U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Offshore Wind Strategy Follow-On Analysis

Project ID #A5

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National Renewable Energy Laboratory

FY17-FY18 Wind Office Project Organization

"Enabling Wind Energy Options Nationwide"

Technology Development	Market Acceleration & Deployment
Atmosphere to Electrons	Stakeholder Engagement, Workforce Development, and Human Use Considerations
Offshore Wind	Environmental Research
Distributed Wind	**Grid Integration**
Testing Infrastructure	**Regulatory and Siting**
Standards Support and International Engagement	
Advanced Components, Reliability, and Manufacturing	

Analysis and Modeling (cross-cutting)

Project Overview

A5: Offshore Wind Strategy Follow-On Analysis

Project Summary

This project answered specific questions emerging from the 2016 Offshore Wind Strategy regarding value and innovation opportunities. Project tasks are organized into three specific categories:

1. Offshore Wind (OSW) System Benefits Analysis
2. OSW Technology Pathways and Innovation Analysis
3. Market, Risk, and Resource Analysis.

Project Objective & Impact

The primary objectives of this project are to:

- Provide enhanced characterization of non-levelized cost of energy OSW power system benefits
- Identify unique innovative cost reduction solutions and conduct analysis to assess their value and validity
- Develop advanced floating offshore wind cost modeling capabilities
- Inform key areas of persistent uncertainty in the offshore wind resource and risk

Project Attributes

Project Principal Investigator(s)

Walt Musial (Lead)
Garrett Barter
Philipp Beiter
Jessica Lau
Eric Lantz

DOE Lead

Patrick Gilman (project lead)
Alana Duerr (offshore lead)
Daniel Beals (activity lead)

Project Partners/Subs

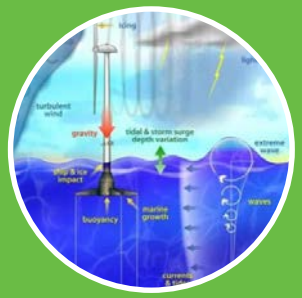
IEA Wind (Task 26 and Task 30)
BVG Associates
KIC Innoenergy

Project Duration

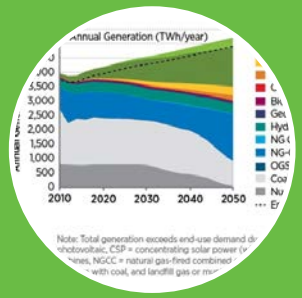
2 years: FY17 and FY18

Technical Merit and Relevance

Project Scope: Research spans turbine component modeling to system integration of offshore wind across the United States



Offshore Wind Technology Characterization



Electric Sector Modeling

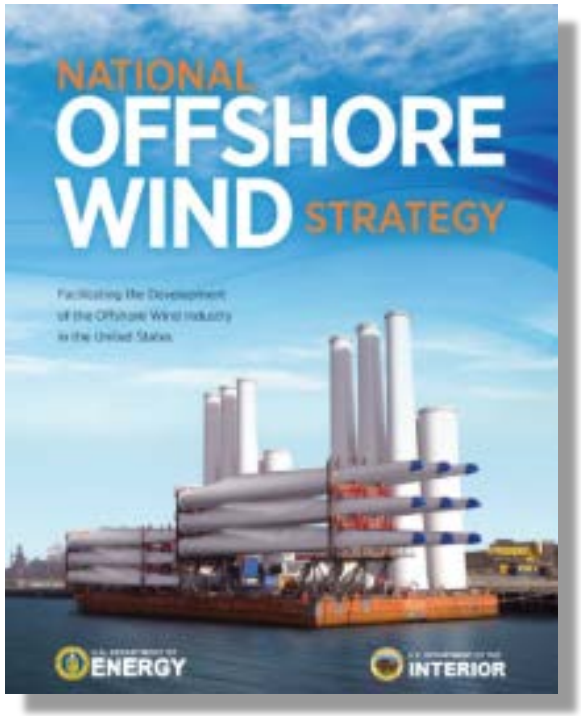
Spatial Analysis

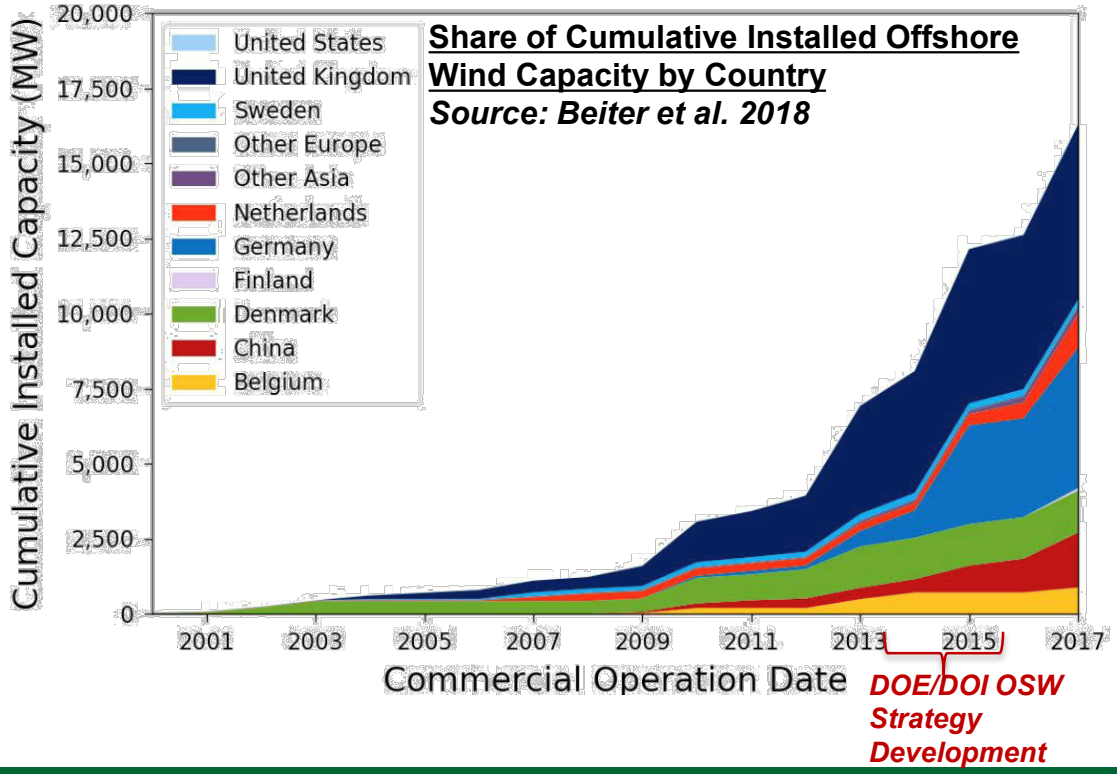
Note: While similar in scope to other analysis activities, the project was conceived as direct two-year follow-on to the DOE/DOI OSW Strategy (2016) in order to address critical persistent questions raised during the strategy development, primarily around future costs and R&D needs and system value

Technical Merit and Relevance

This project was well timed as the 2016 DOE/DOI Offshore Wind Strategy report was produced at a time of rapid change in the industry

- **Questions raised by the report:**
  - Significant uncertainties in terms of future costs and technology pathways, particularly around floating OSW
  - Persistent questions around the value of OSW to the power system beyond the first few plants and as the power system evolves (e.g., with more PV and land-based wind)





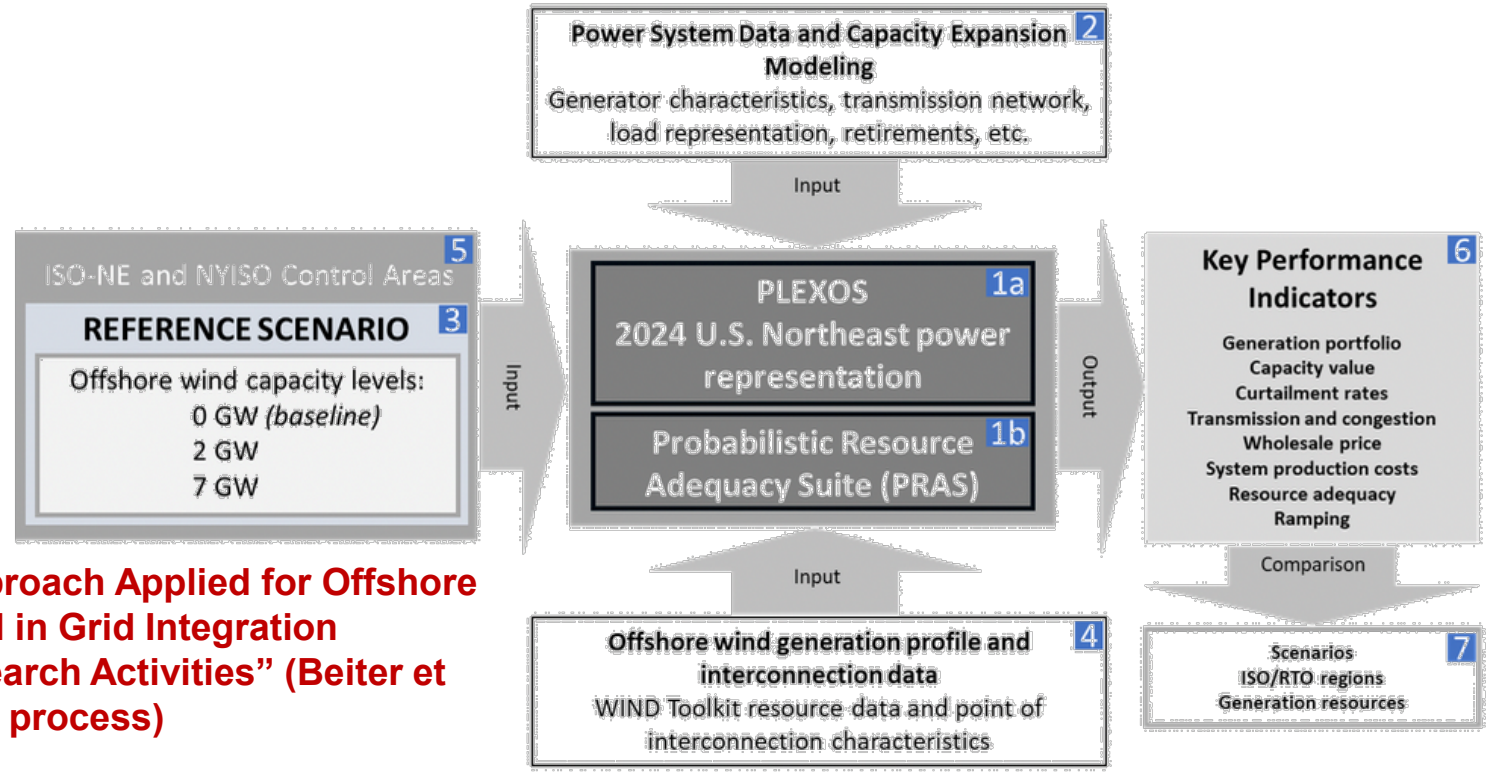
Technical Merit and Relevance

Key distinctions from other analysis projects include:

- Emphasis on **capabilities development** for understanding R&D needs and opportunities **for floating offshore wind substructures**
- Emphasis on the power system **operational impacts for offshore wind**
- Emphasis on **issues of direct relevance to offshore wind**
  - Ex: crossover points between fixed-bottom and floating substructure technology

Approach and Methodology: Deal With Near-Term Questions and Analysis Capability Gaps

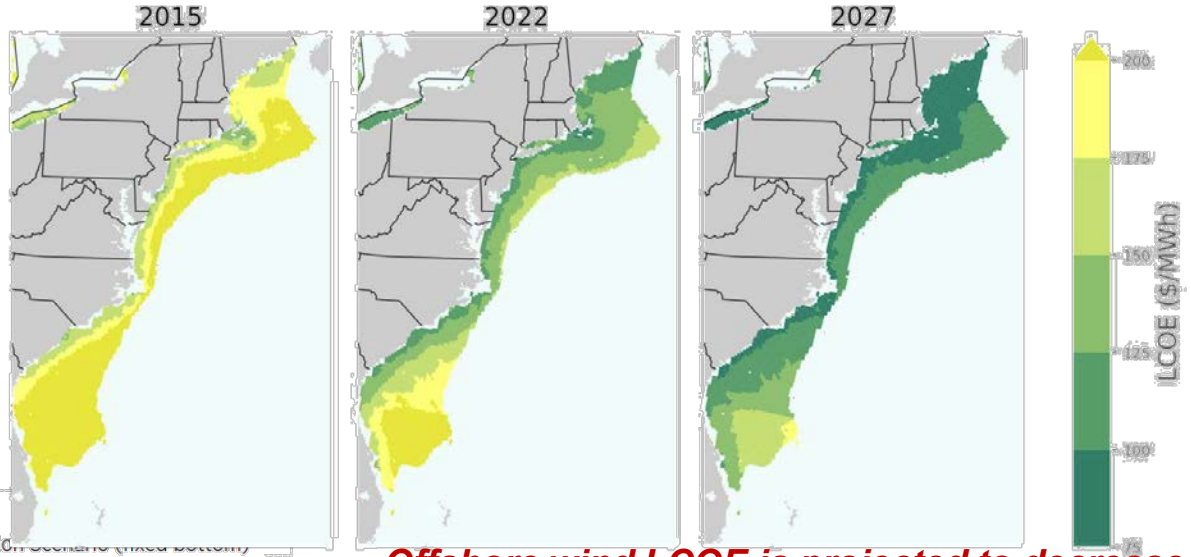
- **General approach is to deal with key near-term questions and analysis capability gaps critical to offshore wind development in the US**
- **Also produce a robust R&D program, based on NREL models, for long-term success**
  - Grid integration research (PLEXOS)
  - Systems engineering research (WISDEM)
  - Market trends and developments (Offshore Wind Tech Market Report)
    - Maintains an empirical baseline of offshore wind technology as a yardstick for R&D progress



"Approach Applied for Offshore Wind in Grid Integration Research Activities" (Beiter et al. in process)

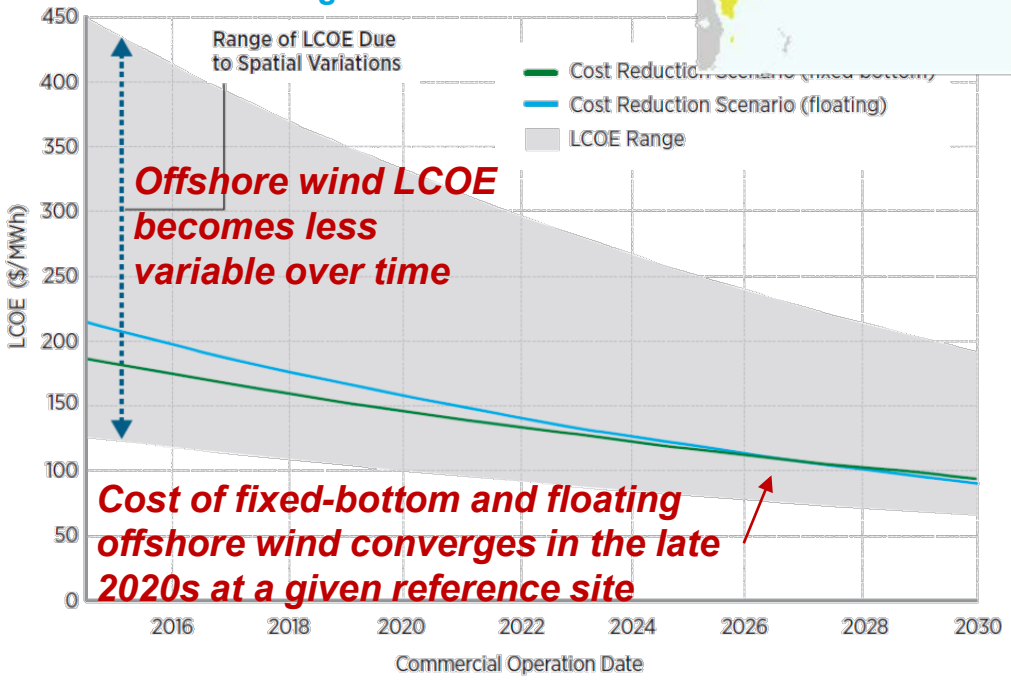
Accomplishments and Progress: Economic Potential of Offshore Wind

US Atlantic offshore wind LCOE 2015-2027



Offshore wind LCOE is projected to decrease over time in most offshore U.S. locations

LCOE for U.S. offshore wind across all sites through 2030

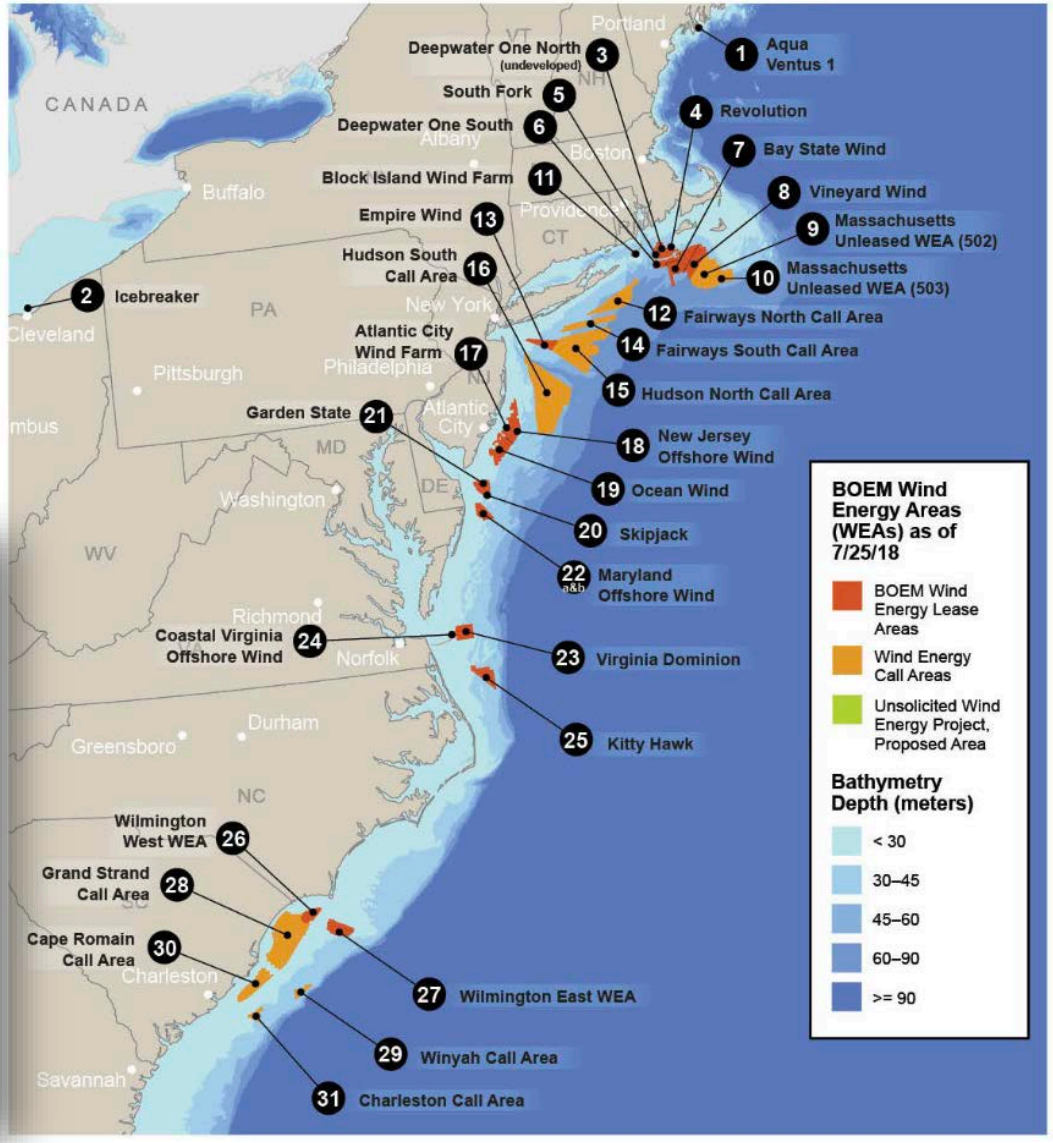


Beiter et al. (2017) captured the economic potential of offshore wind across all U.S. resource sites and from 2015 to 2030

Accomplishments and Progress: Annual US Offshore Market Report

The project produces an Annual Offshore Wind Market Report that

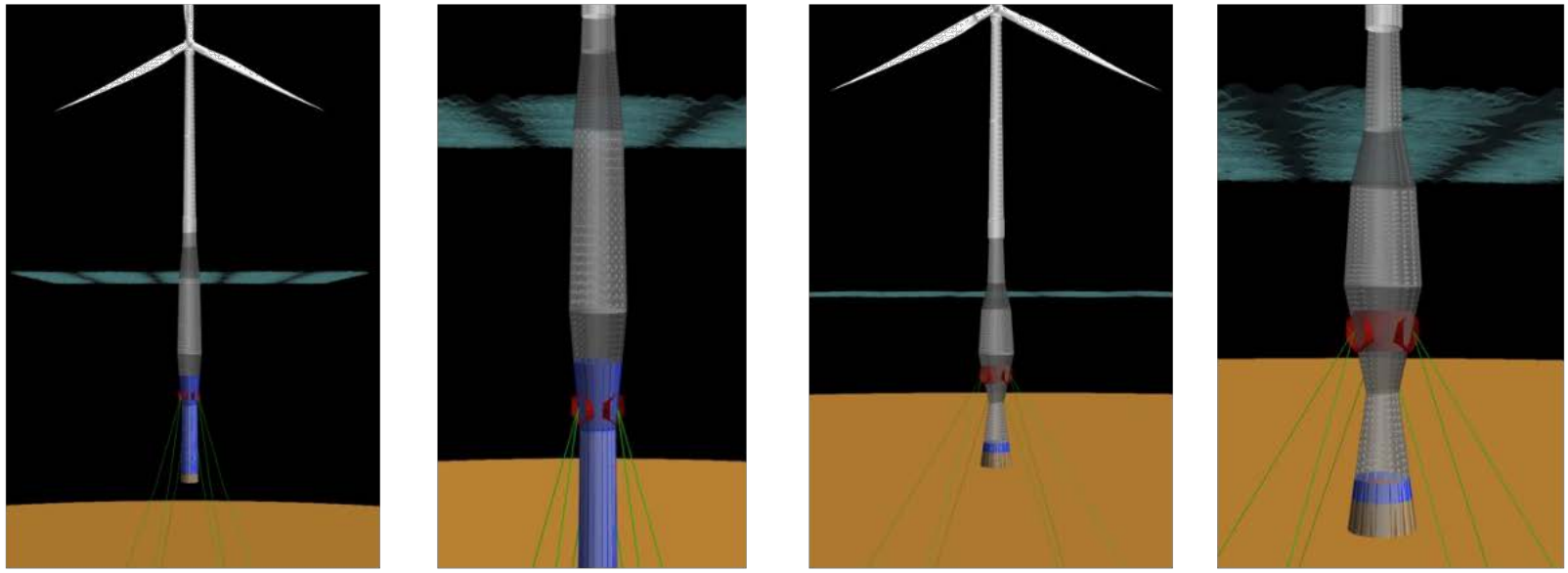
- Captures key trends in technology, markets, pricing, and innovation
- Maintains an empirical baseline by which to measure technology and industry progress



Key Point

Accomplishments and Progress: Floating Offshore Wind Technology Pathways

Spar Designs for 10-MW (DTU) Reference Turbine



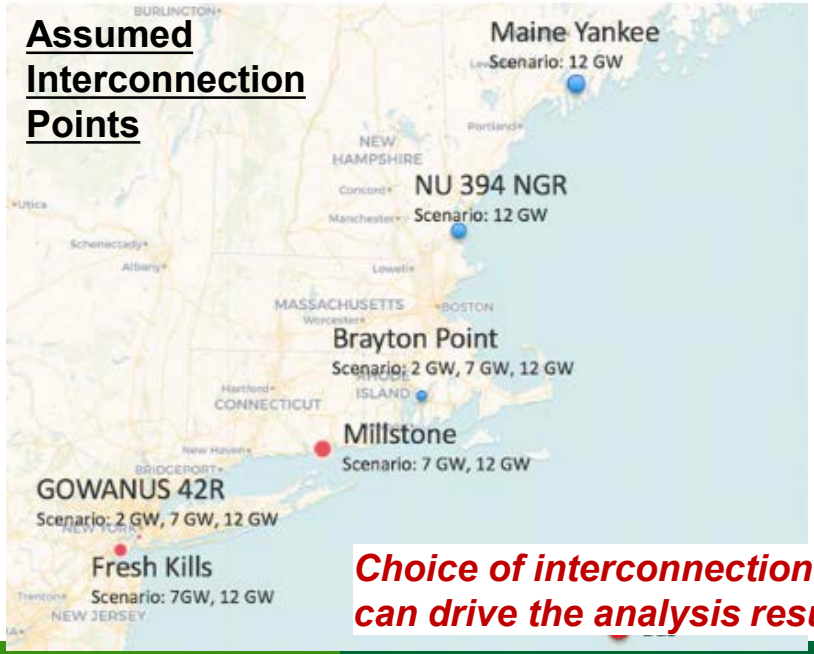
(a) Mass-optimized (b) Mass-optimized (c) Cost-optimized (d) Cost-optimized

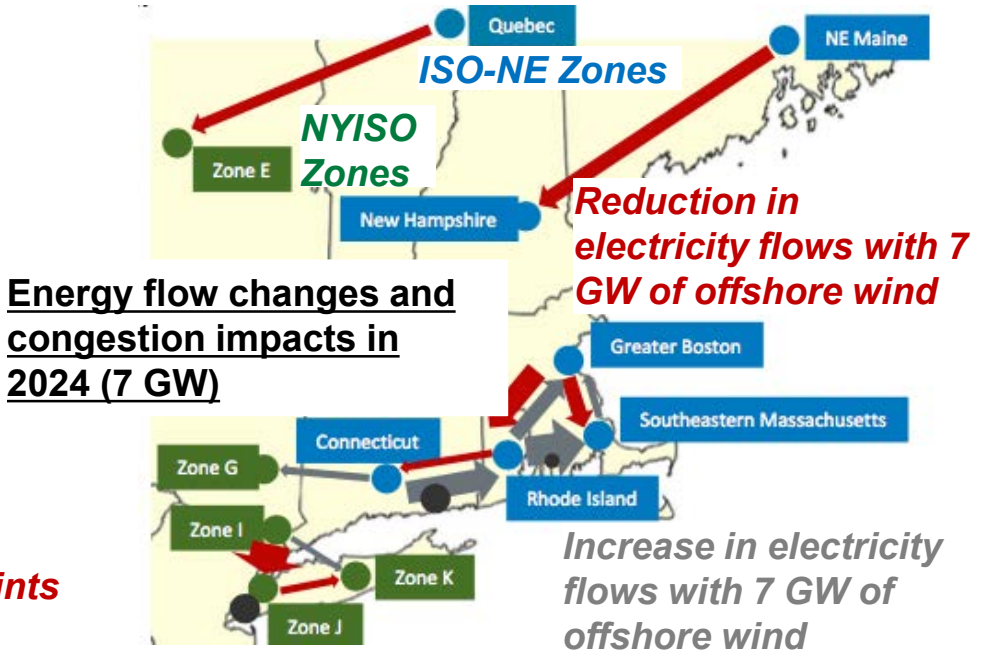
- New capabilities focused on floating substructures are in development and emerging within the WISDEM toolset
- To date, full turbine and substructure optimization with hydrostatic loads is feasible
- Future work will capture the dynamic environment, critical to market validity and ultimate characterization of R&D needs
- Enables identification of technology pathways for system cost reduction, cost-benefit tradeoff studies, and system sensitivities
- Journal submission (Barter et al. in process)

Accomplishments and Progress: Is there unique impact of offshore wind to ISO-NE & NYISO?

Beiter et al. (in process), characterizes the impacts and value of offshore wind in the ISO New England (ISO-NE) and New York ISO (NYISO) power systems in the mid 2020s:

- The Northeast power system can reliably accommodate 2–7 GW of offshore wind capacity, with offshore wind curtailment levels of 4%–5%
  - Increases system-wide congestion hours with varying sub-regional impact
- Thermal generation, primarily from natural gas combined cycle, decreases when high levels of offshore wind are added, but flexibility requirements increase
- Beyond energy impacts, offshore wind can also contribute to reliability, which is dependent on interconnection locations and transmission constraints





Accomplishments and Progress: Thought Leadership and Impact on National and State Offshore Wind Growth

- Provision of expert input into BOEM lease area designation
- Provision of expert input to MassCEC RFP development and design
- Provision of expert input to California PUC around offshore wind opportunities in California
- Developed economic analysis and resource characterization focused on opportunities for offshore wind in Maine
- Organizational input and leadership in offshore wind conferences (AWEA, New Energy Update and the Business Network For Offshore Wind)

Milestones and Schedule: FY17-FY18

- **Formal milestones listed in narrative summary of project—not repeated here**
  - Reflect formal annual operating plans (AOPs)
- **In practice, this project tends to complete 5–7 deliverables per year (internal and external) beyond formal milestones**
  - Sometimes replanned or prioritized, depending on case-specific circumstances
- **Grid study faced extended delays (1 year) due to the structure of the modeling effort**
  - To enable a more robust analysis and substantially reduce costs, we took the opportunity to leverage a multiyear grid modeling effort for our offshore grid study
  - Unfortunately, that larger modeling effort was delayed by a year due to factors beyond our control, and so our analysis was delayed as well

Go/no-go decision points

- **FY17 – Proceed with REPRA and PLEXOS modeling for one regional limited offshore wind scenario?: Go**
- **FY18 – Proceed with expanding grid modeling analysis to an additional region (Task 1) dependent upon successful model calibration and runs of Seams Interconnection model for ISO-NE and NYISO service territories?: Go**

Communication, Coordination, Commercialization

[see: https://www.nrel.gov/research/publications.html]

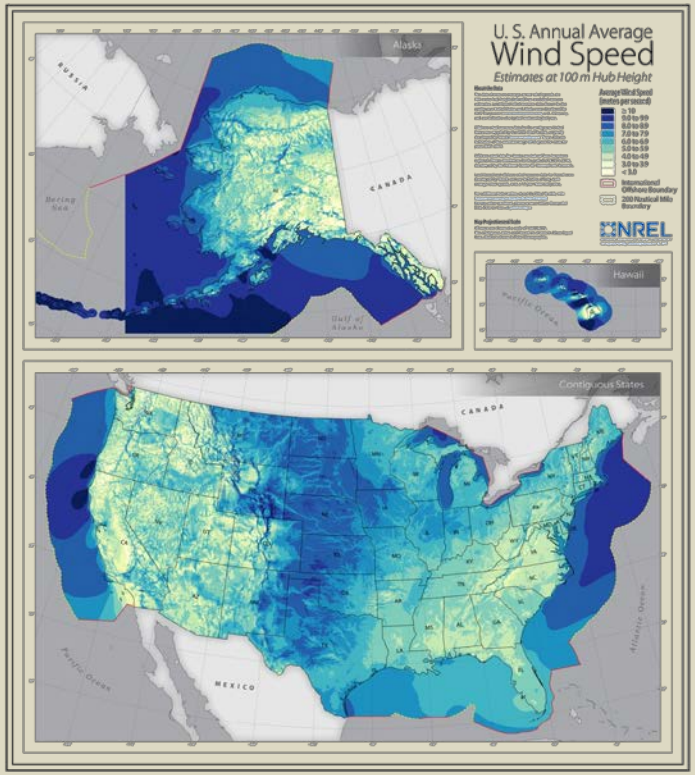
- Tight coordination and collaboration with other labs (including LBNL), international community via IEA Wind, consultancies, and wind industry

- *With total spending over this period at about $2.0M, the average cost per publication is approximately $220k*

Upcoming Project Activities

- **With 2+ years since the DOE/DOI 2016 OSW Strategy report, this project has been merged back with other core analysis projects**
- **Current offshore activities include:**
  - Offshore balance of station and operational cost models
  - Scaling impacts
  - Spatial sensitivity analysis
  - 15-MW offshore reference turbine

- **Core capabilities in floating systems engineering are being considered under technology & development investments through the "lab call" process**



3–5 year goal: optimize wind plants at every resource pixel**, considering logistics, siting, and permitting challenges **across an array of R&D pathways