U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2021 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
WIND ENERGY TECHNOLOGIES OFFICE

Program Area Presentation:
Technology Research, Development, and Testing

Mike Derby, Program Manager

August 2-5, 2021

FY21 Peer Review - Program Overview

Program Summary: Technology Research, Development, and Testing

Optimize wind plant cost of energy reduction through complex aerodynamics R&D, advanced component development, wind plant reliability improvement and resource characterization. Significant advances are required across multiple domains to enable required cost reductions:

- Master the physics of wind flow
- Enable further scaling of the largest, most flexible rotating machines ever built
- Optimize and control wind plants made up of hundreds of individual generators to supply and support the electric grid
- Continue aggressive cost-reduction for all technologies
- Enable supersized, lightweight wind turbines

Directed lab research, competitive awards, collaboration with Federal partners and industry, communication with stakeholders

Program Objective(s) 2019-2020:

- LBW – Tall Wind: large rotors, lightweight generators, plant optimization
- OSW – Addressing U.S. unique challenges – deep water, resource characterization
- DW - Facilitate adoption at local levels through technology innovation, controls, and standardization

Overall Program Objectives (life of program):

- Advance scientific knowledge and technological innovation to enable clean, low-cost wind energy options nationwide

FY19 - FY20 Budget Under Review (Labs): $80.7

FOA Project Budget: $507.8M

- Total DOE: $120.7M
- Total Cost Share: $306.7M

Current budget (FY21): $82,585,078 (FY21BU $44,786,520)

Number of projects under peer review: 37

Total number of current projects: 90

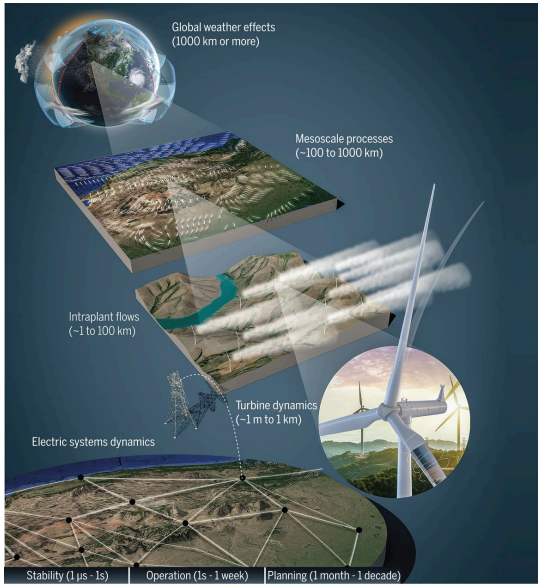


ILLUSTRATION: JOSH BAUER AND BESIKI KAZAISHVILI, NREL

How We Organize Our Work: Crosscuts

Clean, low-cost wind energy options nationwide .....

	Land-Based Wind	Offshore Wind	Distributed Wind
Technology Research, Development and Testing	Atmospheric Science & Wind Plant Systems Engineering	Atmospheric Science & Wind Plant Systems Engineering	Atmospheric Science
	Standards and Certification	Standards and Certification	Standards and Certification
	Technology Innovation	Technology Innovation	Technology Innovation
	World Class Testing Facilities	World Class Testing Facilities	
	Tech to Market Commercialization	Tech to Market Commercialization	
	Integrated Systems Design	Integrated Systems Design	
		Offshore Specific R&D	
		Advanced Technology Demo Projects	

How We Organize Our Work: Activity Areas

Atmosphere to Electrons

- Provide a better physical understanding of the atmospheric boundary layer interaction with wind plants and develop new plant technologies that maximize energy capture, resource **predictability** and optimize cost performance
  - Atmospheric Science
  - Wind Plant Flow Physics
  - Wind Plant Controls
  - Wind Plant Systems Engineering

Offshore-Specific R&D

- Research specific to offshore wind technologies and systems
  - Offshore Atmospheric Science & Resource Characterization
  - Generator Light-weighting
  - National Offshore Wind R&D Consortium
  - Floating Platform Technology Development.
  - Advancement of Resource and Environmental **Measurement** Technologies

Offshore Wind Demonstrations

- Demonstration projects facilitating a competitive U.S. industry through the development and demonstration of innovative technologies with the potential to lower the cost of energy
  - LEEDCo IceBreaker Wind
  - UMaine Aqua Ventus 1

How We Organize Our Work: Activity Areas

Distributed Wind

- **Facilitate adoption at local levels through technology interfaces, controls, and standardization**
  - Hybrid/microgrid system integration and controls
  - Packaged hybrid systems (wind + solar, storage, other distributed energy resources)
  - Turbine cost reduction (kW scale)
  - Affordable, accurate resource assessment
  - Reduce balance of station costs
  - Address barriers to adoption via standardization and best practices.

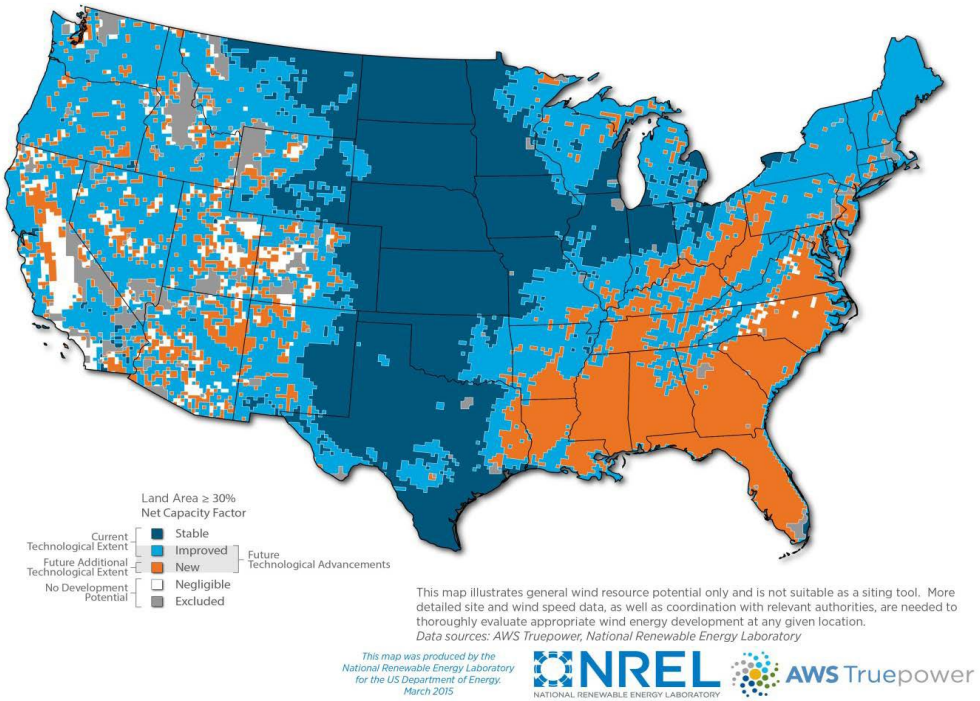
Materials and Manufacturing

- **Advances in component design, reliability, materials, and manufacturing**
  - Blade & Drivetrain Reliability
  - Additive Manufacturing
  - Low cost high performance materials
  - Big Adaptive Rotor

Program Impact: Enabling Wind Nationwide

The combined land-based and offshore domestic wind resource potential is more than 10 times greater than the total U.S. electricity demand

- Untapped Wind Market Potential in All 50 States: Land-based utility-scale wind (LBW), Offshore wind (OSW) and Land-based distributed-scale wind
- Barriers: Wind Turbine Design, Reliability, Wind plant optimization, Cost reduction, Grid integration, and Mitigation of environmental impacts and human use impacts such as radar interference.



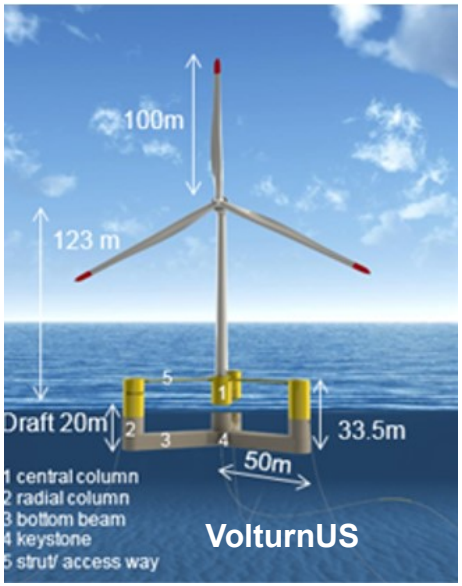
Land area achieving a minimum 30% net capacity factor, based on current technology, increased rotor diameter and a 140-m hub height. Areas of expanded access to wind power are highlighted in orange.

Program Accomplishments & Progress

Offshore Wind Demonstration:

Demonstration projects facilitating a competitive U.S. industry through the development and demonstration of innovative technologies with the potential to lower the cost of energy

- UMaine - Significant progress in the development, siting, and future deployment of a single, floating concrete platform, 10+MW full-scale offshore wind turbine in the Northeast US (off Monhegan Island) in FY-23

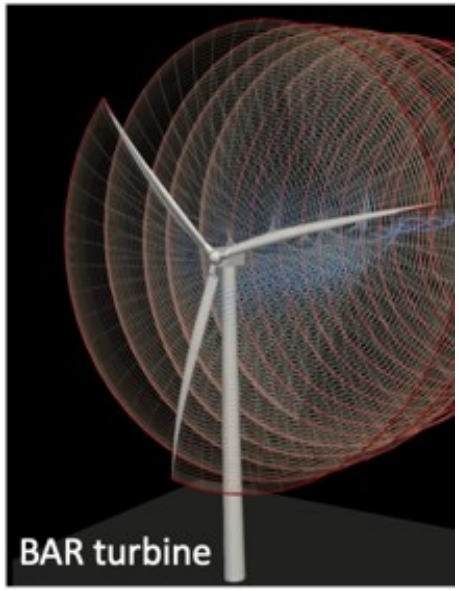


Materials & Manufacturing:

Advances in component design, reliability, materials, and manufacturing to lower the overall cost of energy and accelerate innovative technology deployment both on and offshore.

- BAR - Completed Phase I of the Big Adaptive Rotor project with the assessment of over 20 innovative concepts and advanced design modeling tools that overcome rail transportation limitations.
- Carbon Fiber Design - Performed initial analysis and analytical modelling work for assessing compressive performance for different carbon fiber shapes and sizes leading to superior mechanical properties and fatigue resistance of carbon fiber vs glass.
- Fusion Welding Composites – Successfully demonstrated a method to protect highly susceptible fusion-joined thermoplastic blade from lightning damage.
- 3-D Printed Core Structures – Established the baseline additive manufacturing database, design load case criterion, structural requirements and model for a 13M blade based on the existing NRT blade architecture.

3-D NRT Printed Blade



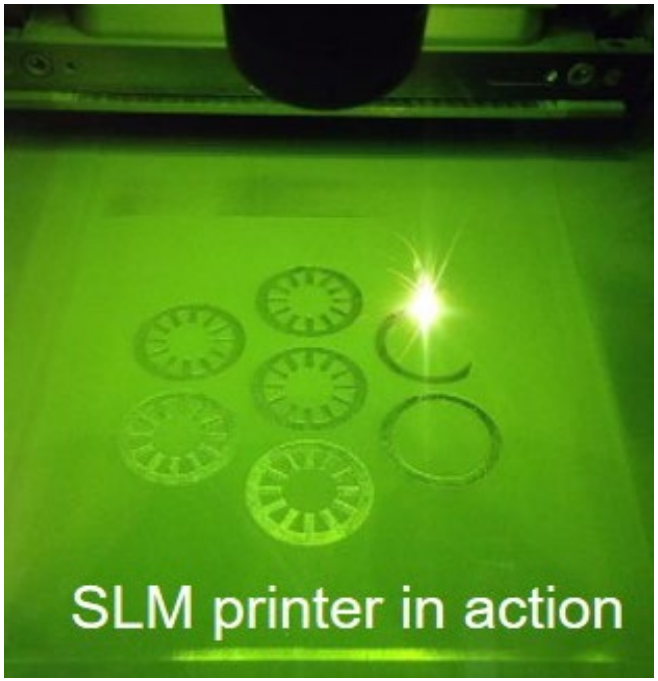
Program Accomplishments & Progress

Materials & Manufacturing (Continued):

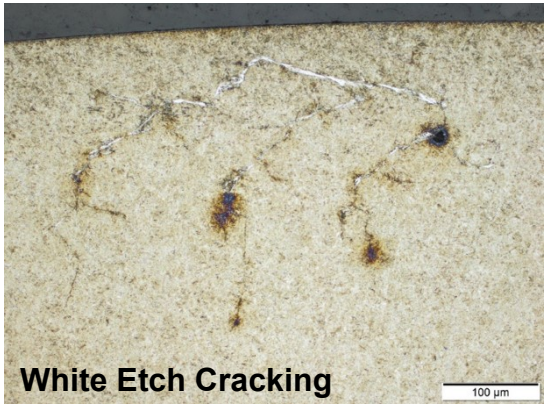
- Additive Manufacturing – The efficacy of Big Area Additive Manufacturing was demonstrated with the production of a 13M blade mold that was subsequently used to produce a blade rotor set for the SWiFT facility.
- Electric Machines & 3-D Printing – Advanced first of its kind accelerated multi-material magnetic topology optimization tools utilizing ML accelerating the design process by 1000x & demonstrated printing of critical rare earth free magnets.
- Drivetrain Reliability – Provided detailed assessments, measurement campaign and failure analysis of influenced by main bearing axial motion on lubricant film thickness (white-etch cracking, micro-pitting) and validated existing design and probabilistic failure models.
- Advanced Materials – Establish operational and material drivers for white-etch cracking bearing failures, develop benchtop testing to replicate effects, quantify effectives of material-based mitigation.
- Remaining Useful Life Prediction - Developing physics domain drivetrain dynamic model to assess tapered roller bearing failures utilized on the high-speed shaft.
- Durability & Damage Tolerance – Developed an advanced autonomous blade inspection robot capable of subsurface blade defect inspection (ARROW).

Mold setup

13-m blade




ARROW Crawler



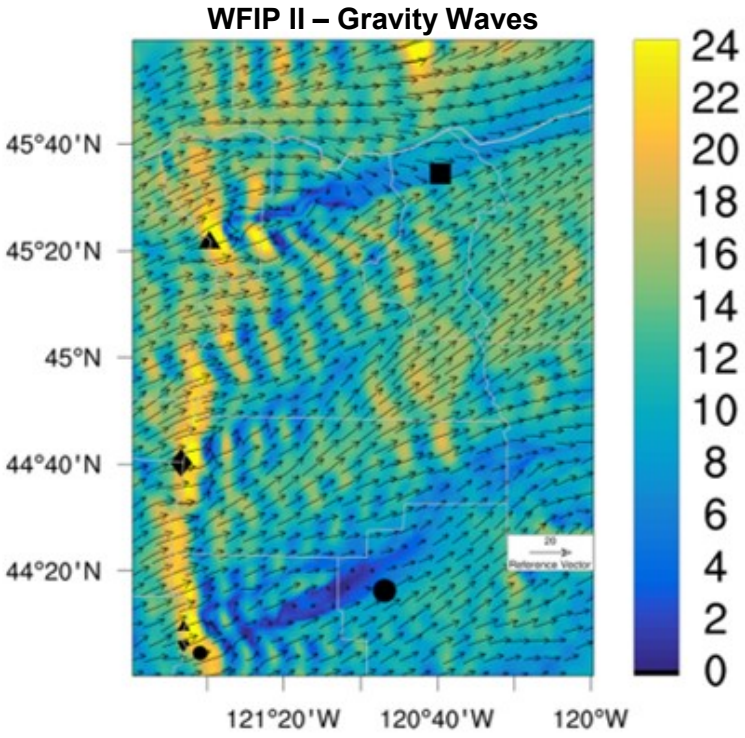
White Etch Cracking

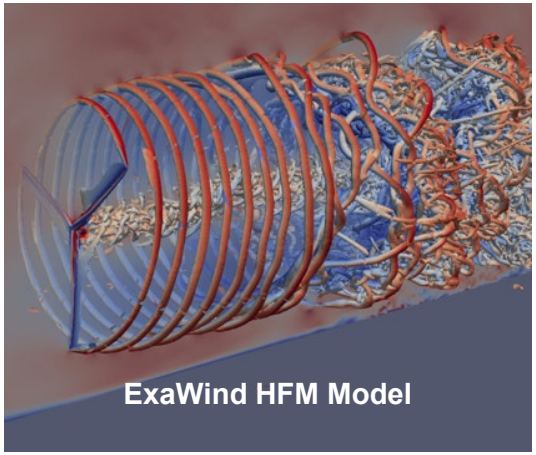
Program Accomplishments & Progress

Atmospheric Science & Wind Plant Interaction (A2e):

Provide a better physical understanding of the atmospheric boundary layer interaction with wind plants and develop new plant technologies that maximize energy capture and optimize wind plant cost & performance

- DAP – Providing a state-of-the-art, secure data sharing platform for wind industry partners, consultants, and researchers for all DOE/WETO programs.
- WFIP II – Substantively improved the ability of numerical weather prediction models in partnership with NOAA to calculate wind characteristics at hub height in complicated terrains and under diverse operating conditions utilizing comprehensive field measurement data.
- MMC Modeling - Evolved the methods and technologies necessary to couple mesoscale physics to wind plant microscale for performance modeling and predictive AEP estimates.
- ERF - Developing a modern atmospheric scalable code to accurately and efficiently transfer data between weather (energy) and the wind plant on next-generation high-performance computing architectures.
- HFM – Developed ExaWind, an HFM code running on DOE leadership class computer systems that fully resolves turbulent inflow/rotor interactions and wake flows in modern wind plants operating in complex terrain.
- Controls - Developed and demonstrated the methods, and analysis strategies for wind farm controls, based on advanced HFM simulation modeling of wake steering, that are currently be integrated into modern land-based wind farm control strategies by industry.

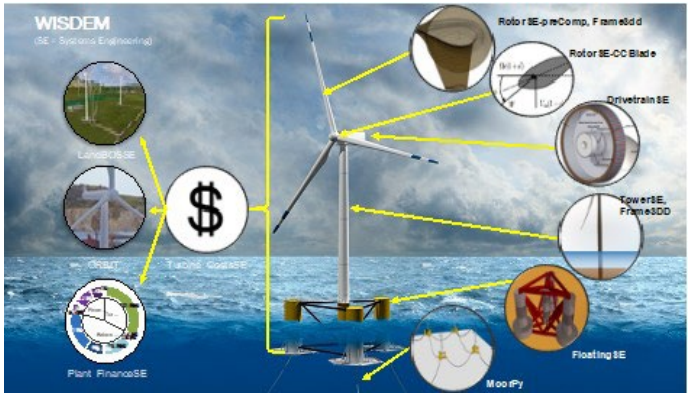


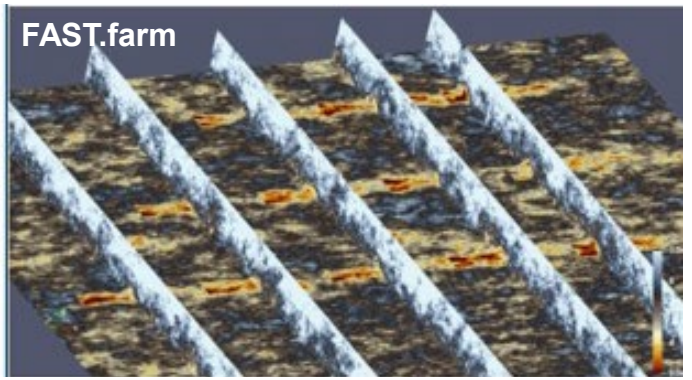


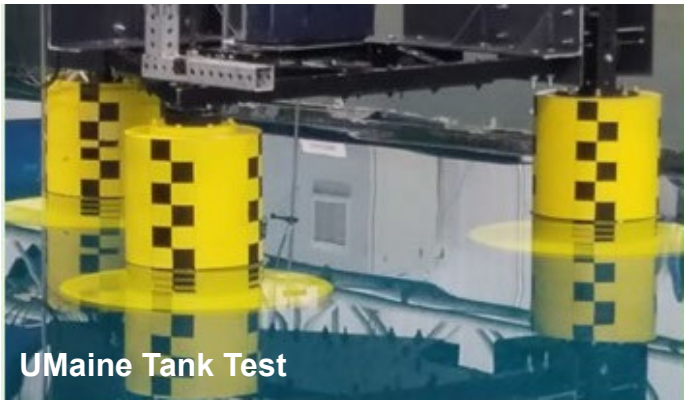
Program Accomplishments & Progress

Atmospheric Science & Wind Plant Interaction (A2e) :

- ISDA SEO - Established an analysis platform and research capability to capture full wind plant system interactions considering the entire wind plant cost, performance and life cycle as a single system utilizing best practices in multidisciplinary design, analysis, and optimization.
- ISDA MPMV – Continuous improvement of the key design tool suite used by industry (e.g., FAST.Farm, OPEN.Fast, and lower tier modules) through formal verification and validation processes, enhanced model accuracy incorporating improved physics/algorithms, and resolving/understanding design driver sensitivities.
- Verification, Validation & Uncertainty Quantification - Developed and applied formal V&V and UQ techniques to wind design, development and deployment applications (e.g., HFM, design tools, and systems optimization models) to ensure viability and accelerate industry adoption and utilization.
- Modeling and Validation for Offshore Wind - Assessing hydrodynamic modeling tools, provide a better understanding of uncertainties, and identify needed areas of improvement by utilizing HFM, Engineering level design tools, and Experimental Wave -Tank Test & Validation
- Aeroacoustic Assessment of Wind Plant Control – Experimentally quantified the changes in aerodynamic noise generation due to yawed wind turbine operation utilizing advanced acoustic monitoring data collection and analysis at utility scale; determined nominal wake steering yaw control would not impact acoustic emissions.
- Rotor Wake Measurements and Predictions for Validation – Developed an experimental field campaign to provide HFM validation data for highly flexible rotors and detailed wake development characteristics at utility scale.
- American Wake Experiment (AWAKEN) – Collect the highest fidelity of wind farm atmosphere interactions to date, use that data to better understand complex wind farm flow phenomena, and validate and improve wind farm modeling tools to use for future improved wind farm performance.





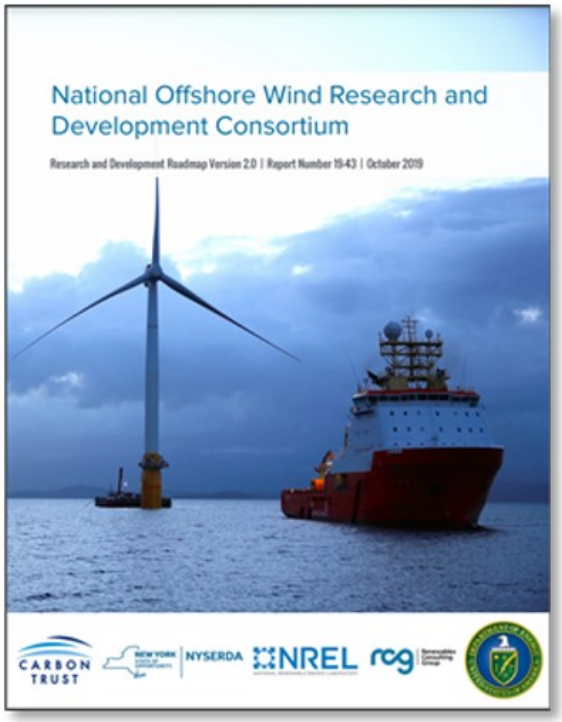


Program Accomplishments & Progress

Offshore-Specific R&D:

Maximize the deployment potential of U.S. offshore wind and domestic supply chain development through expanding technology options, improving performance, and reducing costs.

- NOWRDC - Awarded 40 R&D projects that promote research and development that reduce cost of offshore wind while supporting U.S.-based manufacturing and supply chain development.
- Testing Facilities – Significant progress has been made across six FOA projects to enable domestic testing of simulated, scaled, and full-size offshore wind systems and to improve component design and monitoring
- Advanced Next Generation High Efficiency Lightweight Wind Turbine Generator Developing a lightweight efficient drive train for wind power generation at turbine ratings of 10MW+ for offshore eliminating the use of rare earth elements.
- High Efficiency Ultra-Light Superconducting Generator (SCG) for Offshore Wind Completed conceptual design utilizing WISDEM of a 15MW class low mass, high efficiency superconducting generator.
- Model Test of an Innovative Offshore Floating Wind System (TCF) – Completed preliminary design & analysis of the SpiderFLOAT floating platform substructure concept to achieve cost competitiveness
- Lidar Buoy Deployments & Science & - Developed and deployed wind buoys for MBL data collection to improve forecasting modeling in eastern and western costal offshore wind deployment zones and post process data to characterize offshore wind resources.
- Offshore Wind Resource Sciences - Improve physics of offshore wind numerical models for wind resource characterization and prediction and work with NOAA to enhance and implement operational forecast models where appropriate.



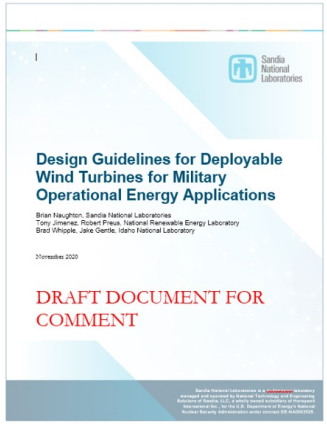
Program Accomplishments & Progress

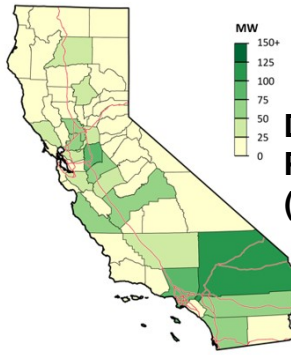
Distributed Wind:

Enable wind technology as a key player in a growing market for Distributed Energy Resources by reducing LCOE and increasing reliability.

- Distributed Wind Research, Development, and Testing - Awarded 16 Competitiveness Improvement Project (CIP) worth $4.5 million to support innovation and certification of competitive small to mid-sized wind turbines
- Tools Assessing Performance (TAP) - Developed new DWT-specific modeling and tools to improve turbine design and performance, resource assessment and streamline siting processes
- Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad (MIRACL) - Accelerate DW technology development and demonstration system modeling and decision support tools, advanced controls development for hybrid systems and grid integration, and increased support for cybersecurity.
- Defense and Disaster Deployable Turbine – In collaboration with DOD and industry stakeholders, facilitate the development and deployment of deployable wind technology as a viable source of power for defense and disaster response.
- Distributed Wind Strategic and Technical Engagement – Provide strategic industry market engagement and support through analysis and market reports, informational products, standards development and promotion of international engagement.

Deployable Turbine





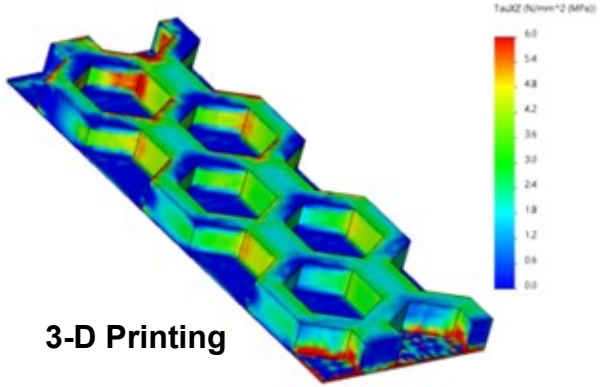
DW Economic Potential (dWind)

Program Upcoming Activities

Materials & Manufacturing:

- BAR Phase II will assess the techno-economic and advanced design viability for innovative large-rotor technologies identified in Phase I (e.g., highly flexible rail transportable, upwind & downwind, distributed aerodynamic controls).
- Carbon fiber material design - Demonstrate the potential to achieve increases in compression strength of 25% or more, resulting in a reduction of spar cap material cost of greater than 50% and enable lighter and more fatigue-resistant blades that would be prohibitively expensive to make today.
- 3-D Printing - Deliver an extremely lightweight 3D printed blade core structure that outperforms traditional core structures such as balsa and foam on a strength, stiffness, mass, cost and durability basis
- Additive Manufacturing – Final techno-economic analysis report comparing AM vs. Conventional manufacturing concluding mBAAM produced nodes were the most cost competitive from a lead time, transportation and production cost perspective.
- Electric Machines & 3-D Printing – Advance the MADE3D-AML and cost models, validate toolsets, advance and scale multi-material processes and incrementally develop a new light-weight electrical machine designs for wind turbine application.
- Drivetrain Reliability - Develop rating life models, mitigation methods, and validated design tools to predict remaining useful life, increase gearbox availability and operational life expectancy.
- Advanced Materials – Identify root cause of tribological component failures, develop testing tools to accelerate identification and develop mitigations technologies.

Carbon Fiber Processing



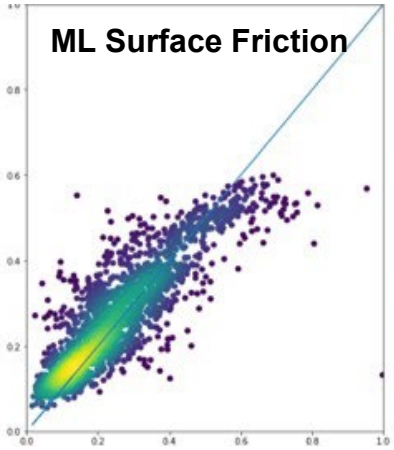
3-D Printing

DT Reliability

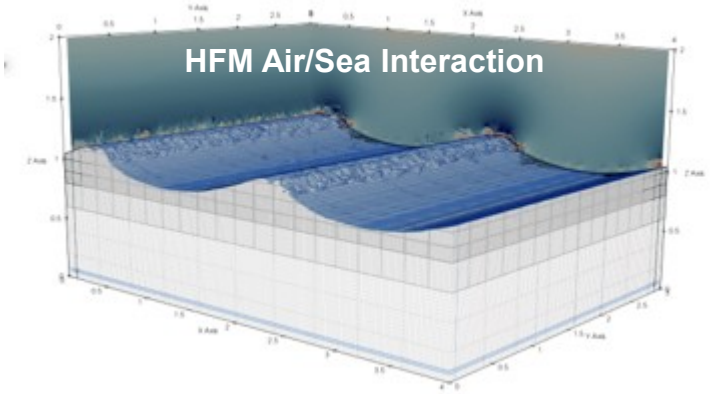
Program Upcoming Activities

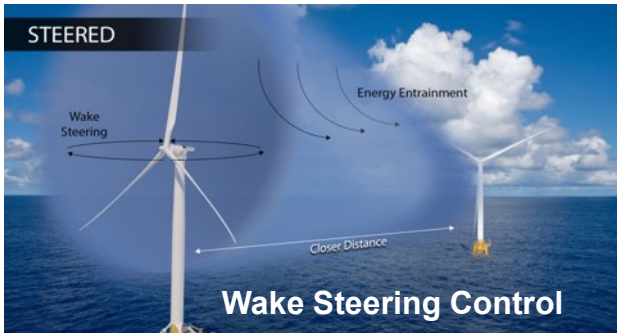
Atmospheric Science & Wind Plant Interaction (A2e):

- DAP – Continue to support major field campaign efforts and provide a centralized infrastructure for projects to develop and utilize ML and AI based capability with ML-friendly based data structures.
- MMC Modeling - Incorporation of AI and ML methods into the next generation of forecast and wind resource characterization models that include enhanced physics, computational speed and predictive accuracy.
- ERF - Provide high performance atmospheric model code base on AMRx to seamlessly couple mesoscale energy flows with microscale wind plant simulation to advance wind energy deployment for HFM and Design Tool applications.
- HFM – Validated HPC model to fully resolve deep water floating turbine architectures and coupled dynamic motions with marine inflow boundary layer and air/sea turbulent boundary conditions.
- Controls – Leverage the models, methods, validation and analysis of wind farm controls developed for land-based systems to provide state of the art plant control strategies for offshore wind systems based on the unique marine and floating turbine architectures.
- ISDA SEO - Apply advanced multidisciplinary methods and highly trained design team in wind plant systems analysis to explore new pathways in performance and cost improvement for both on and offshore applications.
- ISDA MPMV – Upscale and validate code suite at larger turbine sizes, novel architectures and incorporate advanced control strategies.



ML models out-perform prior models even at sites where not trained

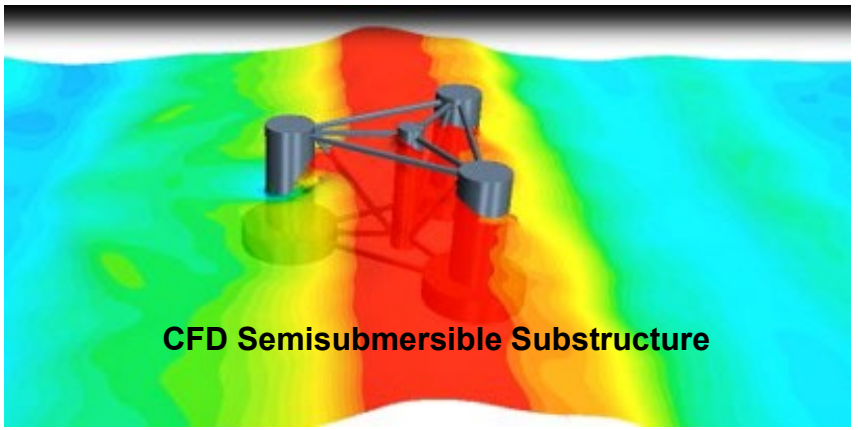


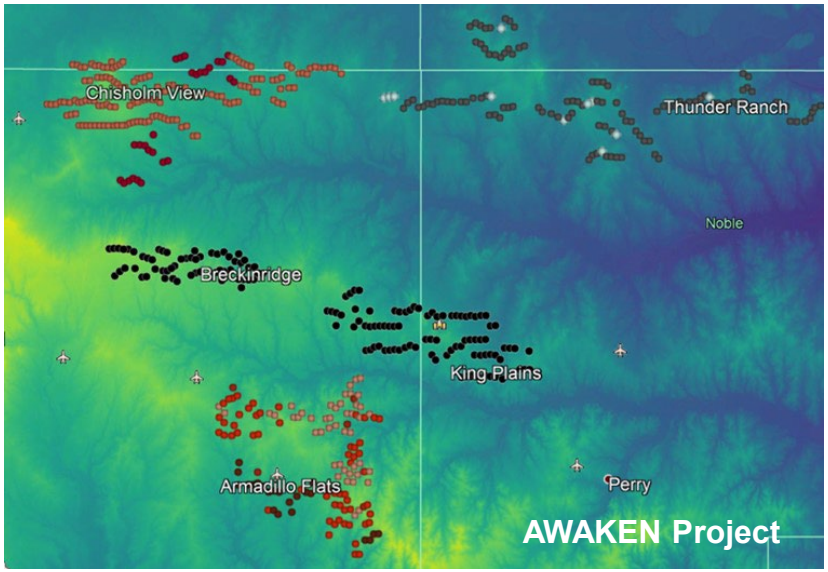


Program Upcoming Activities

Atmospheric Science & Wind Plant Interaction (A2e):

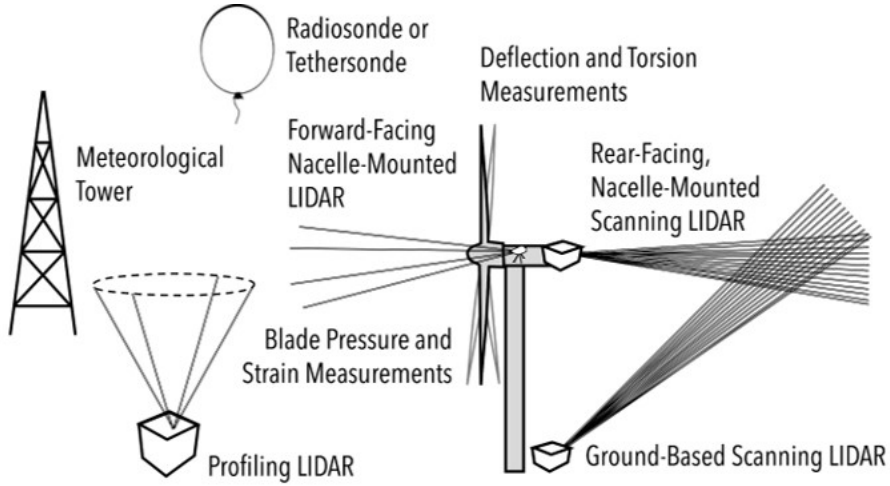
- Modeling and Validation for Offshore Wind - Complete OC6 modeling campaign and provide the necessary datasets and offshore wind modeling tools that incorporate best practices and critical physics for offshore hydrokinetic modeling effects.
- Rotor Wake Measurements and Predictions for Validation – Complete experimental field campaign in partnership with a major turbine OEM to provide HFM validation data for highly flexible rotors and detailed wake development characteristics at utility scale.
- American Wake Experiment (AWAKEN) – Completion of the AWAKEN Atmospheric Measurement & Turbine performance field campaign FY-24


CFD Semisubmersible Substructure



AWAKEN Project

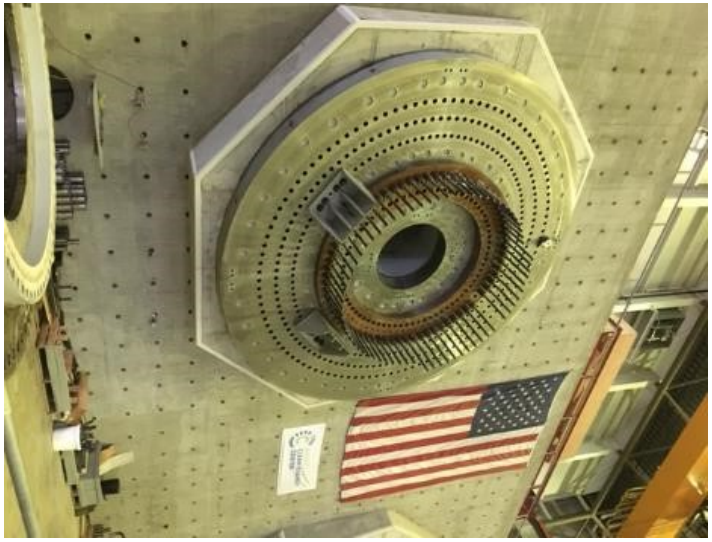
RAAW Experiment Completion



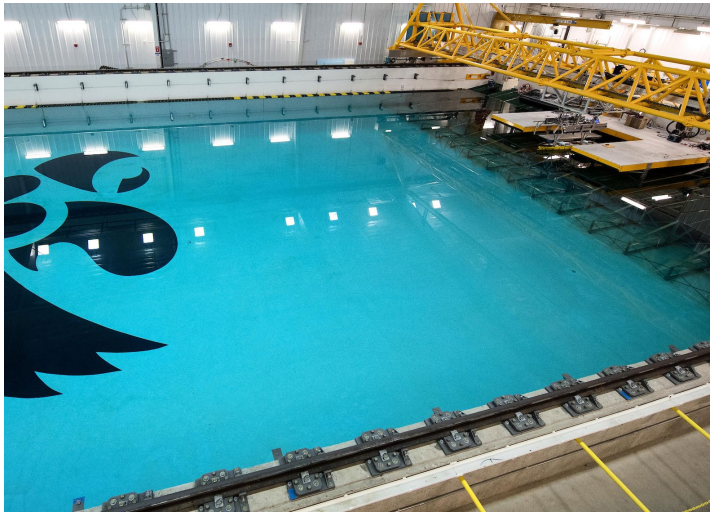
Program Upcoming Activities

Offshore R&D:

- NOWRDC - Upcoming solicitations are planned for fall 2021 and spring 2022 in line with the new Roadmap 3.0 and outreach will continue on awarded projects as well as industry topics of interest
- Testing Facilities - Upgrade blade testing facility, upgrade soil-foundation interaction laboratory, develop real-time and hybrid-simulation testing capabilities, develop autonomous blade monitoring, and support standards development for concrete fatigue.
    - Umass Lowell will test their blade health acoustic monitoring system at the Mass CEC Wind Testing Facility
    - Mass CEC will install a blade mounting angle adjustment system and expanded static test loading equipment to support testing of blades up to 120m
- Advanced Next Generation High Efficiency Lightweight Wind Turbine Exploring cost reduction technology pathways and actively engaging with potential energy partners for market commercialization..
- High Efficiency Ultra-Light Superconducting Generator (SCG) for Offshore Continue detailed design and development for future field test of a commercially super conducting generator on a wind turbine.
- Model Test of an Innovative Offshore Floating Wind System (TCF) – A 1/50 scale model will be tested at UI's Hydraulics Wave Basin Facility to collect detailed performance data.
- Lidar Buoy Science & Buoy Deployments - Continue detailed planning for out-year buoy missions in close partnership with BOEM that that provide critical operating data for the design and rapid deployment of offshore wind systems.
- Offshore Wind Resource Sciences - Continued evaluation and improvement of forecast and microscale models using case studies & deployed Lidar Buoy Data.



Mass CEC 120 m Test Stand

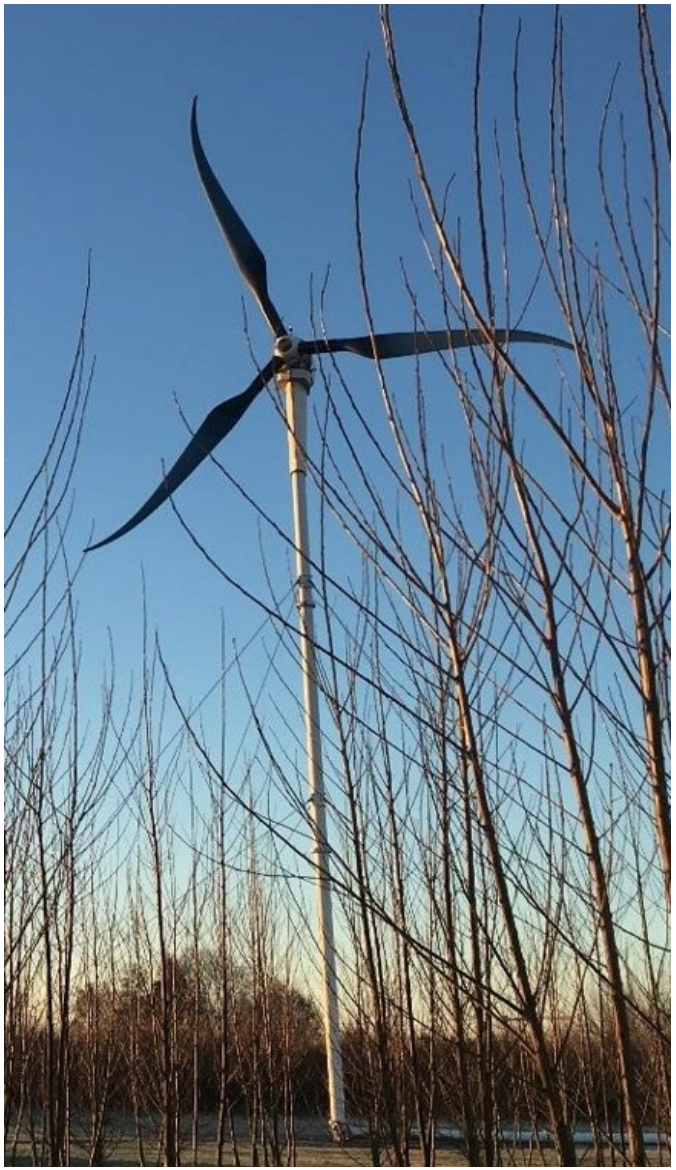


UI Wave Tank Test Facility

Program Upcoming Activities

Distributed Wind:

- Distributed Wind Research, Development, and Testing – Continue to support innovation and certification of competitive small to mid-sized wind turbines through cost share program development, benchmark validation, and comprehensive technical assessment.
- Tools Assessing Performance (TAP) – Continue to provide access to wind resource data, timely and accurate performance assessments and advanced modeling capabilities to better predict turbine performance and advance more economically viable and reliable distributed better predict turbine performance—enabling wind turbines to become a more economically viable and reliable distributed wind technology
- Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad (MIRACL) - Expand on distributed wind centric hybrid integration research and complete integration of infrastructure across the MIRACL laboratories into the MIRACL Data Hub, to enable laboratories and industry to share data, models, and physical assets for research, demonstration, and validation.
- Defense and Disaster Deployable Turbine – In collaboration with DOD and industry stakeholders, discuss opportunities to partner with military and industry stakeholders to develop, deploy, and test hardware in the field
- Distributed Wind Strategic and Technical Engagement – Continue to build and evolve strategic industry market engagement and support including distributed Wind Futures study update, publication of the American Clean Power 2021 Small Wind Turbine Standard, and continued assessment of existing distributed wind system topologies and aeroelastic capabilities to allow technology innovation and certification.



Questions for Peer Reviewers

- Are we going in the right direction, regarding the strategic direction of the Technology R&D Program?
- Will our planned actions have a real impact on the wind industry?
- Are there any gaps in our research focus?
- Are there research areas that we should consider including in the future?
- Is our team built and aligned for success?