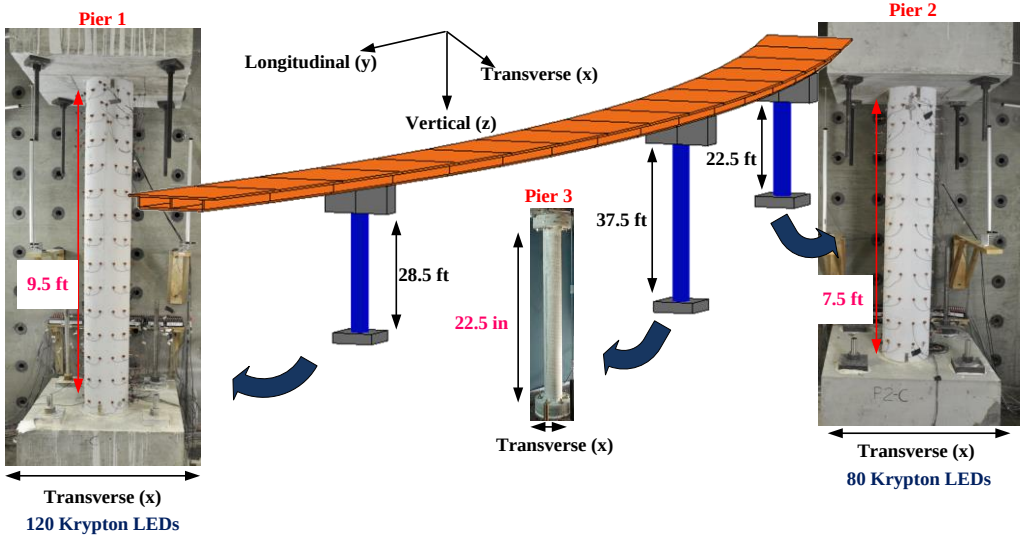
University of California, San Diego
http://nees.ucsd.edu/



University of Texas at Austin
http://nees.utexas.edu/

University at Buffalo, SUNY
http://nees.buffalo.edu/

Earthquake Network -> Performance-Based Design



POWER-US Research White Paper

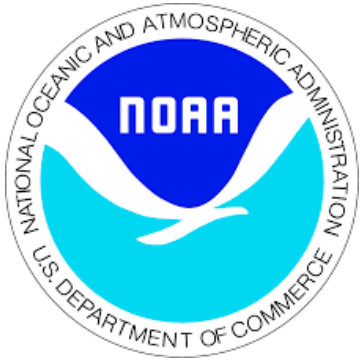
POWER-US Ocean Testbed Presentation

Woods Hole Oceanographic Institution | Tufts University | UMass Dartmouth

POWER-US Ocean Testbed Presentation

U.S. DEPARTMENT OF ENERGY

BOEM
Bureau of Ocean Energy Management



NIST
National Institute of Standards and Technology
U.S. Department of Commerce

WHAT WE DO

› Understand

⌄ Explore

⌄ Ships

› R/V *Atlantis*

⌄ R/V ***Neil Armstrong***

– Specifications

– Ship Diagrams

– Inside the Ship

– Where is the *Neil Armstrong* Now?

› R/V *Tioga*

› Marine Facilities & Operations

– Ship Schedules

– Cruise Synopsis

– Ship Tracker

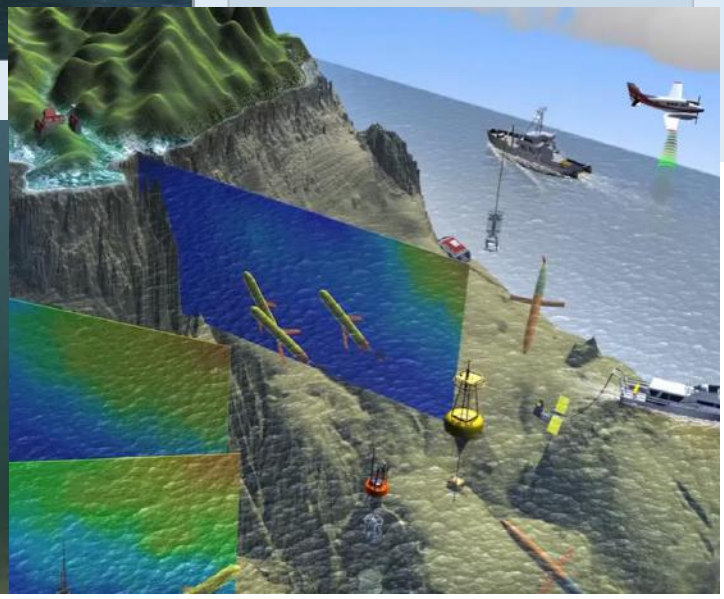
R/V *Neil Armstrong*

SHARE THIS:

Join the Celebration

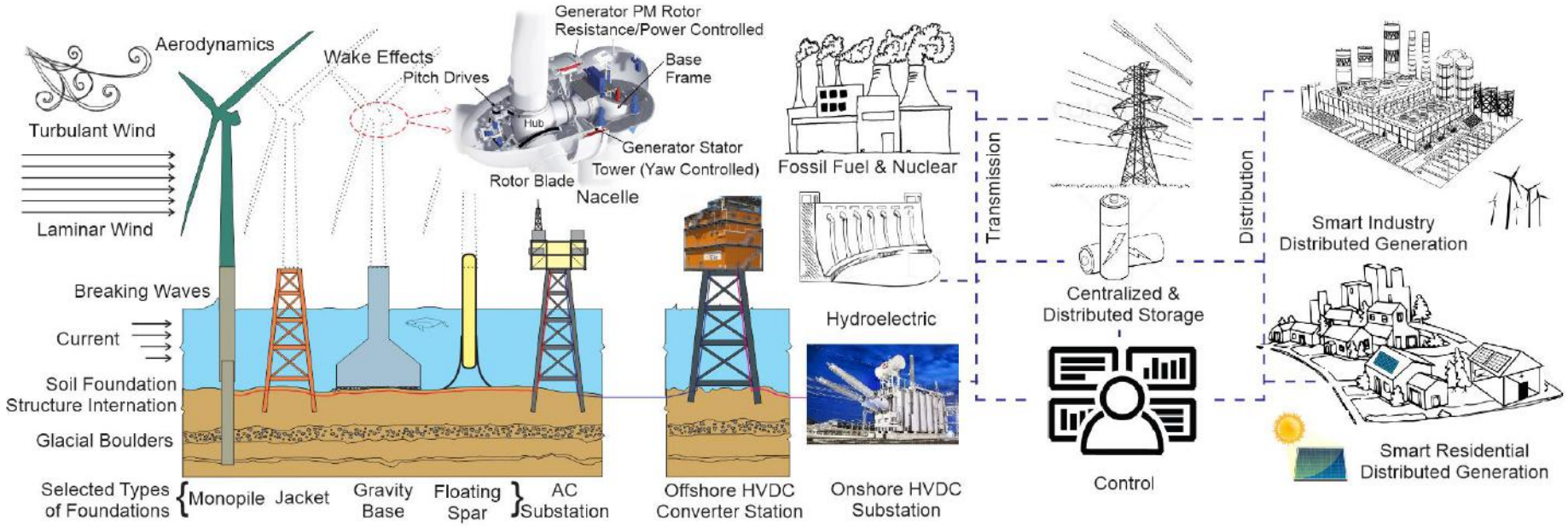
Meet the Ship on June 25!
See the ship, explore with activities, and meet researchers in this free public event.

From the Fantail
Follow R/V Neil Armstrong on its maiden voyage



NSF Engineering Research Center on OW

Offshore Wind Energy Center for Infrastructure Resilience, Control, Innovation, and Transmission (OWE-CIRCIT)



POWER-US Interagency Workshop

Presentations by Key Agencies

José Zayas *Director*
Wind and Water Power Technologies Office
Department of Energy

Barry Johnson *Acting Deputy Assistant Director*
Engineering Directorate
National Science Foundation

Rodney Cluck *Chief*
Division of Environmental Sciences
Bureau of Ocean Energy Management

Andreas Reuter *Managing Director*
Fraunhofer Institute for Wind Energy
and Energy System Technology

“Our Thinking” Where are we wrong?

1. floating foundations will be > ½ of annual installations in 10 years
2. lifespans beyond 25 years should be used for heavy infrastructure
3. large volume of development requires OW to be considered public infrastructure
4. need data-driven systems-level framework to progress design and ops of offshore wind energy plants
5. need to move from LCoE to Societal Cost of Energy (SCoE)
6. need fundamental science and public data to advance models, tools, and requirements
7. need to advance performance-based design
8. need integrated hardware-in-the-loop control across systems
9. need common open-access simulation platform