U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Wind Energy Technologies Office

Programmatic Overview

Prepared for DOE’s State Energy Advisory Board (STEAB) | April, 2019

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EERE Wind Energy Technologies Office

Vision: Low-cost wind energy options nationwide

Mission: Advance knowledge and technological innovation to enable low-cost wind energy options nationwide

- Wind energy is a core component of a diverse energy supply

Government Role: The DOE Wind Office and national laboratories conduct unique research beyond industry capabilities and resources

Value: The DOE Wind Office creates value to the nation – growing the economy, supporting grid reliability, enabling clean air and clean water, and providing national scientific and technology leadership

WETO Multi-Year Program Plan

- Single integrated strategic document focused on land-based wind, offshore wind, and distributed wind. Resources include:
  - Wind Vision (2015) and Wind Vision Roadmap Update (2017-2018)
  - Enabling Wind Power Nationwide (2015)
  - National Offshore Wind Strategy (2016)
  - Assessing the Future of Distributed Wind (2016)
  - Enabling the SMART Wind Power Plant of the Future Through Science-Based Innovation (2017)
- 5-year plan with annual updates used for internal planning and budgeting
- Articulates DOE's unique program strategy to stakeholders (Congress, wind industry, national labs)
- Linked to Administration strategies & guidance




Wind Office Strategic Plan & MYPP

Projects are detailed for each wind application type

- Land-based wind,
- Offshore wind (fixed and floating), and
- Distributed wind (kW and MW-scale, behind the meter)

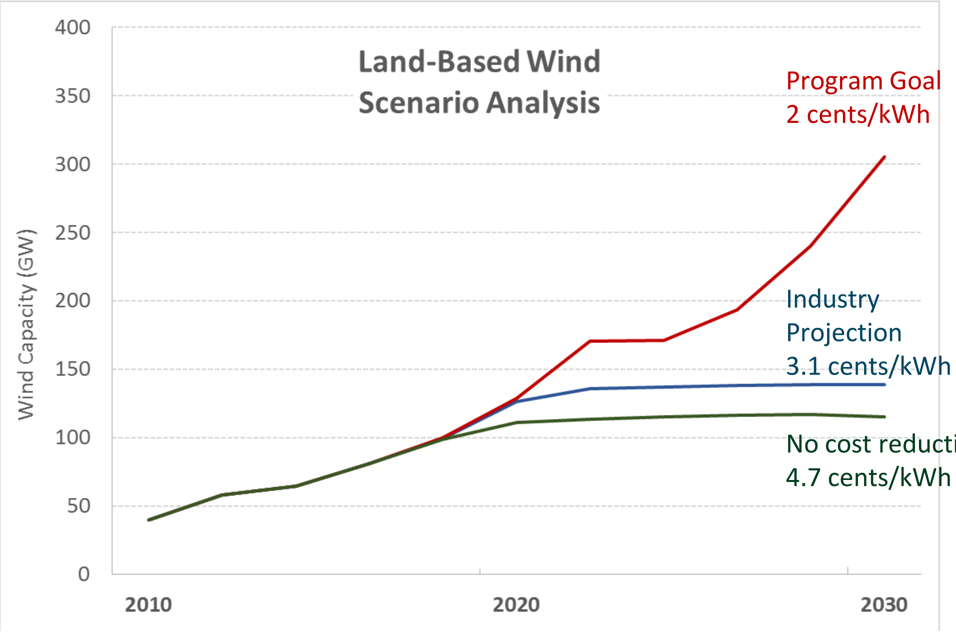
DOE R&D impacts support 50% cost reduction targets by 2030

- In all wind types, enabling 300GW+ of affordable wind,
- Which are significantly beyond industry improvements alone

And supports Grid Systems Integration

- For wind support of grid reliability, resilience, and cyber security

- Land-based wind (LBW): $.02/kWh
- Offshore wind (OSW): $.06/kWh
- Distributed wind – MW scale: $.04/kWh
- Distributed wind – kW scale: $.07/kWh



Wind Plant Science Driving Innovation

Wind plant science R&D for all wind types driving innovation (A2e)

- Science of whole wind plants and turbine-to -turbine interactions
- Atmospheric science

Wind Grand Challenges

- Advancing the understanding of the wind system physics;
- Modeling the full wind energy system;
- Application of physics and models to wind designs

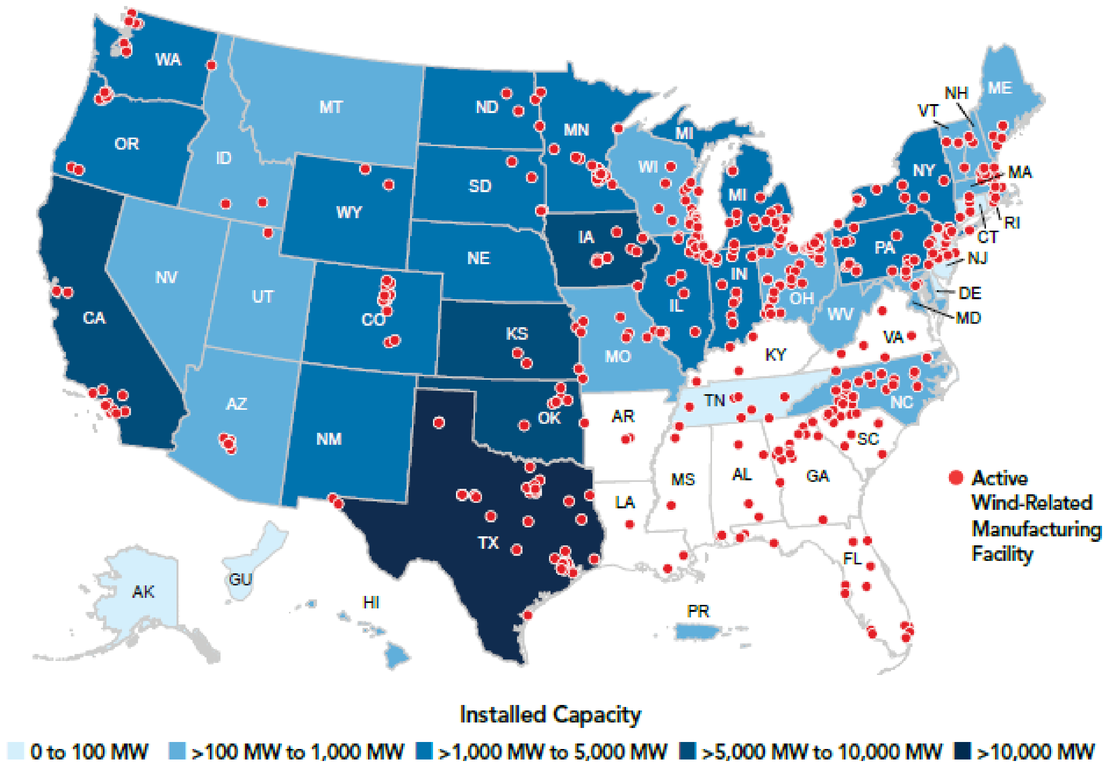
Wind LCOE Impacts

- Science drives an estimated 54% ($.012 cents/kWh) of 2030 LCOE goal reduction

Creating the core underpinning science supporting transformative next - generation plant and turbine designs, supporting the Grid of the Future

Land-Based Wind: *State of the Industry*

Wind provides over 6.5% of the nation's electricity and supports 114,000 domestic jobs, including over 500 manufacturing facilities in 42 States



Wind-Related Manufacturing Facilities and Installed Capacity by State at end of 2018 (AWEA, 2019)

The Southeastern U.S. has more than 100 manufacturing facilities supplying components and materials to the wind industry

Robust Industry

- Utility-scale land-based wind power in 41 states and distributed wind power in all 50 states
- 14 states ≥10% wind generation, with five states >25% generation
- U.S. utilities operate high wind penetration land-based wind without one-to-one backup or storage requirements today through balancing and forecasting management
- Land-based wind power represented 30% of capacity additions over the past 10 years

Domestically Sourced Components and Raw Materials

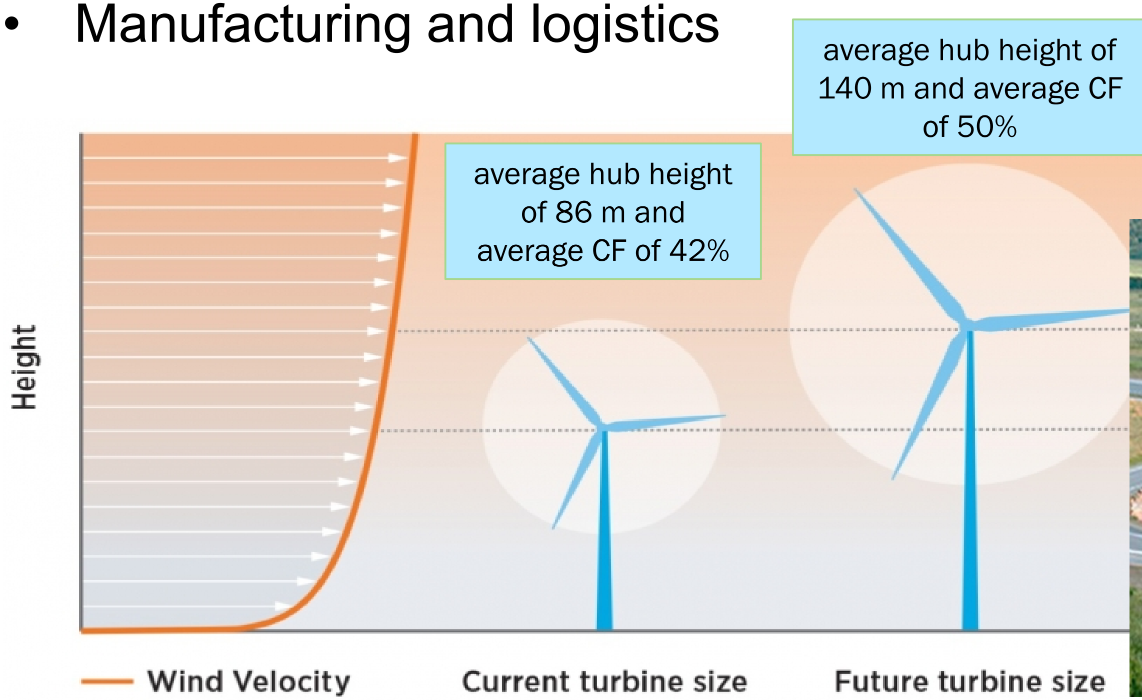
- Through innovations and a robust wind market, 70-90% of towers and 50%-70% of blades and hubs installed in the U.S. in 2017 were made in America.
- Today's U.S. wind manufacturing capacity is approximately 15,000 MW of turbine nacelles, 11,400 individual blades and around 3,650 towers annually.

Tall Wind across America

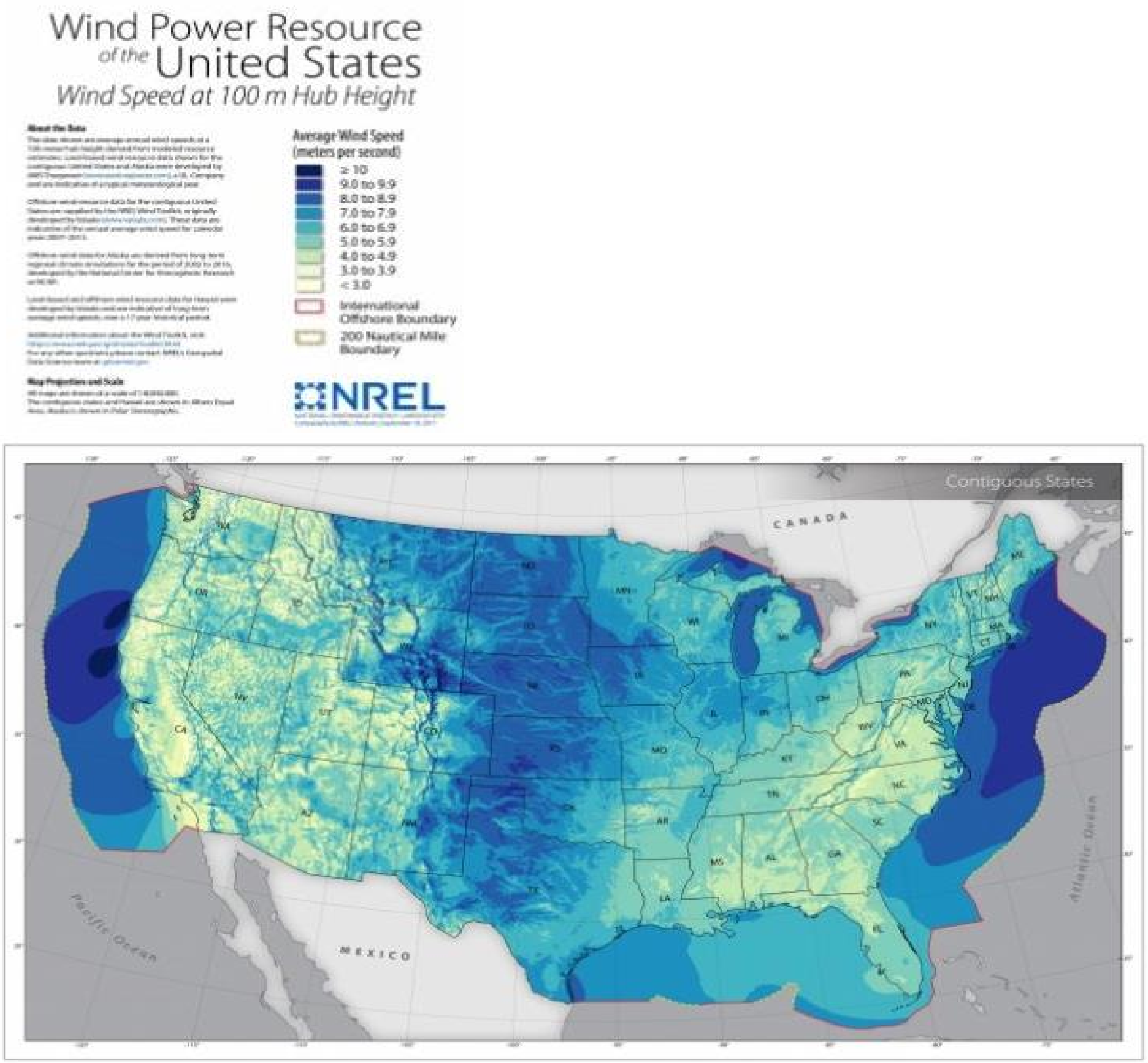
R&D innovations for land-based wind

- Lightweight drivetrains (FY 18 FOA)
- Big adaptive rotors
- Tall towers (FY 19 FOA)
- Wind radar solutions
- Wildlife technology solutions
- Manufacturing and logistics

Supports accessing significantly stronger and more consistent wind speeds at higher elevations, creating cost-effective solutions for every region



Offshore Wind: *State of the Industry*



Continental United States—Land-Based and Offshore Annual Average Wind Speed at 100 Meters above the ground

- 2,058 GW technically accessible resource potential, options for every coastal region of the nation, including the Great Lakes.
- Projected to provide18.6 GW of cost-effective power in seven states on the Atlantic Seaboard by 2030
- This will present a nearly $70 billion opportunity to businesses in the offshore wind power supply chain over the course of the next decade.
- 60% of the U.S. offshore wind resource is in deep water requiring floating platforms.
- 30 MW Block Island (RI) first offshore wind project began producing power in 2016.

Offshore Wind for the American Market

Offshore Wind Challenges

- U.S. offshore wind needs to operate in calm "weather windows" for installation and operations due to either wind or wave conditions,
- Less suitable existing infrastructure, particularly ports capacities (dock-side bearing capacity, lack of draft etc.)
- Lack of large specialized vessels, Jones Act restrictions on hiring ships flagged in other countries
- Nascent/undeveloped offshore wind supply chain and workforce.

R&D Innovations for Offshore Wind

- Science for offshore wind applications – atmospheric science over water
- Innovations for OSW – floating platforms, scaling solutions for large offshore designs, advanced turbine controls, lightweight drivetrains
- Enable OSW to provide optional essential reliability services with coastal grids
- OSW solutions for wind project development barriers: marine wildlife, radar and human use considerations

Offshore Wind Advanced Technology Demonstration Projects
Brief History

2013 - Seven Projects

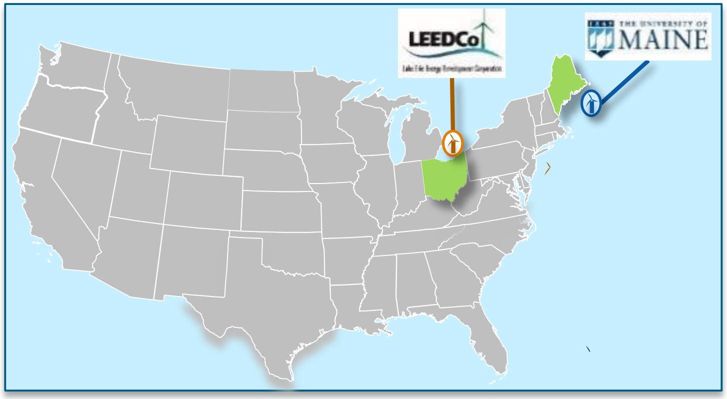
- Regionally and technologically diverse
- Goal: 50% Front End Engineering Design (FEED) including vendor quotes
- Down-Select based on progress and technical viability

2014 – Five Projects (three projects, two alternates)

- Goal: 100% FEED, vendor quotes, installation and O&M, completion of NEPA, regulatory and interconnection requirements
- Go/No-Go based on progress to accomplishing goals, including power purchase agreement

2017 – Two Projects

- Goal: Fabrication, installation and commissioning of the project by 2020; environmental and performance data collection 5-years beyond project completion
- Regular Go/No-Go decision points



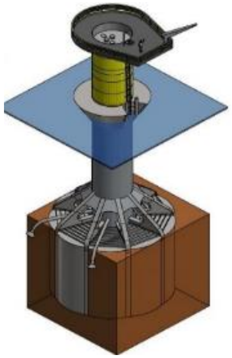
Current Portfolio

University of Maine

- Monhegan, ME
- 12 MW project, 2 turbines
- Floating concrete semi-submersible to handle deepwater offshore wind resources

LEEDCo

- Cleveland, OH
- 20.7 MW project, 6 turbines
- Monobucket (monopile large suction pile) to resist weak soils surface ice conditions of the Great Lakes

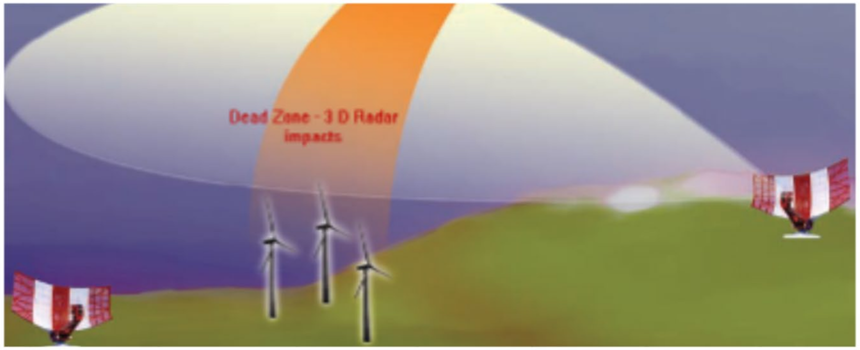


Solutions for Wind Project Development Barriers

Environmental Impact Solution R&D

- R&D to develop solutions to wind wildlife impacts to lower costs, reduce impacts, and reduce regulatory timelines
- FY18 FOA to provide $6m in funding to:
  - advance smart curtailment strategies to reduce energy loss and impacts,
  - advance instrumentation to be used in lieu of curtailment
  - Develop monitoring and mitigation solutions for offshore wind

Radar Interference Mitigation R&D



- Key partners: DOD Siting Clearinghouse, FAA, NOAA, BOEM, DHSNOAA, BOEM, DHS.
- Improve capacity to evaluate the impacts of wind energy on sensitive radars
- Develop and deploy mitigation measures to increase resilience of existing radars to wind turbines
- Encourage the development of next-generation radars resistant to wind turbine interference

Develop technical solutions for land-based and offshore wind to allow for wind development in areas where radar interference or wildlife impacts would otherwise prevent it.

Solutions for Wind Project Development Barriers

Human Use Conflicts

Convenes diverse stakeholders in a national dialogue and provides state based data key for local decision-making.

- Information dissemination of credible information to inform wind energy decision making, such as state-based resources including state-specific wind resource assessment maps
- A National Public Acceptance Baseline Study provided the first quantitative assessment of the factors associated with public acceptance of wind energy development to inform future technology development e.g. noise mitigation.

STEM Education & Workforce Development

Wind technician is the second fastest growing occupation in America and the wind energy sector is a growing industry requiring a skilled domestic workforce.

- Supporting the development of STEM education through activities like the Wind for Schools project, integrating small wind turbine installations at rural U.S. elementary & secondary schools to power their schools and complement curriculum and K-12 STEM activities.
- Workforce preparation to catalyze the wind workforce of the future, through activities such as the Collegiate Wind Competition, providing real-world experience to challenge college students to develop solutions to complex wind energy challenges.

To provide for land-based and offshore wind the best available solutions to enable well-informed wind energy deployment decisions, reduce regulatory barriers surrounding human use conflicts, and to ensure the availability of a robust domestic workforce

Grid Systems Integration

Wind grid integration, grid services, and cyber security support – support for all wind types

- Wind grid services and wind control capabilities
- Grid designs and requirements
- Wind cyber roadmap
- Collaboration with DOE Offices of Electricity, Fossil Energy, Nuclear Energy

Supports designs and requirements for effective wind grid integration and wind grid support services

National Wind testing and demonstration platform: validation and verification for all wind types

- Grid & storage integration test facilities
- National Wind Technology Center, SWiFT, & other test facilities
- OSW test facilities

Creates ability for advanced grid integration, component and system level testing with next-gen storage and dynamic grid controls

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USDA Engagement

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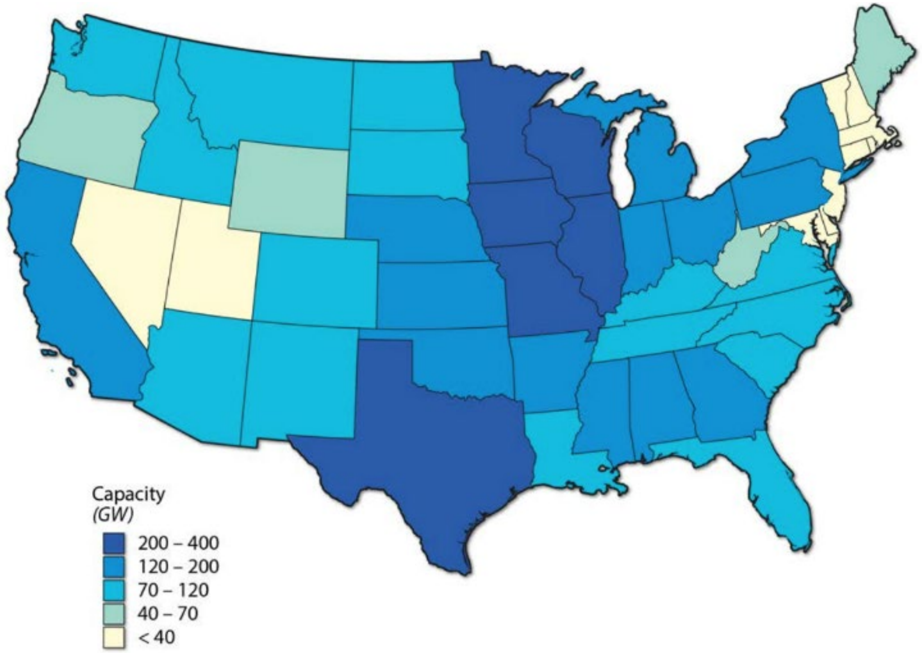
Distributed Wind for American Communities

Distributed energy resources (DERs) gaining in popularity and wind energy has vast economic potential in rural windy regions

- Technically feasible for approximately 49.5 million residential, commercial, and industrial sites nationwide, mostly in rural communities
- Economic potential of nearly 48 GW by 2030 and 85 GW by 2050.



Addressable resource of megawatt-scale turbines by state

Assessing the Future of Distributed Wind: Opportunities for Behind-the-Meter Projects (NREL, 2016)

Distributed wind can be a cost-effective and reliable option for rural communities, businesses, Co-ops and Municipal Utilities

Wind Innovations for Rural Economic Development (WIRED)

WIRED Workshop held October 2018:

- Included representatives from the U.S. government, national laboratories, rural electric utilities from around the country, national associations, the wind energy industry, and the financial community

Goals of the workshop were to develop a better understanding of:

1) opportunities and challenges rural electric utilities face regarding distributed wind and other distributed energy resources
2) research and development pathways that could enable wind technology to be more valuable for rural electric utilities, and
3) improvements that DOE, in partnership with utilities and stakeholders, could make to the deployment process of distributed wind systems

USDA Participation at WIRED Workshop

Workshop included two USDA staff on the Finance Panel

- Aaron Morris, Assistant Deputy Administrator, Rural Development Energy Program
- Joe Badin, Assistant Deputy Administrator, Rural Utility Service Electric Loan Program

USDA specific workshop report findings

- DOE and USDA could partner to support local capacity building with rural electric utilities about the USDA Rural Utilities Service (RUS) Electric Program and distributed wind in general
- DOE and USDA could also work more closely to diversify and ensure the success of USDA Rural Energy for America Program projects

https://www.energy.gov/sites/prod/files/2019/01/f58/WIRED%20Workshop%20Report-010219-final.pdf

Funding Opportunity Announcement (FOA) Number: DE-FOA-0002071

Topic Area of Interest	Subtopics	Funding Amount
1. Wind Innovations for Rural Economic Development	a) Innovations to enhance resilience and reliability of rural electric utilities through integration of hybrid distributed energy systems utilizing wind b) Balance of system cost reduction through standardization in distributed energy project development and deployment	Up to $6.1M a) $3.05M b) $3.05M

Concept Papers Due: 04/29/2019

Full Applications Due: 06/17/2019

USDA Engagement – Technical Training

EERE Technologies Workshop and Training for USDA Staff:

- Coordinating with Aaron Morris, Assistant Deputy Administrator, USDA Rural Development Energy Program
- Tentatively Scheduled for 08/20-22/2019 at NREL
- 60 USDA Rural Development Energy Program Staff, mainly from state extension offices
- Trainings will address full suite of EERE technologies available today, and prepare staff for what EERE technologies may look like in the future
- **Drivers of Training:**
  - Technology and markets evolving quickly, staff need to be on the leading edge
  - Rural Development Energy Program investments dominated by solar technology, USDA would like to diversify investments

Wind Energy Technologies Office

Distributed Wind Program

Prepared for DOE's State Energy Advisory Board (STEAB) | April, 2019

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Distributed Wind: *State of the Industry*

Significant Economic Potential

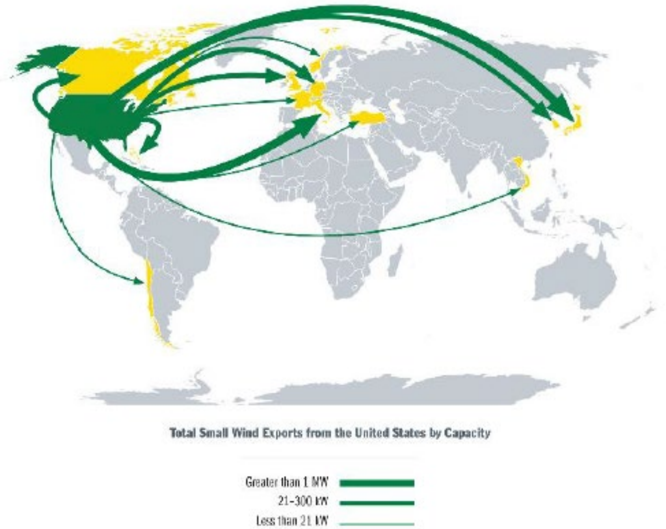
- Presently over 81,000 wind turbines, totaling 1,076 MW in cumulative capacity, deployed across all 50 states.
- Technically feasible for approximately 49.5 million residential, commercial, and industrial sites nationwide, mostly in rural communities
- Economic potential of nearly 48 GW by 2030 and 85 GW by 2050.

American Made, Global Leadership

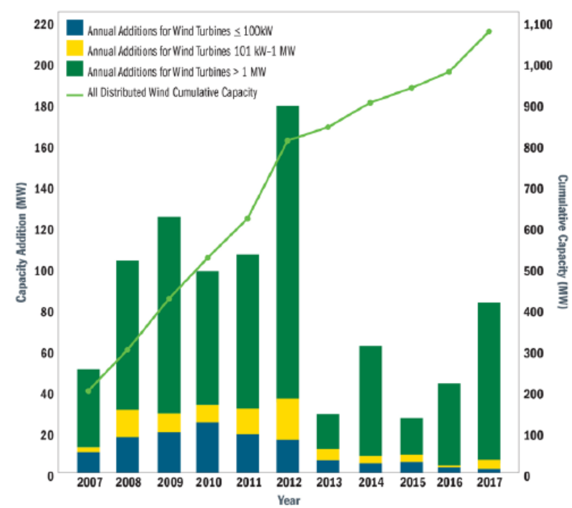
- U.S. small wind (≤ 100kW) turbine manufacturers report domestic content levels ranging from 66% to 100%.
- U.S. small wind turbine manufacturers accounted for 94% of domestic sales in 2017.
- In 2017, exports represented 75% of sales for U.S. small wind manufacturers

Trend Towards Larger Distributed Wind Systems

- Of the 84 MW of distributed wind capacity installed in 2017, 78 MW came from distributed wind projects using turbines greater than 1 MW
- For U.S. distributed wind projects using 1 MW-or-larger turbines, distribution utility owned systems accounted for 32% of capacity installed in 2015, 60% in 2016, and 83% in 2017



U.S. Small Wind Capacity Exports Map

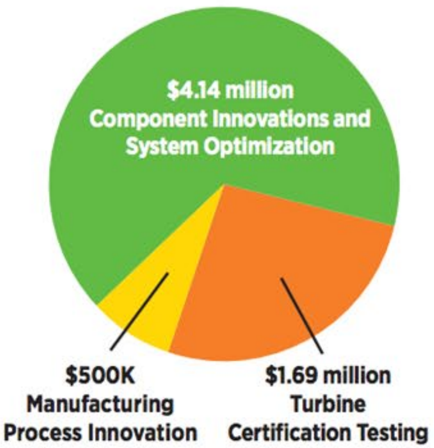


U.S. distributed wind capacity

Technology Development for Distributed Wind

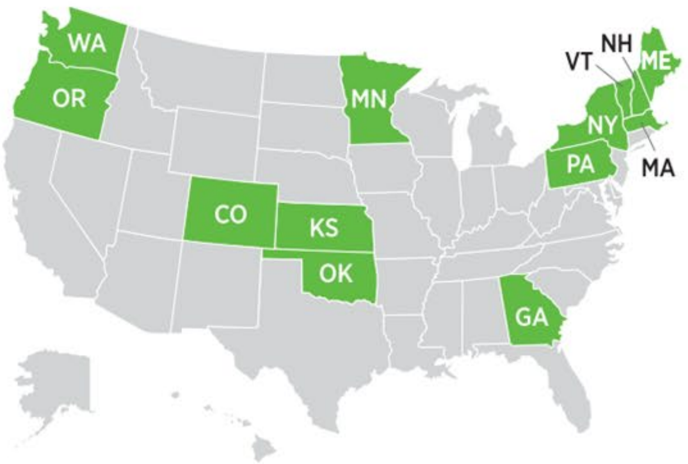
Support small businesses who design and manufacture small or medium wind turbine technology with innovations to reduce costs and increase system performance

28 Subcontracts to 15 companies, totaling $6.3 million of DOE investment while leverage additional $3.5 million of awardee cost share



Funding breakdown for three CIP research areas

Bergey Windpower (Norman, OK)
Endurance Wind Power (Seattle, WA)
Intergrid (Temple, NH)
Northern Power Systems (Barre, VT)
Pecos Wind Power (Somerville, MA)
Pika Energy (Westbrook, ME)
Primus Windpower (Lakewood, CO)
Rock Concrete (Augusta, KS)
Sonsight (Lawrenceville, GA)
Star Wind Turbines (East Dorset, VT)
Urban Green Energy (New York City, NY)
Ventera Wind (Duluth, MN)
Wetzel Engineering (Lawrence, KS)
Windurance (Coraopolis, PA)
Xzeres (Portland, OR)



Distributed Wind Technology Highlight

CIP Highlight: Bergey Windpower Cuts Costs Nearly 50%

BERGEY EXCEL 10

- 20-year-old design
- 9.8 kW
- 7-meter rotor diameter
- Pultruded fiberglass blades
- Power control by furling

Levelized cost of energy: 25¢ per kilowatt-hour

BERGEY EXCEL 15

- 2017 design
- 15.6 kW
- 9.6-meter rotor diameter
- Carbon fiber blades
- Power control by blade stall

Levelized cost of energy: 13¢ per kilowatt-hour

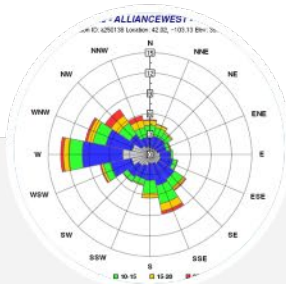
Next-generation, low wind speed technology yields near 50% reduction in levelized cost of energy, making this small wind turbine cost-competitive with solar (photovoltaics)

Cost reductions increasing affordability for Americans and economic competitiveness of American companies

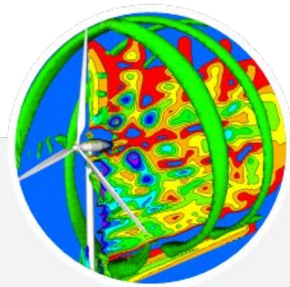
Distributed Wind: Future Priorities (FY19 and beyond)

Strategic Area	Future Priorities	Collaborators
Tools Assessing Performance	• Develop benchmark data sets for evaluating existing tools • Identify gaps and opportunities in existing modeling tools • Prioritize R&D to advance modeling capability • Integrate backend with User-facing tools	• NREL • PNNL • ANL • LANL

Stakeholder Engagement



Wind Resource Dataset



Flow Modeling

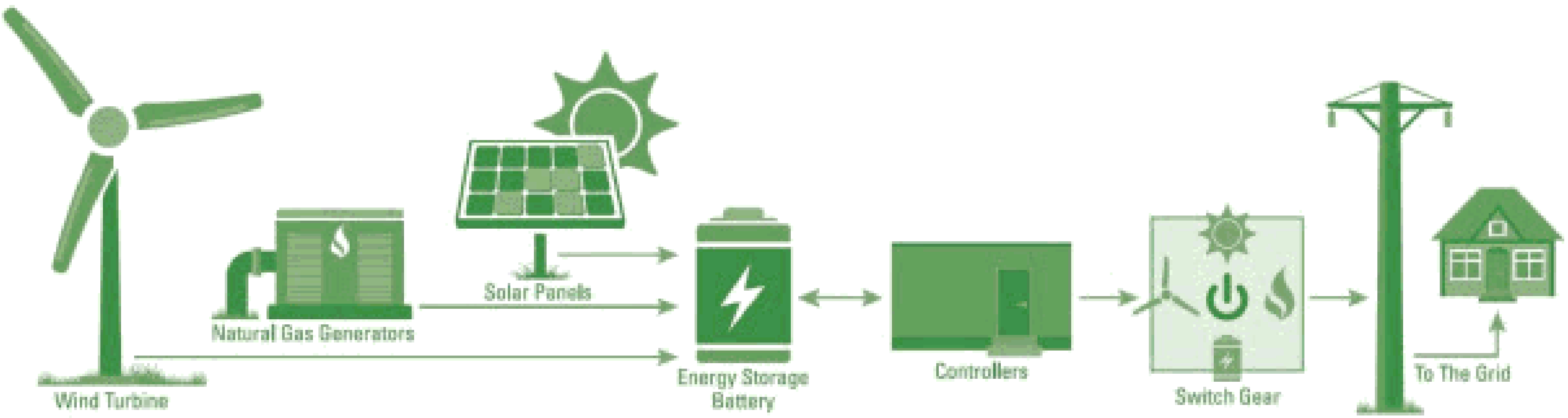
Computational Framework

User-facing Tool Design

Accurately and reliably predict distributed wind power production for informed decision making and financial risk mitigation

Distributed Wind: Future Priorities (FY19 and beyond)

Strategic Area	Future Priorities	Collaborators
Microgrids, Infrastructure Resilience and Advanced Controls Launchpad	• Modernize and virtually connect lab infrastructure • Develop advance controls for transactive systems blending Distributed Energy Resources (DERs) • Develop cyber security standards and integrate into turbine technology • Develop approach to value integrated system services to central power system	• NREL • PNNL • SNL • INL



Securely integrate wind into distributed energy systems to enable power system resilience and provide grid services

Distributed Wind: Future Priorities (FY19 and beyond)

Strategic Area	Future Priorities	Collaborators
Defense and Disaster Deployable Wind Turbine	• Assess market for deployable wind turbines in operational applications • Develop design requirements for deployable wind turbines • Evaluate commercial technology against design requirements • Develop new technology as needed to meet market need	• SNL • NREL • INL

Enable wind technology to be easily and reliably deployed by first responders to natural disasters and by our military

Thank You!

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Backup Slides

BACKUP SLIDES

National Offshore Wind R&D Consortium – Status

Goal A nationally-focused, not-for-profit organization collaborating with industry on focused R&D activities to reduce LCOE of offshore wind in the U.S. and maximize economic benefits

Administrator (competitively awarded): New York State Energy Research and Development Administration (NYSERDA)

Project Value $41 M ($20.5 DOE funds, matched by NYSERDA)

Duration 4 years under current funding; goal is to become self sustaining through research partner funding

Near Term Milestones

- 06/2018 – DOE announced selection of NYSERDA
- 10/2018 – Contract finalized
- 11/2018 – Initial roadmap of R&D priorities published
- 12/2018 – Notice of Technical Challenges issued
- 03/2019 – Published 1st open solicitation
- 05/2019 – *Planned:* Initial project award(s)
- 04/2019 – *Planned:* Add 2nd and 3rd technical areas to open solicitation

Board Members

Major developers, states (MA, MD, NY, VA), energy companies, and research organizations

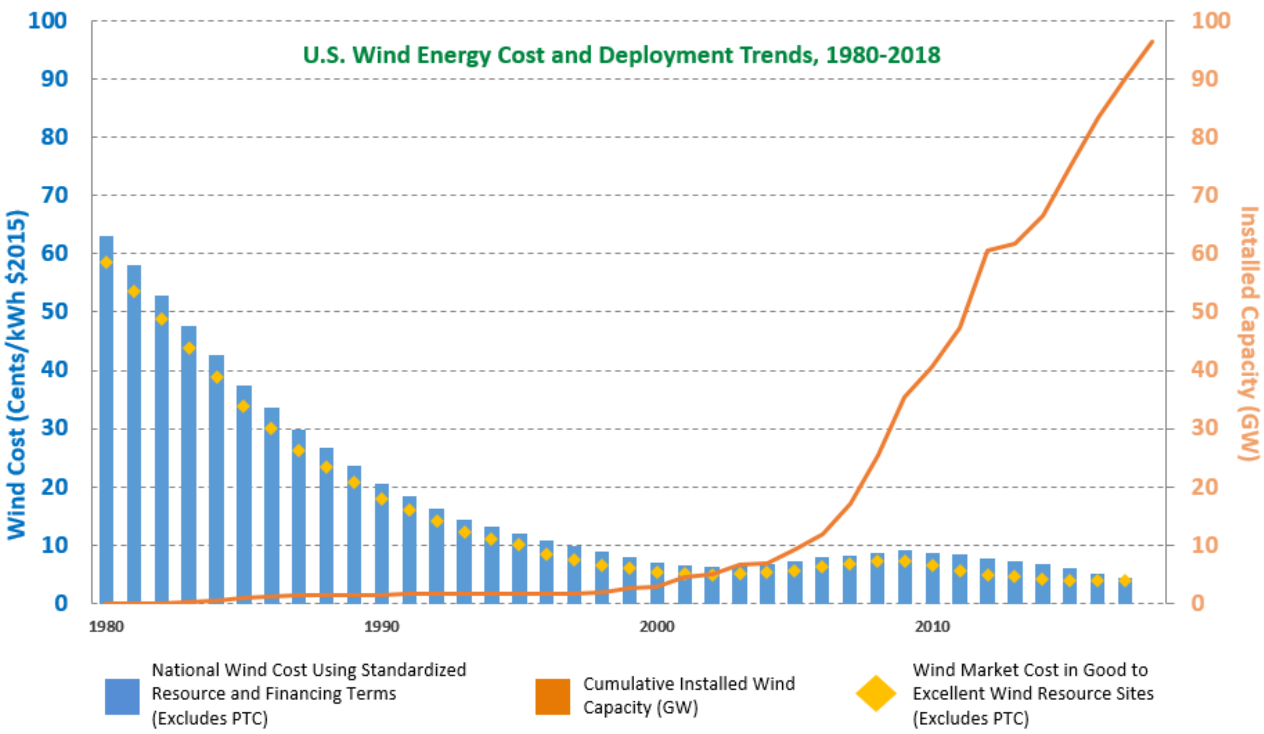
Status of Offshore Wind Demonstrations

- **UMaine and LEEDCo have received $13.7M each (across 2 awards) and remain in budget period 2.**
  - LEEDCo has completed the DOE NEPA process.
  - LEEDCo, no cost time extension to end of June 2020
  - Maine, no cost time extension to end of December 2020

- **FY19 FOA released 3/28/2019 provides $10M to provide additional project development for offshore wind demonstration project(s)** that will be complete by 2025. Applications sought for incorporating innovative technologies that reduce OSW cost and risk into projects already underway e.g. site selected, turbine layout and foundation technology confirmed, etc.

R&D has Contributed to Significant U.S. Wind Industry Innovation and Cost Reduction

National laboratories and federal wind test centers have enabled cost-effective development and validation of high-risk innovative wind technologies for over four decades



U.S. Wind Cost and Cumulative Deployment. The unsubsidized cost of wind energy in good to excellent wind sites dropped 90% from 1980 to 2018 – driven by DOE research and innovation. Industry has deployed a cumulative 96 GW as of 2018 year-end.

Sample DOE R&D Innovations

- **More than 154 DOE-funded wind patents** from 1978 through 2017, with an **additional 21 wind energy patents pending**
- **Advanced computer code development** and validation have accelerated technology innovation
- Airfoil and blade designs, including **aeroelastic tailoring, flatback airfoils, and carbon fiber design**, have enabled larger rotors with increased energy capture
- Development and demonstration of **MW class machines** and low wind speed turbines enabled cost-competitive utility-scale wind

National Offshore Wind Energy R&D Test Facilities

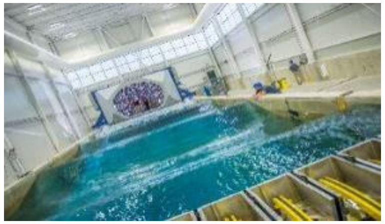
Purpose: For WETO to learn from industry, academia, research laboratories, government agencies, and other stakeholders about issues related to national offshore wind test facilities in order to have a full picture of the capabilities and gaps in offshore wind testing facilities in the U.S.

Timeframe: RFI Issued 7/30/2018; closed 9/14/2018
FOA issued 3/28/2019; closes 6/17/2019

RFI Responses Received: 21 total, from a range of industry and engineering firms, university research centers, national laboratories, and state and national business development organizations

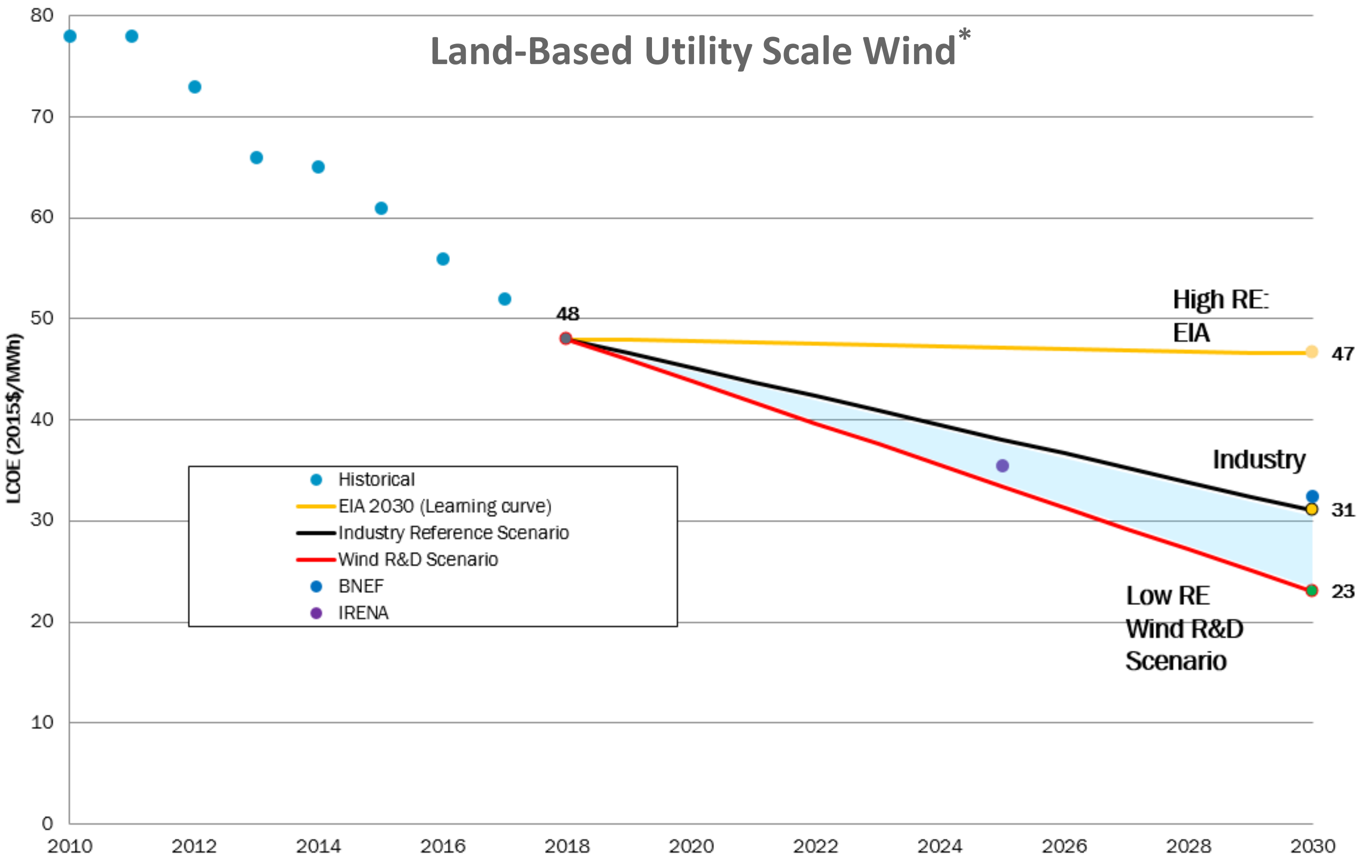
RFI Responses and Congressional language helped inform FOA: $7M for projects to conduct testing in support of innovative offshore wind R&D utilizing existing national-level testing facilities. A subtopic is included for projects that upgrade the capabilities of existing facilities to enable them to perform specific research activities.

FY19 National Laboratory R&D: $2.5M to upgrade DOE offshore wind LIDAR buoys, and 500K for NREL support of floating offshore wind testing



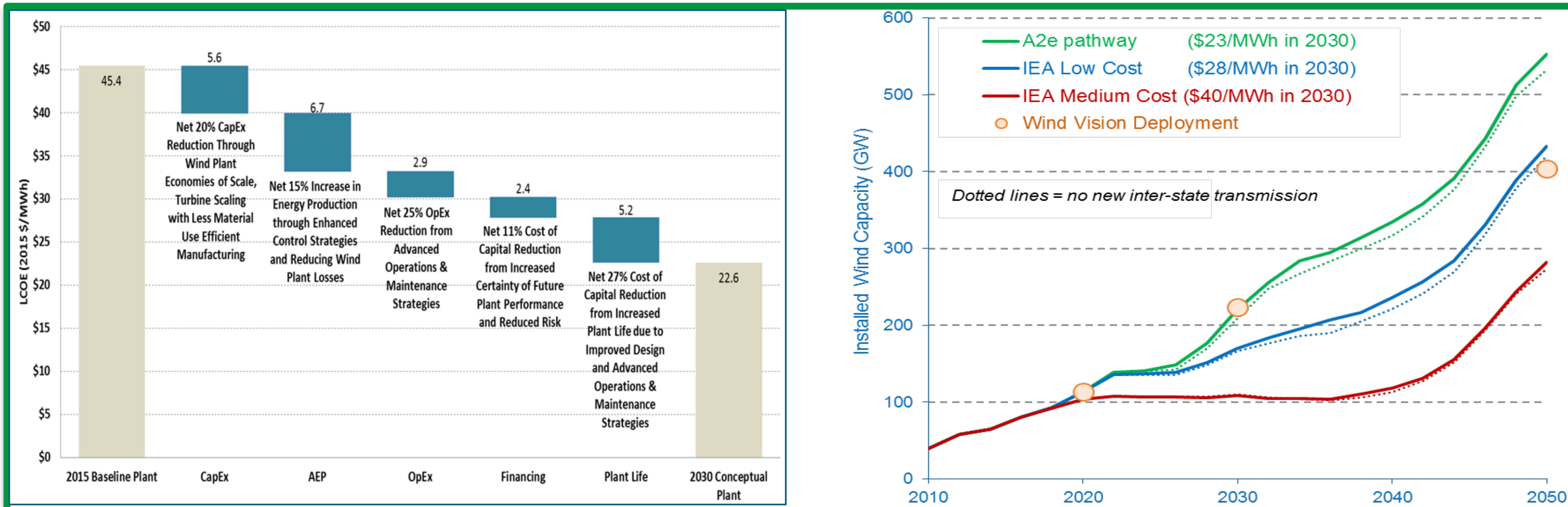

Wind Energy Cost Targets

The Wind Energy Technologies Office works to achieve breakthroughs in **reducing the levelized cost of energy (LCOE) for land-based wind by 50% from today's LCOE**, to $.023/kWh without subsidies by 2030 and achieving a **50% reduction in offshore wind and distributed wind by 2030 from a 2015 benchmark.** Achieving these 2030 goals would make wind electricity one of the most affordable forms of electricity in the U.S.



*LCOE shown here without the Production Tax Credit

Analysis and Modeling



A2e R&D LCOE reduction opportunity (left) and potential impacts to electricity sector(right)

R&D Pathway Assessment

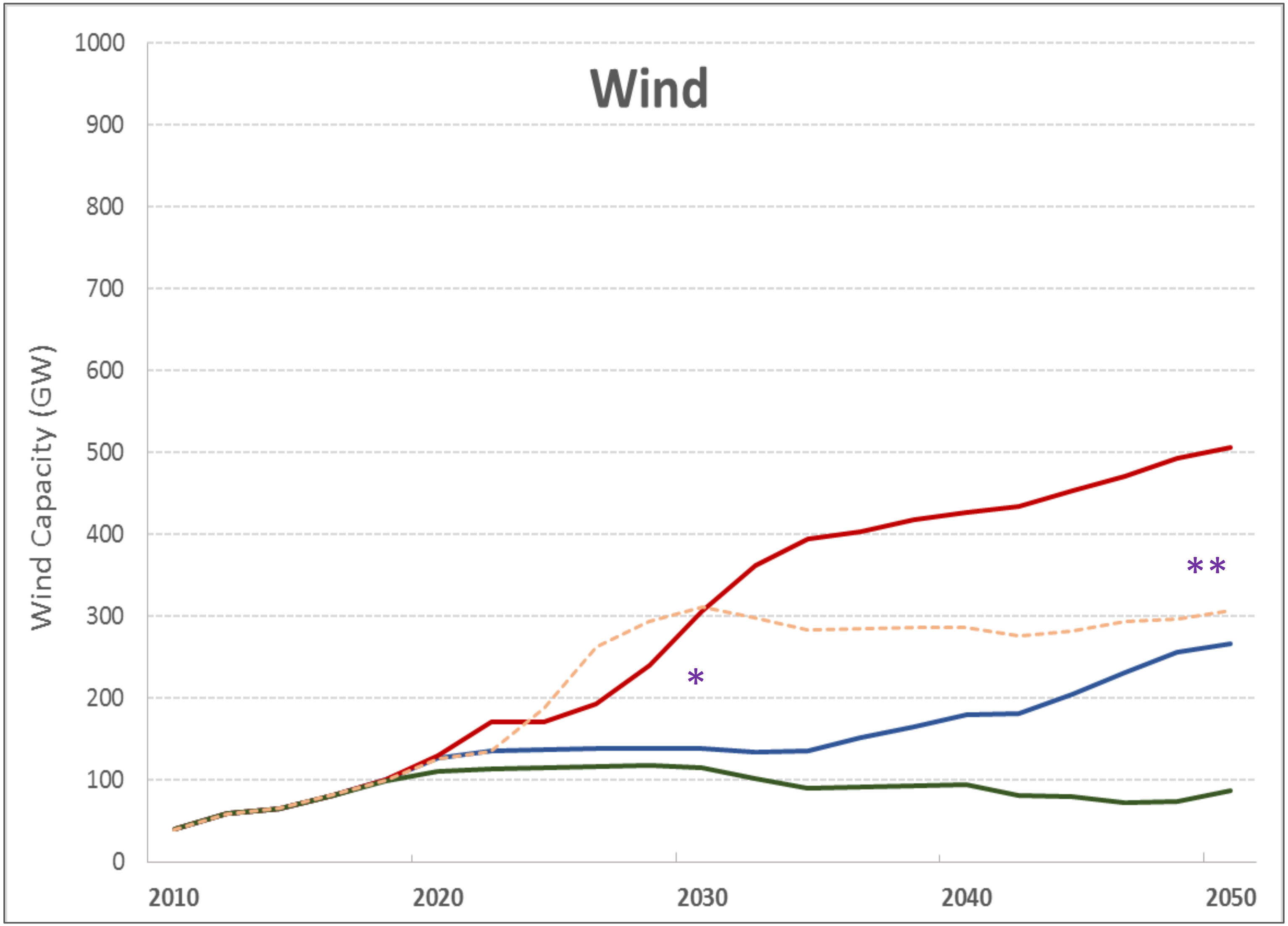
- Technical and economic analysis to find the most promising technical pathways for early-stage federal R&D investment to reduce cost, increase value to grid and overcome regulatory and other market barriers
- FY18 Highlight: Overcoming Large Blade Barriers: chart best technology path (through industry workshop and follow-on analysis exploring onsite manufacturing, advanced logistics, and hybrid solutions) to achieve ultra-large wind blades not currently deployable in US land-based market

Market and Strategic Scenario Analysis

- Provide insight into wind's costs and benefits in the electricity sector, and explore impacts of DOE R&D investment on grid, economy, and environment
- FY19 Highlight: "Beyond LCOE": collaborative work with RP programs and SPIA to understand RP technologies' full costs and value streams to the grid and enable more robust evaluation and comparison of energy options

Wind Office Research Strategy

Implications of Hitting WETO Cost Targets for Land-based Wind



*Wind Vision 2030 Scenario

**Wind Vision 2050 Scenario

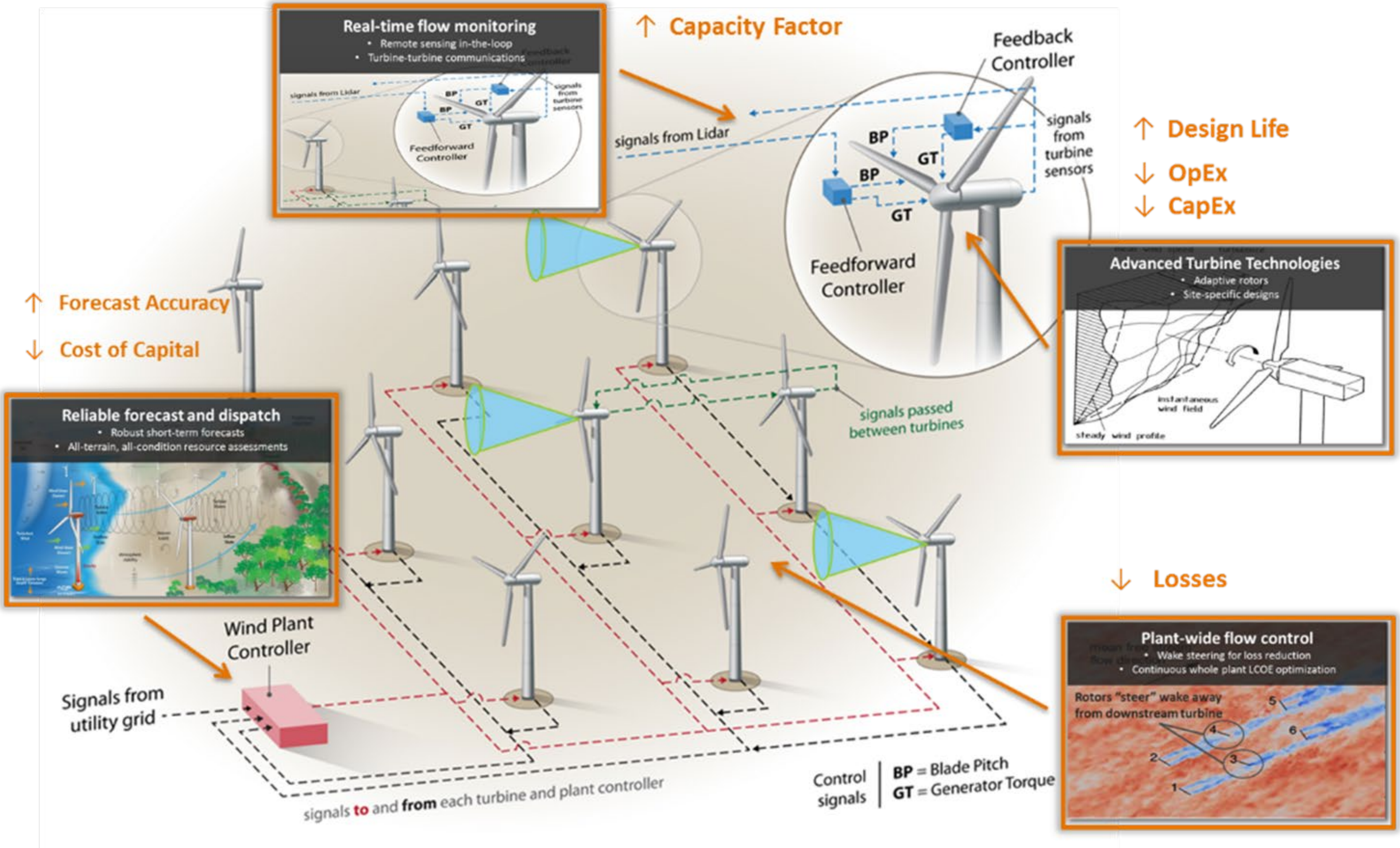
Low RE Cost
2.3 cents/kWh

Industry Reference
3.1 cents/kWh

High RE Cost
4.7 cents/kWh

Atmosphere to Electrons (A2e)

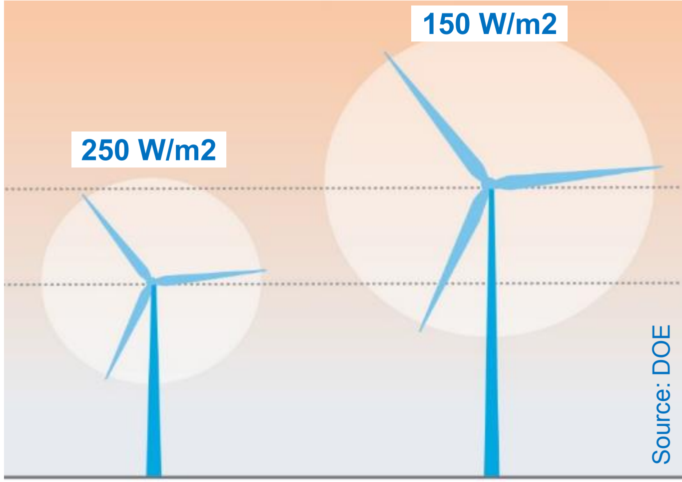
Wind Plant Design Improvements for LBW and OSW



Big Adaptive Rotor Initiative

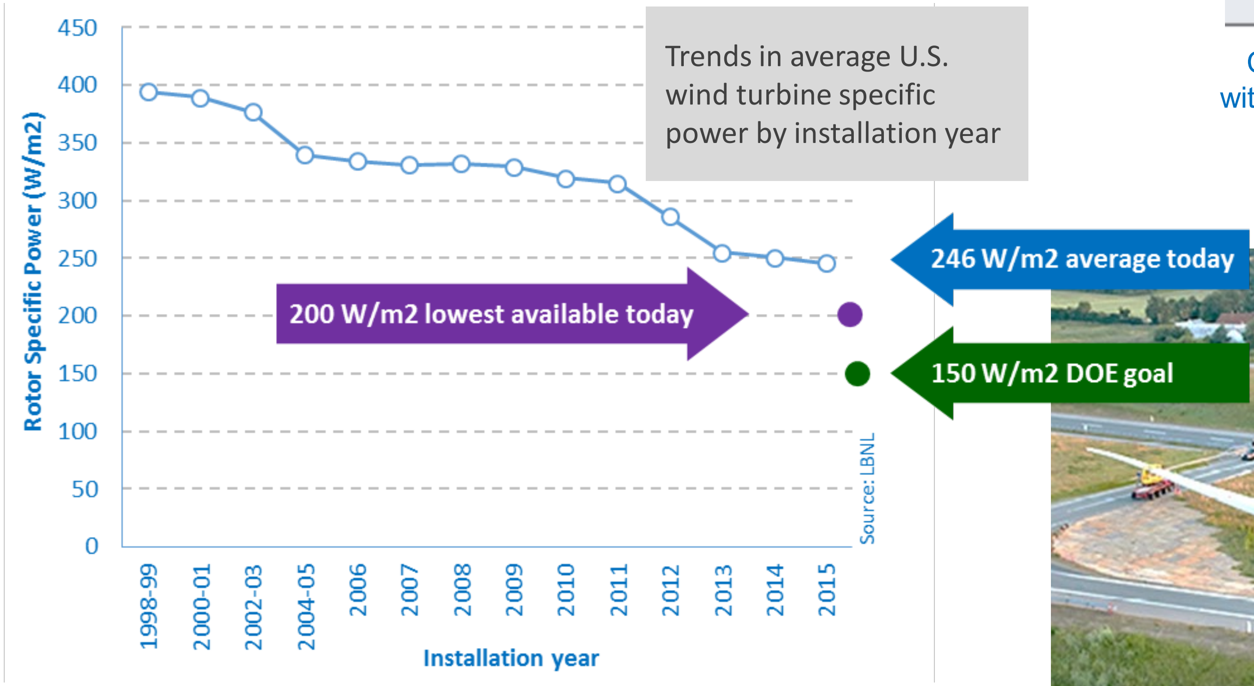
Technology Innovation and Testing

Advanced technology is required to design and manufacture very large <u>low specific power density rotors</u> that are lightweight, durable, and high-performing. In addition, transportation and other logistical challenges for tall wind applications must be addressed.



Current turbine size with contemporary rotor

Future turbine with larger size advanced technology rotor

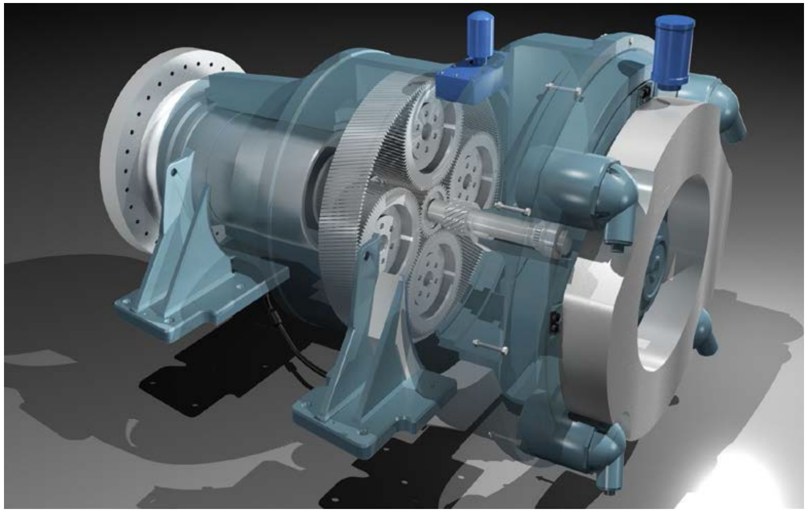


Technology Innovation RD&T

Continuous R&D and Collaboration

- Improving the wind turbine fleet reliability and **increasing U.S. manufacturing competitiveness through additive manufacturing**
- **Blade Reliability Collaborative** through understanding the effects of manufacturing defects and lightning damage on blade structures
- Wind turbine **Drivetrain Reliability Collaborative** to enable reductions in wind plant O&M costs
- Strengthening the body of knowledge necessary for reliable and cost-effective materials for use in additive, or **3-D, Manufacturing** that could remove limitations on tooling, configuration, component design and variations, or production time, lowering costs and transforming the wind manufacturing industry.

Additive, or 3-D, manufacturing has recently been used to manufacture wind rotor blade molds, offering significant time and cost savings. Blade sections produced from these molds are currently undergoing testing at the NWTC.



National Offshore Wind Strategy
Key Messages

Offshore Wind Represents a Significant Opportunity for the Nation

- Technically accessible resource with ample space available for lease
  - **2,058 GW** – double the current installed energy generation capacity in the U.S.
- Electricity demand growth and power plant retirements create a significant market opportunity for new generation
- Potential to achieve competitive cost

Key Challenges Remain

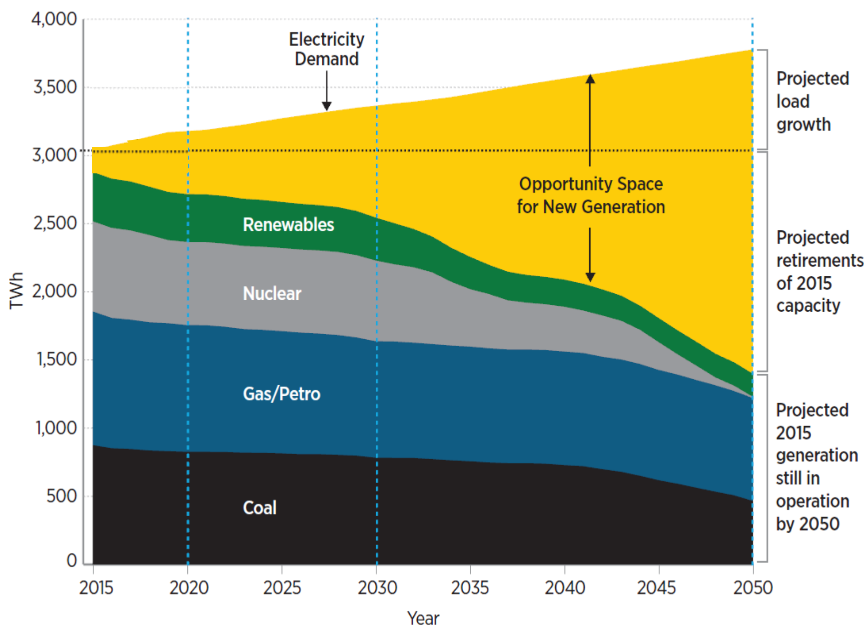
- Reducing technology costs and risks
- Ensuring efficient, effective regulatory construct
- Supporting effective stewardship of the environment and public space
- Improving understanding of offshore wind's benefits

Robust and Credible Plan for Federal Action

- **Over 30 DOE and DOI initiatives** to address seven action areas and three strategic themes

Market Opportunity for Offshore Wind Generation

Utilizing announced and projected retirements, and projected demand, the opportunity space for offshore wind is ~2,400 TWh/yr by 2050, while total U.S. offshore wind potential is ~7,200 TWh/yr



Scheduled and age-based retirements and load growth create opportunity for new offshore wind generation in coastal regions.

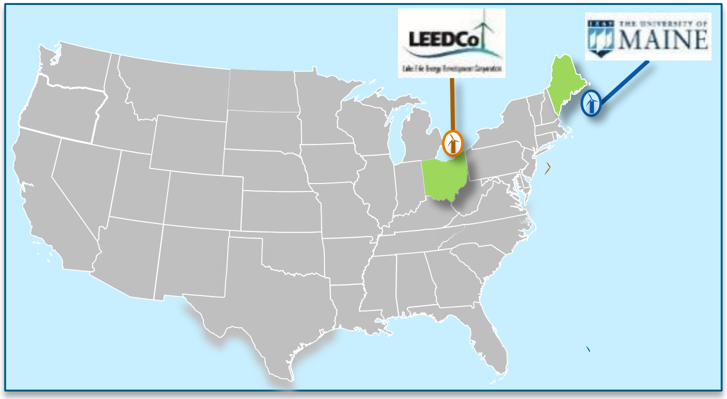
Note: the opportunity space for the year 2015 represents energy currently imported to coastal states from non-coastal states.

Offshore Wind Advanced Technology Demonstration Projects
Brief History

2013 - Seven Projects
- Regionally and technologically diverse
- Goal: 50% Front End Engineering Design (FEED) including vendor quotes
- Down-Select based on progress and technical viability

2014 – Five Projects (three projects, two alternates)
- Goal: 100% FEED, vendor quotes, installation and O&M, completion of NEPA, regulatory and interconnection requirements
- Go/No-Go based on progress to accomplishing goals, including power purchase agreement

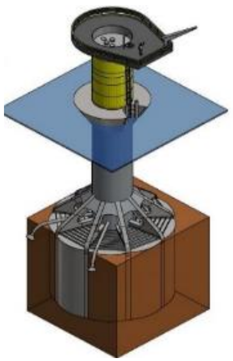
2017 – Two Projects
- Goal: Fabrication, installation and commissioning of the project by 2020; environmental and performance data collection 5-years beyond project completion
- Regular Go/No-Go decision points



Current Portfolio

University of Maine
- Monhegan, ME
- 12 MW project, 2 turbines
- Floating concrete semi-submersible to handle deepwater offshore wind resources

LEEDCo
- Cleveland, OH
- 20.7 MW project, 6 turbines
- Monobucket (monopile large suction pile) to resist weak soils surface ice conditions of the Great Lakes



Wind Grid Systems Integration

- **Coordinated with the DOE Grid Modernization Initiative**
  - The program leverages resources across EERE and DOE's Office of Electricity to address challenges common to multiple generation and grid technologies, including Beyond LCOE. Additionally, the program focuses on several issues more directly germane to wind energy, including a wind cybersecurity roadmap.
- **Providing Essential Reliability Services**
  - Changes in the national generation mix require that variable generation sources work to improve their ability to provide the suite of reliability services that had historically been provided by conventional generation sources.
  - This is accomplished by testing these capabilities and working with industry to refine how the capabilities are further developed to meet the needs of the ever-changing power grid. These efforts will need to be further coordinated with A2e efforts to enable the wind plant of the future.
- **Market Design**
  - As the generation mix changes, so too must the process by which generators are compensated for providing energy , capacity and reliability services.
  - This is accomplished by developing models of electricity markets and evaluating how rule changes impact overall compensation, sharing the results and iterating on how rules can be adjusted to maximize market efficiency for all generation sources.
- **Infrastructure Investment and Utilization**
  - The long-lived nature of transmission infrastructure requires careful upfront analysis to ensure that any new lines will be best utilized. New technologies, such as dynamic transmission line rating (DLR), can allow increased utilization of existing infrastructure.
  - This is accomplished by conducting integration studies to evaluate various transmission build-out scenarios which are informed by ever-changing technology improvements; and supporting the development of DLR technologies.

Wind turbine blade testing is a critical factor in maintaining high levels of reliability and evaluating the latest technological developments in airfoils and materials.

National wind testing and demonstration platform: validation and verification for all wind types

- Grid & storage integration test facilities
- National Wind Technology Center, Scaled Wind Farm Technology (SWiFT) & other test facilities
- Offshore wind test facilities

Creates ability for advanced grid integration, component and system level testing with next-gen storage and dynamic grid controls

Operations

Standards, Analysis, Communications

IEA Wind Participating Member Countries, Wind Europe, and CWEA

IEC

Cross-cut support: standards, international collaboration, finance, analysis and modeling, and communications

- Standards
- International collaboration
- Small Business Innovation Research
- Financing/Performance, Risk, Uncertainty, and Finance (PRUF) - Digitalization
- Analysis, modeling & reporting
- Strategic assessment and planning
- Communications

Wind Plant Science Driving Innovation

Wind plant science R&D for all wind types driving innovation (A2e)

- Science of whole wind plants and turbine-to -turbine interactions
- Atmospheric science

Wind Grand Challenges

- Advancing the understanding of the wind system physics;
- Modeling the full wind energy system;
- Application of physics and models to wind designs

Wind LCOE Impacts

- Science drives an estimated 54% ($.012 cents/kWh) of 2030 LCOE goal reduction

Creating the core underpinning science supporting transformative next - generation plant and turbine designs, supporting the Grid of the Future